PLANT ECOLOGY AND ETHNOBOTANY OF TWO SACRED FORESTS (*KAYAS*) AT THE KENYA COAST

by

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A thesis submitted in partial fulfilment
of the requirements for the degree of
Master of Science
in the School of Life and Environmental Sciences
University of Natal
Durban
September 2000

PREFACE

The fieldwork described in this thesis was carried out in the coastal sacred forests (*kayas*) of Kenya between August 1997 and August 1999, under the supervision of Prof. John Cooke (University of Natal, South Africa) and Dr. Robert Höft (UNESCO, Kenya).

The study represents original work by the author and had not been submitted in any form to another university. Where use was made of the work of other authors, this has been duly acknowledged in the text

This work is bound as two volumes. Volume I contains the main results of the study and Volume II provides other methods, results and discussion as a series of eight appendices.

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September 2000

ACKNOWLEDGEMENTS

I am much indebted to the People and Plants (UNESCO) Programme for funding the research report in this thesis. I would also like to thank the Coastal Forest Conservation Unit (CFCU) in Kenya for hosting me during the field study, and also for allowing me to benefit from their students' funding scheme.

I am very grateful to my supervisor, Prof. John Cooke (The Head, School of Life and Environmental Sciences, University of Natal), for constant advice and enthusiasm towards the success of the research work. Many thanks are also due to Dr. Robert Höft (People and Plants – UNESCO, Africa Projects Co-ordinator, Nairobi), who was also co-supervisor. I appreciate the limitless assistance he extended to me to get the project off the ground, and the progressive support and advice during the fieldwork and in data analysis. It was through tireless effort in plant species identification which was conducted with the help of Quentin Luke (Project Executant, Coastal Forest Conservation Unit), that I was in a position to make meaningful conclusions in the floral aspects of the study.

I would like to acknowledge the support received from Prof. Celia Nyamweru (Social Scientist and lecturer at St. Lawrence University, USA) in the structuring of the questionnaire, for guidance in the questionnaire administration trials, and for the advice in the data analysis. I acknowledge the guidance in vegetation data analysis from Prof. Fred Ellery, Prof. Norman Pamenter, Dr. Rob Slotow and Mr. Bruce Page (all staff of the University of Natal, in the School of Life and Environmental Sciences). I also acknowledge the useful comments on the soil data from Dr. Willington Wamicha (Faculty of Environmental Studies, Kenyatta University, Kenya).

I wish to extend my gratitude to the *kaya* elders and *kaya* guards who in many ways assisted me in achieving the objectives of this study. I am grateful to the field assistants Mary Kwekwe Mwambawa, Nzara Kambe and Irine Changawa; to my ethnobotanical information respondents Hamisi Kazungu Kalume, Gatoka Foyo, Mwayaya Chuphi, Charo Ngoba, Mungwari Mwagwaha and Mtaveta Kadzomba, and to the rest of the community members who in one way or another participated in the study.

Special thanks are due also to my colleagues at both Ukunda and Kilifi CFCU offices, who supported me with great sacrifices. I thank you Anthony Githitho, Juma Lumumba, Severenius Jembe, Matano Abdulrahman, Jeremiah Mbinda, Tunje Chiro, Amin Tengeza, Hamisi Mududu, Elias Kimaru and Stanline Kibet.

ABSTRACT

The coastal forests of Kenya represent a rare and threatened forest type which has over 3,000 plant taxa, of which about 500 are endemic. The patches which comprise this forest type include sacred forests, the *kayas*, that are rich in biodiversity. The aim of the study report was to investigate the phytosociological relationships in two selected *kayas*, Mtswakara and Fungo, and the plant utilisation by the people of the Duruma and Giriama tribes who live around these forests.

The vegetation was sampled using the phytosociological approach developed by Braun-Blanquet. In *kaya* Mtswakara 51 relevés of 0.2 ha. were sampled and a total of 317 species from 191 genera in 79 families were recorded, representing 48 tree species, 134 shrubs, 82 herbs, 45 climbers, and 8 epiphytes. In *kaya* Fungo, 280 species from 213 genera in 74 families, representing 35 tree species, 125 shrubs, 73 herbs, 43 climbers, and 3 epiphytes, were recorded in 54 relevés. TWINSPAN classification of the data indicated the existence of four plant communities and six sub-communities in *kaya* Mtswakara; and three plant communities, four sub-communities, three stages, three sub-stages and one undetermined vegetation type in *kaya* Fungo. The phytosociological results indicated that diagnostic species for plant communities are not necessarily the dominant tree species; and interactions of edaphic factors, plant resource extraction, fire and grazing influenced the formation and distribution of vegetation types.

The human populations living around the forests depend upon and utilise plant species found in the *kayas* to meet some of their basic domestic needs and cultural requirements. But, unlike in the past, the council of *kaya* elders (*ngambi*) cannot address all the forest management problems, due to factors such as increased disrespect of cultural traditions in the communities, increasing demands of forest plant resources due to population increase, conflicts between local faction groups claiming legitimacy in *kaya* management and socio-political changes. Surveys conducted in the local markets showed that although forest plants formed a small percentage of the building poles traded, the firewood trade was considerable. In addition to the regular market trade, there is a 'house-to-house' trade conducted by some community members who sell poles, timber planks and firewood which probably had been collected from the *kayas*. Although a considerable amount of pole resource wais available in the *kayas*, the

observed vegetation degeneration through plant resource extraction, fire, and grazing, was likely to be at a faster rate compared to the natural regenerative ability of the forests, thus threatening the existence of these *kayas* forests. The immediate challenges facing *kaya* conservation, therefore, include re-empowering the cultural management systems, and the provision of short-term and long-term alternatives for the forest plant resources in the face of increasing demand for the resources and social change.

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CHAPTER ONE
GENERAL INTRODUCTION

1.1 KENYA COASTAL FOREST VEGETATION

The coastal forests of Kenya are part of the 'ancient coastal vegetation mosaic' of eastern Africa, which is rich in biodiversity, and forms one of the most important biological systems of the World (Robertson & Luke 1993). The biodiversity of the East African region is a source of both major socio-economic and ecological services, and its conservation while being extremely important must occur within a management context which allows for its continued utilization. Mugabe and Clark (1998) noted that most of Africa's biodiversity, generally, is a source of cultural development, as plants and animals play specific major roles in the cultural evolution of the native human societies. The ethnobotanical surveys that have been conducted in East Africa (Glover 1969; Kokwaro 1975, 1983; Schmidt 1991; Beentje 1994; Mugisha1997) highlight the utilisation value of the forest areas to the local communities. Despite its biotic capital, Africa is the world's poorest continent, experiencing economic decline and food insecurity. These problems result partly from environmental degradation that includes loss of biodiversity (Mugabe & Clark 1998).

The East African coastal forests are a heterogeneous group of isolated evergreen and semi-deciduous closed-canopy, seasonal dry forests, found within 60 km from the Indian ocean and usually on low hills rising to not more than 600 m above sea level (Burgess & Mlingwa 1993). These forest fragments are part of the once extensive and diverse eastern lowland forest within the Zanzibar-Inhambane Regional Mosaic (White 1983). The eastern lowland forest extends from southern Somalia in the north, to northern Mozambique in the south (Robertson & Luke 1993), between 1° North and 25° South latitude, and 34 - 41° East longitude (Fig. 1.1), covering approximately 3167 km^2 (White 1983). Within the eastern lowland forest there are about 3000 plant species, of which about 550 species are endemic (White 1983, Burgess *et al.* 1998) and 190 are forest tree species (White 1983).

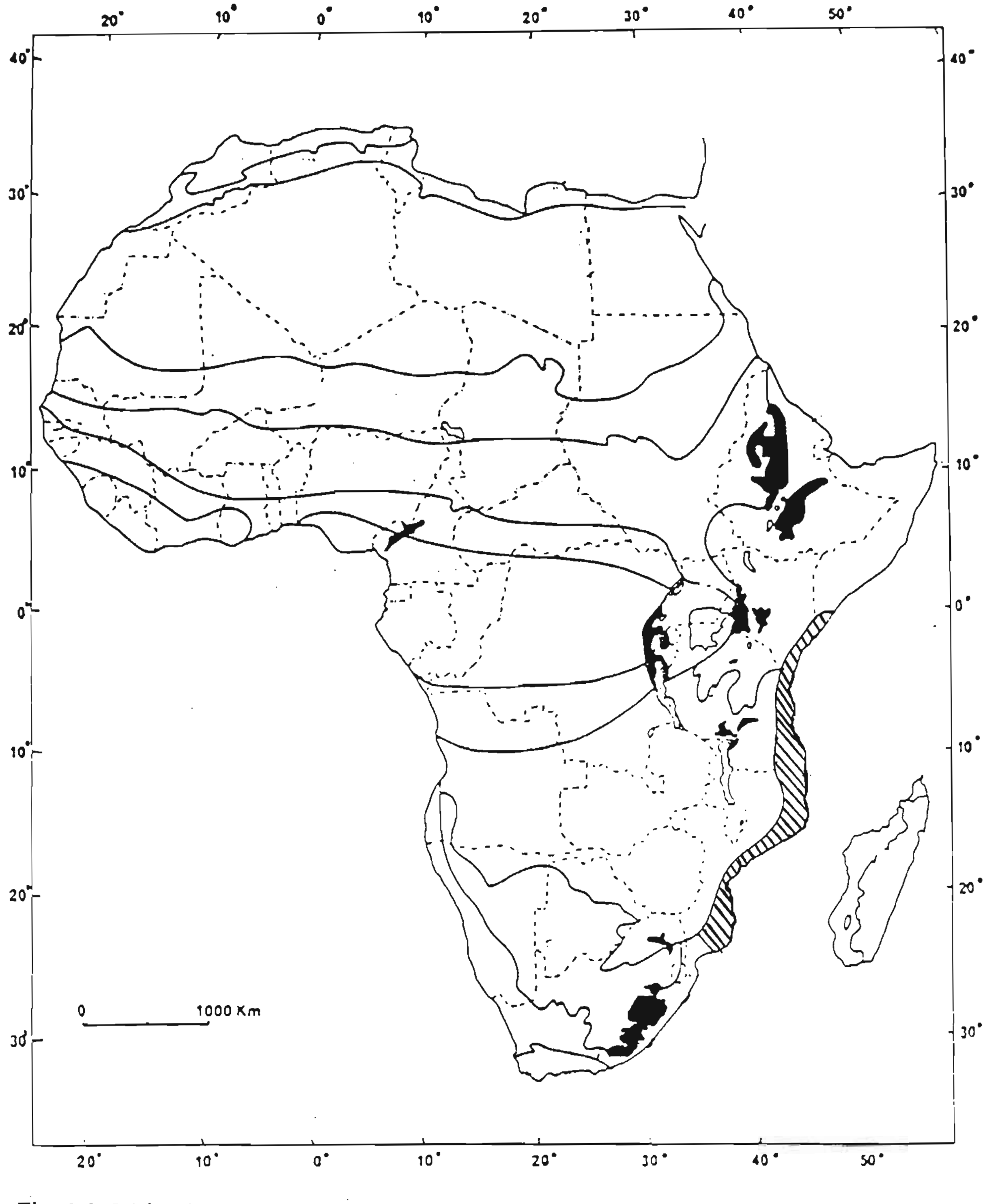

Fig. 1.1: Main phytocoria of Africa and Madagascar, showing the geographical position of Zanzibar Inhambane Regional Mosaic (marked ▧). Figure adapted from White (1983)

According to Burgess *et al.* (1998) East African coastal forests are ecologically important and highly threatened centres of endemism for plants (c 550 spp.); mammals (6 spp.); birds (9 spp.); reptiles (26 spp.); frogs (2 spp.); butterflies (79 spp.); snails (>86 spp.); and millipedes (>20 spp.). The endemic species are concentrated in the forests of the Tana River, between Malindi in Kenya and Tanga in northern Tanzania, and in southern Tanzania (Burgess *et al.* 1998). Plant genera endemic to the region include *Cephalosphaera*, *Englerodendron*, *Grandidiera*, and *Stuhlmannia* (White 1983).

Most East African coastal forest endemics have narrow biogeographical ranges, often exhibiting single-site endemism or with scattered or disjunct distributional patterns (Burgess *et al.* 1998). Such patterns are generally interpreted as relicts and not the results of recent evolution. The formation of these relicts probably started with the separation of the ancient Pan-African rainforest into two parts during the Miocene (Burgess *et al.* 1998). The East African coastal forest was in the distant past connected to the rain forests of Central and West Africa (Hawthorne *et al.* 1981), then was isolated as a result of the uplift of the Central Tanganyikan Plateau about 20 million years ago (Lovett 1986), and differentiated further as a result of increased dry climatic conditions (Waiyaki 1995). This supports the argument that the present East Arican coastal forest mosaic has come about through changes in climate. Unlike the large West and Central African forests, the East African examples are highly fragmented, discrete 'islands' associated with localised areas of high rainfall that are surrounded by a 'sea' of comparatively more arid woodland types (Waiyaki, 1995). The isolation of these forest fragments from each other and from the other large forest blocks has resulted in the high levels of endemism in plants and animals species (Burgess *et al.* 1998).

The East African coastal forests have been described as a 'vanishing refuge' with the endemic species gradually becoming more and more relict, some presumably becoming extinct, due to increased dry climatic conditions and to human disturbance (Burgess *et al.*, 1998). Although the East African coastal forest type was more widespread in the past (Hawthorne 1993), currently it is perhaps the most threatened forest type in Africa (Burgess 1994). As a representative of tropical dry forest, it is an example of the most threatened of all tropical forest habitats (Janzen 1988).

In Kenya, about 70 coastal forest fragments are distributed north and south of Mombasa Island, covering about 660 km^2 and most of these forests are small, measuring less than 0.5 km^2 (Burgess *et al.* 1998). The two significantly large forest areas are the Shimba Hills National Reserve, which covers 220 Km^2 (Schmidt 1991) and Arabuko-Sokoke covers 370 km^2 (Burgess *et al.* 1998). The climatic limits for these coastal forests are probably set by rainfall (decreasing to the north), seasonality (increasing to the south), and by altitude, increasing to the west (Burgess *et al.* 1998).

Botanical collections from the Kenya coastal region started in the mid-19th century (Hawthorne 1993). A research station was established in 1855 on the mainland close to Mombasa (Krapf 1860, 1882) from where the Rev. Thomas Wakefield sent plant specimen to England (Hawthorne 1993). However, Dale (1939) and Moomaw (1960) were the first to examine the floristic patterns of the coastal forests of Kenya. Both authors defined large areas of forest as being under one forest type, despite their great small-scale variation. Dale (1939) defined the coastal forest of Kenya as 'Lowland Evergreen Rain Forest', and Moomaw (1960) identified the whole Kenya coastal forest as '*Combretum-Cassipourea* forest' with some 'Lowland Rain Forest' aspects in the wetter parts.

Moomaw (1960) divided the Kenya coastal vegetation into four major physiographical zones: Coastal Plain, Foot Plateau, Coastal Range and Nyika Plateau. The Coastal Plain varies in width from 5-70 km, and consisting of Pleistocene deposits of coral and sands. The Coastal Plain lies generally below the 30m contour and displays a series of old, flat-bedded coral reefs, coral breccia, calcareous sands and beach sands. The Foot plateau, lying between 60 – 150 m contour, is found on marine shales, mudstones and limestones of Jurassic age. On the eastern side of the Foot Plateau rises the Coastal Range, a low ridge of Pliocene Magarini sands that is found at intervals throughout the entire length of the coast. The Coastal Range is best represented by the Shimba Hills. The Shimba Hills consist of Mazeras sandstone capped with a layer of Shimba grit at about 400 m contour, and carries a heterogenous forest type determined by soils and altitude (Glover 1968, Schmidt 1991). The plant communities on the Shimba Hills and the Coastal Range are different to the other vegetation in the area (Moomaw 1960; Robertson & Luke 1993). To the west and further inland from the Coastal Range there is a lower lying ground, the Nyika Plateau, beginning at about 200 m contour at the eastern edge and gradually rising to 300 m contour extending to the fringes of Taru Desert (Spear 1978). The Nyika Plateau soils and vegetation are developed on the Duruma sandstone series.

According to Poore (1962), Dale (1932) and Moomaw (1960) used informal nodal nomenclature in their vegetation classification, which allows for continual variation in, and incomplete knowledge of, vegetation details. In this classification a spectrum of communities is defined by reference to one or more of the common tree species. This description can be applied to patches of forest ranging from a few hundred square metres to tens of hectares. Inspite of these definitions being acceptable, there is a broad spectrum of plant communities within the mosaic (Schmidt 1991; Hawthorne *et al.* 1993). Hawthorne *et al.* (1993) described the vegetation variation on the basis of finer physiognomic aspects, and that author made two contrasting broad designations of forest types, namely the Dry and Moist Forests.

According to Hawthorne *et al.* (1993) the Moist Forest type has a canopy cover of 20-35 m in less disturbed patches and, generally, the trees have larger, and less sclerophyllous leaves than the Dry Forest. Moist forests occur on coastal hills or other areas where precipitation is high (>1200mm), or where ground water and nutrients are abundant. Species found in a broad range of the Moist forest types include the tall, deciduous trees *Antiaris toxicara, Milicia excelsa* and *Ricinodendron heudelotii* (Hawthorne *et al.* 1993). However, almost half of the species found in Moist Forest are also common in other forests defined by other factors, and the common species in Dry Forest make an important contribution to the Moist Forests (Hawthorne *et al.* 1993). According to Hawthorne *et al.* (1993), high moisture demanding species such as *Uvariodendron gorgonis* are restricted to few higher altitude, or higher precipitation coastal forests like Mrima Hill and Shimba Hills.

Dry Forests are found in areas with low rainfall (≤ 800mm) or on soils with low water holding capacity, associated with poor soil fertility (Hawthorne *et al.* 1993) or unpredictable water supply (Andrews *et al.*, 1975). According to Hawthorne *et al.* (1993), undisturbed stands of Dry Forest form a dense canopy usually less than 20 m tall, with local dominance of one or two canopy species. Hawthorne *et al.* (1993) divided Dry Forest into four types:

(i) *Scorodophloeus fischeri - Cynometra webberi* type: This type is often associated with the presence of *Manilkara sulcata, Julbernadia magnistipulata* and *Hymenaea verrucosa* that can be locally dominant.

(ii) *Brachylaena huillensis - Manilkara discolor* type: Although this forest type can be abundant, mass removal of a dominant species (*Brachylaena huillensis*) for the carving industry has affected the forest type distribution.

(iii) *Erythrina sacleuxii - Sterculia schliebenii* type: The dominant deciduous species for this forest type (*Erythrina sacleuxii* and *Sterculia schliebenii*) make rapid growth and thrive as emergents above an evergreen canopy. The common species in this forest type are pioneers of small to medium forest gaps, and are probably less fire-tolerant.

(iv) *Adansonia digitata - Margaritaria discoideus* type: This type is characterised by species that are more typically of savannah or open woodland vegetation. In this type, species regenerate only in medium to large gaps, or derived savannah.

In Kenya the remnants of the 'ancient coastal forest' include sacred forest patches (the *kayas*) scattered along a 250 km South-North stretch, which in addition to their cultural significance are biological rich (Robertson & Luke, 1993). *Kaya* literally means home in the local dialects, and it refers to the role of these forests (as homes) in the early history of settlement in the Kenya Coast. Being part of the prioritized areas for conservation, the *kaya* forests are important biologically as they carry clusters of rare and endemic plant and animal species, which are either representatives of the ancestry taxa or represent a more recent evolutionary lineage (Burgess *et al.* 1998). More than half of the rare plant species in Kenya occur in the Coast region, with many of these being found in the *kaya* forests (Robertson & Luke, 1993).

1.2 HISTORY, CULTURE AND CONSERVATION OF *KAYA* FORESTS

The *kaya*s were established by a Coastal people, the Midzichenda (often spelt as Mijikenda). Midzichenda is a purely descriptive term that literally means nine homes. The Midzichenda are a Bantu-speaking people, constituting nine tribes which are linguistically and culturally closely related (Willis, 1996). These tribes are the Digo, Duruma, Giriama, Rabai (Rahai), Chonyi, Kambe, Ribe (Rihe), Kauma, and Jibana (Dzihana). According to Spear (1978), the

Midzichenda, migrated from Singwaya (Shingwaya) to the south, following a fight with the Galla tribe in the 16th Century. On reaching the Kenya Coast, they formed smaller groups that settled in different fortified *kaya* villages in the current Kwale, Kilifi, Mombasa and Malindi Districts (Spear, 1978; Willis, 1996).

Spear (1978) gave a basic description of the diagrammatic appearance of a *kaya* (Fig. 1.2) as a large palisaded village located in the midst on a dense forest, with two or more paths that cut through the surrounding forest. At the last gate of a path there used to be an earthen-ware pot (Willis 1996), the '*chiza*', that contained a magical concotion used during the prayers for rain (Torophe pers. comm). In the cleared circular glade there were houses grouped on a clanial basis; a central meeting place (the '*moro*'); and a magical device with protective powers (the '*fingo*') (Spear 1978; Willis 1996). Also there was a '*Mwanza*' drum (used during cultural initiation) and burial grounds (Willis 1996).

The dating of the Midzichenda migration and settlement at the Kenya Coast by Spear (1978) as in the 16^{th} Century, has been disputed by other historians (Morton 1972; 1977; Walsh 1992; Willis, 1996). Archeological evidence has dated the movement and settlement in the coastal region as early as the 8th Century (Abungo pers. comm), which suggests that the area has been subjected to movements of peoples and settlements long before the establishment and use of the *kaya* forests (Mutoro pers. comm).

Originally, all members of the nine Midzichenda ethnic groups lived in the primary *kaya* (i.e. the first to be established), and each tribal group formed a closely-knit society controlled by a council of elders (Willis 1996) known as *Ngambi* (Chirapho pers. comm.). Individuals would progressively be initiated from one group level to another, to reach the *Ngambi* level. However, due to population pressures, diseases, sorcery, search for better resources (Mwayaya, pers. comm.) and conflicts between the *kaya* elders and groups of younger men in quest for power, sub-groups moved out of the primary *kayas* and established new settlements (secondary and tertiary *kayas*) elsewhere (Willis 1996). Eventually, about 60 *kayas* and sacred groves were established by the Midzichenda community.

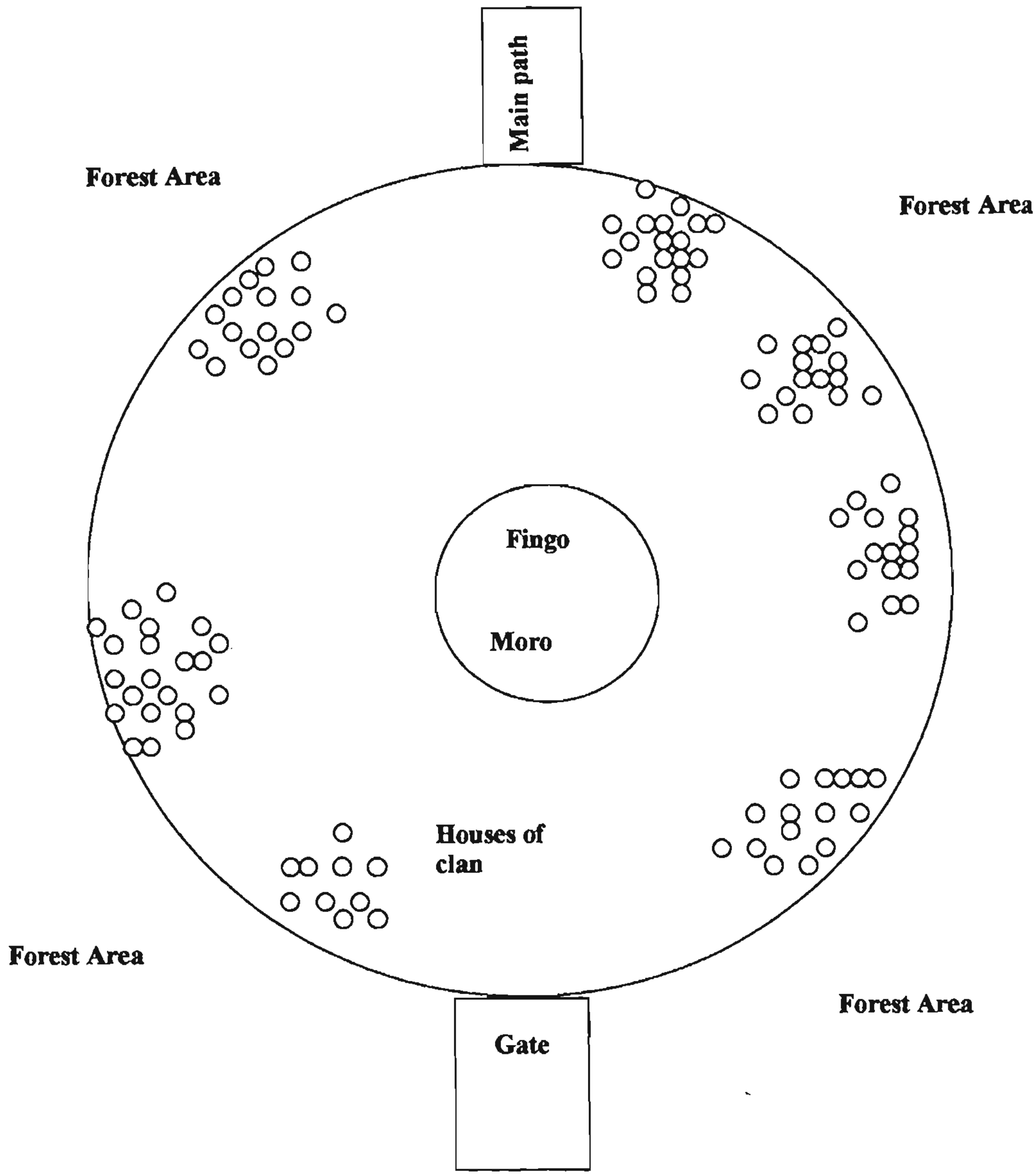

Fig. 1.2: A general diagrammatic representation of a *Midzichenda* settlement in a fortified *kaya* village. For description see text for details. (Figure adapted from Spear (1978))

The wild plant resources from the *kaya* forests provided for a wide range of basic needs: building materials, fuel wood, binding materials, household utensils, medicines, food supplements, and a source of income from some sales (carvings, household items) or through practising as herbalists, mid-wives, or veterinary medicine experts (Pakia 1997). When the Midzichenda social institutions were at their most highly developed stage, the *kaya*s were well managed and the plant resource extraction was successfully controlled through traditional and customary laws (Befukwe pers. comm.; Chirapho pers. comm.).

During the time when the Midzichenda lived in the *kaya* settlements, farming was practised on the lower slopes of the hills, areas that could only support a limited population (Spear 1978). With the increase in population, compounded by the prevailing peaceful conditions then, some community members moved out of the *kaya* villages to occupy vacant land, in the 19th Century (Spear 1978). This dispersal from the *kayas* had significant effects on the natural vegetation of the area, because it led to major disturbance and clearance of the forest (Robertson & Luke 1993). There was a rapid clearing and burning of the virgin forests and woodlands for farming, particularly because shifting cultivation was practised (Spear 1978). Within a few decades most of the natural forest had been cleared, but the original *kaya* forest patches were spared, some members of the community continued to live inside the *kayas*, and traditional protection through customary laws continued.

When Kenya was made a British Protectorate in 1886, the Colonial Government developed interest in the coastal forests mainly for economic benefits. It is likely that the economic benefits of the forest resources influenced the gazettement of some *kaya*s as Forest Reserves (Marenje, Dzombo, Mrima, Chonyi) and as National Reserves (Shimba Hills National Reserve in which *kayas* Kwale, Longo-ya-Mwagandi and Mwele are found), which were directly under Government management. This, in principle, excluded the local communities from these *kayas* and therefore, from their cultural heritage and traditional practices (Alluwi pers. com.).

In 1963 Kenya became independent and this was followed by the creation of a *de facto* one party state with basic policies that favoured capitalism and a free market economy (Azevedo, 1993). The central government administrators ranged from National level (the president) to the village level (the village chairman). This new governance system further weakened the administrative powers of the *kaya* elders, and rendered the *Ngambi* an organ that could not address administrative issues independently without the participation and influence of the local government structures.

New life-styles and changing socio-economic conditions created new priorities and demands in life, and more young people broke away from the traditional ways of life (Willis, 1996). Destruction and devastation of the *kaya* forests started to be experienced at an alarming rate. Although the rate of illegal plant resources collection and incidences of traditional lawbreaking had increased, during an Environmental Assessment in 1984 it was identified that some elders welcomed support in continued protection of the *kaya*s (Robertson & Luke, 1993). This led to the establishment of a Department within the National Mueums of Kenya (NMK), the 'Coastal Forest Conservation Unit' (CFCU) in 1992, which was mandated to compliment the efforts of the *kaya* elders in *kaya* forests conservation.

Currently, the tenure of the land of the *kaya* forests is a contentious issue, as the elders have no direct influence on the subject. The land on which the *kaya* forests stand is held in trust by local councils for the local community. However, an experience of malpractice by some officers in the local council have indicated doubt over the security of that land. Inappropriate allocation of *kaya* forestland to private developers has been recorded in the past, and as a result some of *kaya* forests (Chale, Diani, Ganzoni, Tiwi and Waa) are partly or whole on private land. Already clearing for developments has taken place on some *kayas* (Chale and Ganzoni) while in others (Diani, Tiwi and Waa) clearing might commence if effective protective measures are not put into place.

1.3 RECENT STUDIES IN THE *KAYAS*

Within the last decades there has been scientific and public interest expressed in the *kayas*. Researchers from different disciplines have visited and carried out studies in the *kaya*s. Accounts on the history of the Midzichenda and the cultural significance of the *kaya*s have been published (Prins 1972; Morton 1972; 1977; Spear 1978; Mwangudza 1983; Walsh 1992; Willis 1996) and botanical inventories (Robertson & Luke 1993). The floristic and cultural surveys improved the knowledge of the botanical and cultural wealth of the *kayas*, as well as highlighting the threats to the *kayas*. This information led to the joint action by WWF and NMK to foster and provide national protection of the *kayas*.

Hawthorne *et al*. (1981) was the first to examine floristic patterns of specific *kayas*, Kambe and Ribe, using physiognomic variations. Hawthorne *et al*. (1981) identified vegetation types to be determined by watercourses, slope, presence of limestone and disturbance. Using a phytosociological approach, Schmidt (1991) investigated the ecology of the Shimba Hills National Reserve, which includes the *kayas* Kwale, Longo-ya-Mwagandi and Mwele.

Waiyaki (1995) studied the richness and abundance of birds' communities in twelve coastal forest fragments of Kenya, which included *kayas*. The results of this study showed that some small forests (*kayas* Diani and Muhaka) are important conservation areas for bird life. Lehmann & Kioko (1998) produced notes on butterflies and moths for *kayas* Kinondo and Muhaka. The results of that study proved that even small forest patches can be important for animals. In addition there were new records of moth species from *kaya* Muhaka and records of rare butterfly and moths species in *kayas* Muhaka and Kinonda. Nyamweru (1997) investigated the socio-cultural aspects of the communities surrounding the *kayas*. From a social perspective, Nyamweru noted that among other issues, firewood was a serious problem for all people in all villages where interviews were carried out.

All the studies in the *kayas* share one theme, that these forest patches carry a great diversity of fauna and flora, many of which are still insufficiently known (Robertson & Luke 1993). Among these forest species, many will disappear as the *kayas* continue to be destroyed. This is in addition to the threat on the rich culture and tradition of the people whose history and customs are strongly linked to these forests.

1.4 THE PRESENT INVESTIGATION

1.4.1 Study design and objectives

The *kaya* forests have been identified as being rich biologically and culturally, as well as being a resource base for the local communities living around them. However, the details of the plant ecology of these forests, the plant resource demands and the specific human population's needs from these forests are still not clearly understood. Although it is known that the *kaya* elders are responsible of the traditional management of resource extraction from the *kayas*, little is known of the protocols 'on the ground' and the management strategies employed by the elders. This present study was intended to investigate the ecological and ethnobotanical aspects of the *kaya* forests and their interactions to inform new initiatives in their conservation management.

Initially, the study was intended to involve three Midzichenda ethnic groups, the Duruma, Giriama and Rabai. However, because of the presence of a bandits in *kaya* Rabai which created a security risk, it was not possible to complete this part of the study. Thus the study then was limited to only the Duruma and Giriama communities, with ecological studies conducted in their primary *kayas*, i.e. *kayas* Mtswakara and Fungo.

The specific objectives of the study were:

- To identify phytosociological relationships of plant species in *kaya* Mtswakara and in *kaya* Fungo, and to investigate the factors responsible for the changes in the vegetation types.
- To document information on the vernacular names, and traditional uses of plants by the local ethnic groups living around *kayas* Mtswakara and Fungo.
- To identify the domestic utilisation and the main sources of firewood and building poles, and the existing alternatives for these resources around the selected *kayas*.
- To establish the existing quantities of building poles and firewood resources in the selected *kayas*.
- To identify the local commercial aspects of the forest plant species utilised for firewood and building poles in the neighbourhood of the selected *kayas*.
- To determine the existing traditional strategies employed in the control of plant resource.

- Based on the above, to recommend management options for utilization and conservation of the *kaya* forests in the longer-term.

Volume I of this thesis contains seven chapters which address different objective(s) of the study. Each chapter has a brief introduction, materials and methods used in that section of the study, results and discussion. In Chapter Two there is a phytosociological classification of the vegetation in the two *kayas*. In Chapter Three there is a description of the physical and chemical characteristics of the soils in the *kayas* and in Chapter Four, the vegetation-soil relationships in the selected *kayas* are investigated. Presented in Chapter Five is the ethnobotanical inventory for Duruma and Giriama, and supplementary ethnobotanical information of the Digo was included from another work by the author (Pakia 1997). In Chapter Six there is a discussion of the domestic utilisation of building poles and firewood resources, and existing quantities of the two resources in the selected *kayas*. Also in the same chapter there is a discussion on the domestication of, and trade of wild plant species, particularly buiding poles and firewood resources; and the traditional plant resource extraction control strategies employed in the selected *kayas*. In Chapter Seven, based on the results in the preceeding chapters, the future prospects of the *kayas* are explored. Management recommendations are made, and proposals for future studies are suggested.

Volume II contains eight appendices which provides details of some methods, results and discussion.

1.3.2 The Study Area

Geographical location of study areas

At the Kenya Coast, the ridge rising 150 – 300 m above the coastal plain, extending from Shimba Hills in the south to Kilifi creek in the north, is the historical centre of the Midzichenda settlement (Spear 1978). *Kaya* Mtswakara is found along this ridge, while *kaya* Fungo is found on the much flatter area to the west of the ridge, that is on the Nyika plateau (Moomaw 1960).

Kaya Mtswakara, also known as *kaya* Duruma, is the primary *kaya* of the Duruma community. According to Spear (1978), the Duruma do not share the Singwaya origin with the remaining Midzichenda groups. They were formed by three different groups:

i) a group of Digo from *kaya* Kwale were the first to inhabit the Duruma area and were responsible of building the primary Duruma *kaya*, Mtswakara. This might account for the linguistic and cultural similarities between the Digo and Duruma (Spear 1978).

ii) a group of refugee slaves fleeing Mombasa, who took Digo wives and settled in the area were rapidly assimilated into the Midzichenda culture.

iii) and a group of Kamba immigrants who settled in the area wer similarly assimilated.

The three groups consolidated into a single people through adoption of the Midzichenda culture and formed the Duruma community.

Kaya Mtswakara is found in Kwale District and its geographical location is: 03°59.50 - 04°00.75 South, and 39°30.50 - 39°31.90 East, at an altitudinal range of 20-140m above sea level. The *kaya* comprises an area of approximately 248 ha. and was gazetted as a National Monument in 1997, under the Antiquities and Monuments Act. In the early 1930s the settlement in the *kaya* forest covered an area of about 3 hectares, and was accessible only by two steep narrow paths (Griffiths 1935). The forest of the *kaya* was damaged by troops of the Sultan of Zanzibar in the late nineteenth century through timber extraction, but continued to serve as a ritual centre for the local community (Willis, 1996).

Kaya Fungo, also known as *kaya Giriama*, is the primary *kaya* of the Giriama community. According to Spear (1978), the Giriama after leaving Singwaya were forced south to Kinarani, and eventually to Mwijo where they encountered the Laata (Waata) hunters. The Laata hunters helped them to overcome the Galla, and showed them a forest refuge where they were able to defend themselves, and there they built *kaya* Fungo.

Kaya Fungo is found in Kilifi District, and its geographical location is 03°47.50 - 03°48.40 South, and 39°30.10 - 39°31.20 East. The *kaya* comprises an area approximately 205 ha. and was gazetted as a National Monument in 1996. Another forest fragment culturally linked to *kaya* Fungo, Mirihi-ya-Kirao, is found at a geographical location: 03°49.3 - 03°49.9 South, and 39°30.8 - 39°31.4 East. By the time the field work of this study was conducted, Mirihi-ya-Kirao forest had not been surveyed nor gazetted, but was estimated to be 50 ha (Torophe pers. comm.).

Although the two *kayas* showed a great variety of wildlife, there had been no comprehensive description of the fauna that as yet, has been published. However, during the fieldwork of this study black and white colobus monkeys, Syke's monkeys, Grey monkeys, baboons, bush babies, duikers and dikdiks were encountered in *kaya* Mtswakara. Droppings of wild pigs and their activities were observed in many places in *kaya* Mtswakara, and a leopard was seen once. Many species of birds were seen, as well as of butterflies and moths. Snakes and chameleon were noted. Frogs and toads were spotted near a water point (*Chidongo*). There are also many insect taxa. Along the river Mwache, a variety of crabs and fish types were noted. In contrast, in *kaya* Fungo, the mammals were less common, with only seldom observation of droppings and activities of wild pigs and of duikers. The guards mentioned an observation of buffalo. The other fauna noted in *kaya* Fungo was of birds, arthropods and snakes.

Quentin Luke had made botanical inventories (Luke, unpublished) for both *kayas*, which were continuously updated by the CFCU staff and visiting reseurachers. Prior to this study 282 plant taxa had been recorded for *kaya* Mtswakara, and 214 taxa for *kaya* Fungo.

Climatic conditions in the study areas

The study areas are near to the Kenya Coast and experience the general coastal climatic conditions. The Kenya Coast lies in the latitudes of the truly hot tropics extending from 1°40' to about 4°40' South (Burgess *et al.* 1998). The average temperature is about 28°C during the dry season, while during the cool period (June – September) the mean temperature is 25°C (Boxem *et al.*, 1978). The area is characterised by low variability in temperature and day-length, and the diurnal range is usually very small. The weather of the area is largely controlled by the great monsoonal air currents over the Indian Ocean in combination with ororgraphic effects of coastal hills and convection over the hot, dry hinterland immediately to the west (Moomaw 1960). There is pronounced annual, seasonal, and monthly variability in the rainfall (Nieuwolt 1977), but generally the area is characterised by distinct wet and dry periods (Schmidt 1991). Much of the rainfall is associated with the Intertropical Low or "Convergence Zone" which lies over southern Tanzania in January, and over mid-Sudan in July (Moomaw 1960). The south-east monsoon brings the "long rains" (*mwaka*) in the period between April to August, when most parts receive over 70% of the total annual rainfall. The 'short rains' (*vuri*) are in October – December and a prolonged dry season is usually experienced from December to March (*kazikazi*). Although there is no measurements for precipitation other than rain, dew contributes considerably to the total precipitation of the region (Schmidt 1991). Fog is unknown along the Kenya coast but light mists may occur inland in the early morning especially during the rainy season. Also, during the rainy season the cloud base may be very low causing mist on the higher ground (Schmidt 1991).

High humidity is common particularly along the coastal line. The wind direction is mainly dependent on the land and sea breezes, which are superimposed on the major monsoonal air currents (Moomaw 1960). Surface wind velocity is usually of the order of 12 – 15 m.p.h. and achieves maximum velocity when the sea breeze is strong (Moomaw 1960).

People and their social background in study areas

The Duruma dominate the area around *kaya* Mtswakara, and the Giriama around *kaya* Fungo. The other seven Midzichenda ethnic groups inhabit the other areas of the Coast, while the Swahili (an Afro-Arab community) inhabit coastal towns such as Mombasa, Kilifi, Malindi and Lamu (Boxem *et al.* 1987). A population of communities from other parts of Kenya and abroad, Africans and non-Africans, are also found in the area, especially in the urban centres.

The rural areas around *kayas* Mtswakara and Fungo have low population density (<50 people km^{-2}). This increases (>200 people km^{-2}) in the urban centers like Mazeras, Mariakani and Kaloleni (Boxem *et al.* 1987). The majority of the local population ($\geq$ 85%) in the rural *kaya* areas are poor (Boxem *et al.* 1987, Nyamweru 1997). The local population has long depended on subsistence farming, producing only enough to support themselves for six months or less (Torophe pers. comm.). The tilling and sowing takes place on a seasonal basis and are highly dependent on the rains. The main agricultural implement used is the hand-hoe, and tractors are only hired for land tilling by the relatively rich farmers (Torophe pers. comm.). Traditional grain crops, such as, sorghum, millet and finger millet have been largely replaced by maize (Spear 1978). The other food crops cultivated include: beans; cassava; sweet potatoes; yams and peas. The farm areas under food crops tended to be small and harvests were erratic due to a combination of environmental, technological and cultural factors (Boxem *et al.* 1987). A considerable proportion of household food, therefore, had to be obtained elsewhere with cash (Boxem *et al.* 1987). This had forced a significant movement of labour from the rural farming areas to the industrial urban centres, in search of supplementary household income.

Coconut trees are grown for their oil extract, milk for cooking, traditional palm wine, and the fronds are woven into baskets, fish traps, roofing shingles, and mats (Spear 1978; Hawthorne *et al.* 1981). In the wetter parts of Giriama, around Kaloleni, land was mainly under coconut and cashew trees, and under these trees a mixture of food crops are found. In the drier areas, around *kaya* Fungo, the coconut and cashew trees, gradually give way to bushland and scrub-land, with extensive grazing and charcoal production. Animal husbandry is practised side by side with crop cultivation around both *kaya* areas. The animals reared included cattle, goats, sheep and donkey. The animals provided for meat and milk, products that were frequently sold and rarely consumed by the owners due to financial needs (Mwaringa pers. comm.).

The nutritional status of the diet in the rural areas was low compared to urban areas, hence nutrition deficiency diseases, particularly amongst the children are common (Were & Mathu, 1988). Low education levels among the rural women and social taboos often hindered improvement of this situation (Boxem *et al.* 1987). Mothers tended to be relatively young, this and lack of education were important factors in maternal and health issues (Boxem *et al.* 1987). In those areas, literacy levels were low due to inadequate education facilities. Women were particularly affected, as female school-enrolment lagged behind due to the lower priority attached to female education among the rural communities (Boxem *et al.* 1987). Kilifi and Kwale Districts experience a high infant mortality rates (149 per 1000 births) (Were & Mathu, 1988) and low birth weight is prevalent, which might be the contributory factor to the high infant mortality rates (Boxem *et al.* 1987). The most frequent killer disease in these areas was, and still is, malaria (Were & Mathu, 1988).

CHAPTER TWO
PLANT COMMUNITIES IN *KAYA* FORESTS

2.1 INTRODUCTION

The *kayas* are part of the most species-rich and structurally complex of the Kenyan coastal forests (Robertson & Luke 1993). Although studies focusing on the floral composition and vegetation diversity of coastal forests of Kenya date back to the mid-19th Century (Krapf 1860), it was in the early 1980s that the *kaya* forest patches received individual recognition, when relatively intensive botanical inventories were made (Robertson 1984, Robertson & Luke 1993). These botanical inventories were mainly meant to identify their floral composition and for the development of floral checklists. This basic information is very important and provides a basis for the description of the plant associations which constitute the vegetation of the *kayas*.

A number of studies have examined the variation within the coastal forests of Kenya (Dale 1939; Moomaw 1960; Hawthorne, Hunt & Russel 1981; Schmidt 1991). Dale (1939) made physiognomic descriptions of the vegetation based on the most abundant or most characteristic tree species and classified the *kaya* forests together with other coastal forest as a 'lowland rain forest'. Hawthorne *et al.* (1981) investigated the ecological aspects of the *kayas* Kambe and Ribe, and from their results those authors disagreed with Dale's generalised vegetation description, and noted that Dale's classification was misleading as some of the *kayas* are semi-deciduous because of a pronounced dry season. Hawthorne *et al.* (1981) identified three plant formations in *kayas* Kambe and Ribe, which were described as the watercourse flora, limestone flora and the slope flora.

Plants typically occur together in repeating groups of associated species that create formations (Mueller-Dombois & Ellenberg, 1974), and spatial changes in species combinations may be obvious even to a casual observer. However, changes vary from the relatively abrupt to transitional, consequently plant communities may be self evident or non-evident through casual observation (Mueller-Dombois & Ellenberg, 1974). Some variations that may appear very obvious may only be transitory phases of the same community type. Thus, species lists and qualitative description of vegetation, though still very important, are not an end point in ecological studies, but the beginning towards an understanding of the reasons for vegetational change at a finer scale.

Schmidt (1991) used a phytosociological approach to describe the plant ecology in the Shimba Hills National Reserve of the Kenya Coast. The results of that classification delineated seven plant communities, which were named after the diagnostic species. These were *Leptonychia usambarensis, Lagynias pallidiflora, Isolana cauliflora, Paramacrolobium coeroleum, Manilkara discolor, Aporrhiza paniculata* and *Scleria lithosperma*. Schmidt (1991) concluded that although in the previous physiognomic classifications (Dale 1939; Moomaw 1960; Hawthorne, Hunt & Russel 1981) vegetation types had been named after large trees and lianas, the characteristic species of vegetation types could be understorey plants. This is often because trees have a relatively large ecological amplitude (Mueller-Dombois & Ellenberg, 1974) and sometimes they show little consistency in their vegetation types (Schmidt, 1991). The details of plant communities for most *kaya* forests, both in terms of their ecological and structural details are to date not available or not clearly understood. With regards to the coastal forests of Kenya there has been no other phytosociological work done outside the Shimba Hills National Reserve. This present study seeks to investigate the phytosociological aspects for the two selected *kayas*, Mtswakara and Fungo, to establish a baseline for a further ecological study i.e. of the biologically and culturally aspects of these two *kayas* and other important *kaya* forests at the Kenya Coast.

2.2 MATERIALS AND METHODS

2.2.1 Preliminary survey

The physiognomical variations in the selected *kayas* had not been studied previously, therefore, there were no publications on the general description of the vegetation of the two *kayas*, and there were no recent aerial photographs to consult. The study, thus, was preceded by a reconnaissance or preliminary field survey (August - October 1997) where physiognomically different and repeatedly occurring vegetation segments were identified on the basis of the dominant tree species and other physiognomic characters. The results of the preliminary survey for each *kaya* are given in Appendix I.

2.2.2 Vegetation sampling and data collection

The sampling of forest plant communities in this study was based on floristic-structural relevés which were established using the phytosociological approach introduced by Braun-Blanquet (Braun-Blanquet 1964) as described by Mueller-Dombois & Ellenberg (1974). The Braun-Blanquent methodology follows three basic steps: vegetation stratification, vegetation sampling, and vegetation classification (Mueller-Dombois & Ellenberg 1974; Westfall 1992). In this study the stratification step was accomplished during the preliminary survey, where areas of physiognomically similar vegetation segments were identified and broadly classified. The identified physiognomic vegetation segments were used as the guide to the next step, the vegetation sampling. The Braun-Blanquet method requires that relevés be representative of, and reflect, the general characteristics of the vegetation in the study area (Shimwell 1984). The relevés need to be large enough in area to effectively represent the composition of the plant community, yet remain homogenous, not to include a major trend or change in structure or composition, except where it is a characteristic feature of the community (Mueller-Dombois and Ellenberg 1974).

In this study the locations of all relevés were chosen in the field, and the positions of the relevés were recorded with the aid of a Geographical Positioning System (GPS) device. Homogeneity in terms of vegetation physiognomy and local environmental conditions were prerequisites for a site selection. The relevés were oriented in such a way that the long axis (20 m) ran parallel to any apparent environmental or vegetational gradient, and the relevé was visually checked for internal homogeneity before demarcation. If the relevé was not homogenous, it was either moved to a position that was homogenous, or if this was not possible the relevé size was reduced before the data collection commenced. A 200m^2 (20 x 10 m) relevé was taken as this was considered to be large enough to be representative whilst also being smaller than the patches of different vegetation types that can be found in the *kaya* forests. However, eight relevés out of 51 in *kaya* Mtswakara, and one relevé out of 54 in *kaya* Fungo, had their size reduced to allow for homogeneity (see Table 2.1 and 2.5). At a minimum, five relevés were placed in each physiognomic vegetation type (as recognised in the preliminary survey, see Volume II Appendix I).

In this study, cover was used as the measure of relative abundance of a species in the relevés. Cover was defined as the proportion of the ground occupied by the perpendicular projection of the aerial parts of the plants being studied. Selection of cover as a measure of plant distribution was based on its emphasis as being of greater ecological significance than density (Rice 1967, Daubenmire 1968). This idea was established from the observation that cover gives a better measure of plant biomass and dominance than does the number of individuals (Mueller-Dombois & Ellenberg 1974). In each relevé, vegetation cover, as a percentage of total relevé area, was estimated for four defined strata:

Stratum 1 - emergent layer (T), consisting of very tall trees and lianas above 15m height. Epiphytes and parasites on stems and branches above 15m were also included in this stratum.

Stratum 2 - short tree layer (t) consisting of plants that are between 5 - 15m tall. These included young individuals that may develop into the future T layer, and lianas, epiphytes and parasitic plant species found between 5 - 15m.

Stratum 3 - shrub layer (S), formed by plant species found between 1 - 5 m high. This stratum consisted of shrubs, saplings of taller species, and some woody herbaceous species.

Stratum 4 - herb layer (H), referring to all plant species <1 m tall. This stratum included grasses, creepers and most non-woody plants. In closed canopy forest areas the plants of higher strata shade this stratum, thus the plants found in such situations would be mainly shade tolerant species.

For each relevé a species list was established and the cover abundance for each plant species was estimated separately within the four strata using the Braun-Blanquet scale (Mueller-Dombois & Ellenberg, 1974).

5 - species with cover abundance of more than 75% of the relevé

4 - species with cover abundance of 51-75%

3 - species with cover abundance of 26-50%

2 - species with cover abundance of 16-25%

1 - species with cover abundance of 5-15%

0.5 - species with small but many individuals scattered in the relevé

0.1 – solitary or several individuals with a cover less than 5%

Additional data collected from each relevé included: sampling date, relevé number, altitude, slope, aspect, physiognomic vegetation type (from preliminary survey) and supporting information e.g. signs of fire incidences, past human occupation and grazing. Species of mosses and lichens were neither included in the vegetation data collected, nor in the subsequent data analysis. However, their occurrence in a particular relevé was noted.

2.2.3 Community analysis and vegetation classification

Shimwell (1984) states that there are five objectives in the analysis of vegetation data:

i) to develop an understanding of the various plant communities within an area;

ii) to establish how these communities are related to one another;

iii) to determine the distribution of individual plant species within the communities

iv) to establish how the communities are related to their environment;

v) to determine how communities develop and function as organised ecological systems.

In this Chapter, vegetation analysis was performed to address the first three objectives above, for each *kaya* forest. Two-Way Indicator Species Analysis (TWINSPAN) (Hill 1979, Gauch 1982), following its successful use in previous ecological studies in East Africa (Beck *et al.* 1987; Schmitt 1985; Schmitt1991; Bussmann 1994) and in an area of coastal forest in Kenya (Schmidt 1991), was selected and used for community analysis in this study. TWINSPAN is a polythetic divisive classification technique and is commonly used in community ecology (Kent & Coker 1992; van Tongeren 1995). The basis of the technique is firstly an ordination of the data using reciprocal averaging. Relevés are then polarized emphasizing the species that characterize the ordination axis ends. Relevés are then divided into two clusters by partitioning the ordination axis to separate species that are strongly associated with the poles of the ordination. The process is repeated on the subsequent groups to give clusters until each cluster contains no more than a chosen minimum number of samples. Simultaneously a species classification is produced, and the end product is an arranged matrix of relevés and species. After analysis, the output table displays relevé numbers across the top, and species along the left margin of the table, while the values at the intercepts of the columns and rows in the table indicate the quantity by a cover-abundance index. In the TWINSPAN output tables (given in this Chapter) the indices are defined as follows:

7	- species with cover abundance of more than 75% of the relevé
6	- species with cover abundance of 50-75%
5	- species with cover abundance of 25-50%
4	- species with cover abundance of 15-25%
3	- species with cover abundance of 5-15%
2	- species with small but many individuals scattered in the relevé
1	- solitary or several individuals with a cover of 5% or less

In the output tables, the resulting sample groupings, defined as vegetation types, are here termed as 'communities' if the eigenvalue of the division is 0.45 or more (Ellery, pers. comm.). Formal syntaxonomical nomenclature was not followed, instead the 'indicator' plant species were used as syntaxa to describe the vegetation units, followed by a brief description of the habitat on which the community is found. The term 'community' was used as a central vegetation unit, and 'sub-community' was used for floristically recognisable differences within a community, which cannot be attributed to obvious ecological or historical factors (Schmidt 1991). In a division where a second sub-community is not definable by any suitable characteristic species, that sub-community name is followed by the term '*senso stricto*' (Hoeft pers. comm.). The term 'stage' was adopted to describe floristic differences within a community, which were attributed to historical influences especially if a development in the sense of succession (or seral) stages can be observed or anticipated (Schmidt 1991). The term 'sub-stage' was used to describe a unit derived by a division of a stage.

For each vegetation type, 'indicator' and 'preferential' species were identified.

- Indicator species were defined as the species that occur in 80% or more relevés in a particular group, and in 20% or less relevés in the other groups.

- Preferential species were defined as the species that occur in 20% or more of the total relevés established, and twice likely to occur in the group in question than in any other group.

The numbers of rare and generalist species were also categorised. Rare species included species that made one or very few occurrences in the total data set, while generalist species were those that occurred across many vegetation units (Westfall 1992).

The same species in different strata can be defined as separate pseudospecies within TWINSPAN. However, an attempt to use the data concerning the vertical structure of the vegetation by establishing pseudospecies was not successful, as the results were complex to interpret. Therefore, the results presented in this Chapter are only for the horizontal vegetation groupings. For each species, only one cover abundance value for each relevé was entered for analysis in TWINSPAN. Where a species occurred in more than one stratum, the highest cover value was used in the analysis, thus excluding the presence of pseudospecies in the output table.

TWINSPAN is effective and robust compared to other forms of hierarchical classification techniques (Gauch 1982, Goodman 1990). Due to the robustness of TWINSPAN the results for a given data set are stable despite minor perturbations of the data, and produces effective results for a wide variety of data sets. Minor perturbations of a data set include: the alteration of species abundance cover values by small random fluctuations; the deletion of a few species; the deletion or addition of rare species; and for a large data set, subdivision of the data set into several replicate sample subsets (Gauch 1982). In this study, it is regarded as unlikely that for any species, the estimated cover value index category would be more than one category different from the actual value. Therefore, TWINSPAN is regarded as robust in the sense of allowing for this degree of variation (or error) in the use and estimation of cover values. Robustness or stability against minor perturbations does not mean that classification results are entirely unaltered but that the significant features of the classification remain.

2.2.4 Plant collection and identification

Specimens of plant species were collected during the fieldwork, and tentative identifications were conducted in the field. The plant material were subsequently dried and taken to the CFCU, Ukunda office. At the office, identifications were confirmed through comparison with available material in the herbarium, and by use of the available publications (Agnew 1974; Beentje 1994; Flora of Tropical East Africa (FTEA)). Luke[1] was usually consulted for confirmation of the species identifications. The nomenclature of plant families and family numbering follows that of the FTEA. For families not covered in FTEA, Beentje (1994) was consulted. The plant collections were deposited at the CFCU Ukunda office for further preparation if necessary and inclusion into the herbarium. Sample collections of taxonomic interest were sent to East African National Herbarium (Nairobi) and Kew (United Kingdom).

2.3 RESULTS: *KAYA* MTSWAKARA VEGETATION

2.3.1 Introduction

Between June and December (1998), 51 relevés (Fig. 2.1) were sampled in *kaya* Mtswakara. The details of the 51 relevés are given in Table 2.1. A total of 317 taxa representing 191 genera in 79 families were recorded. The taxa represented 48 tree species, 134 shrub species, 82 herbaceous species, 45 climbers and 8 epiphytes. The data were analysed using TWINSPAN (Hill 1979) which provided hierarchical classification table of the vegetation data matrix. The sample plots were classified on the basis of their similarities to subsequently express the species' synecological relations as succinctly as possible (Hill 1994). The output table of the most common species, based on the occurrence in at least three relevés, is presented in Table 2.2. A complete data set for all species recorded in the *kaya* is given in Appendix II.

[1] Quentin Luke: CFCU Project Executant, and a plant taxonomist at the East African Herbarium (Kenya).

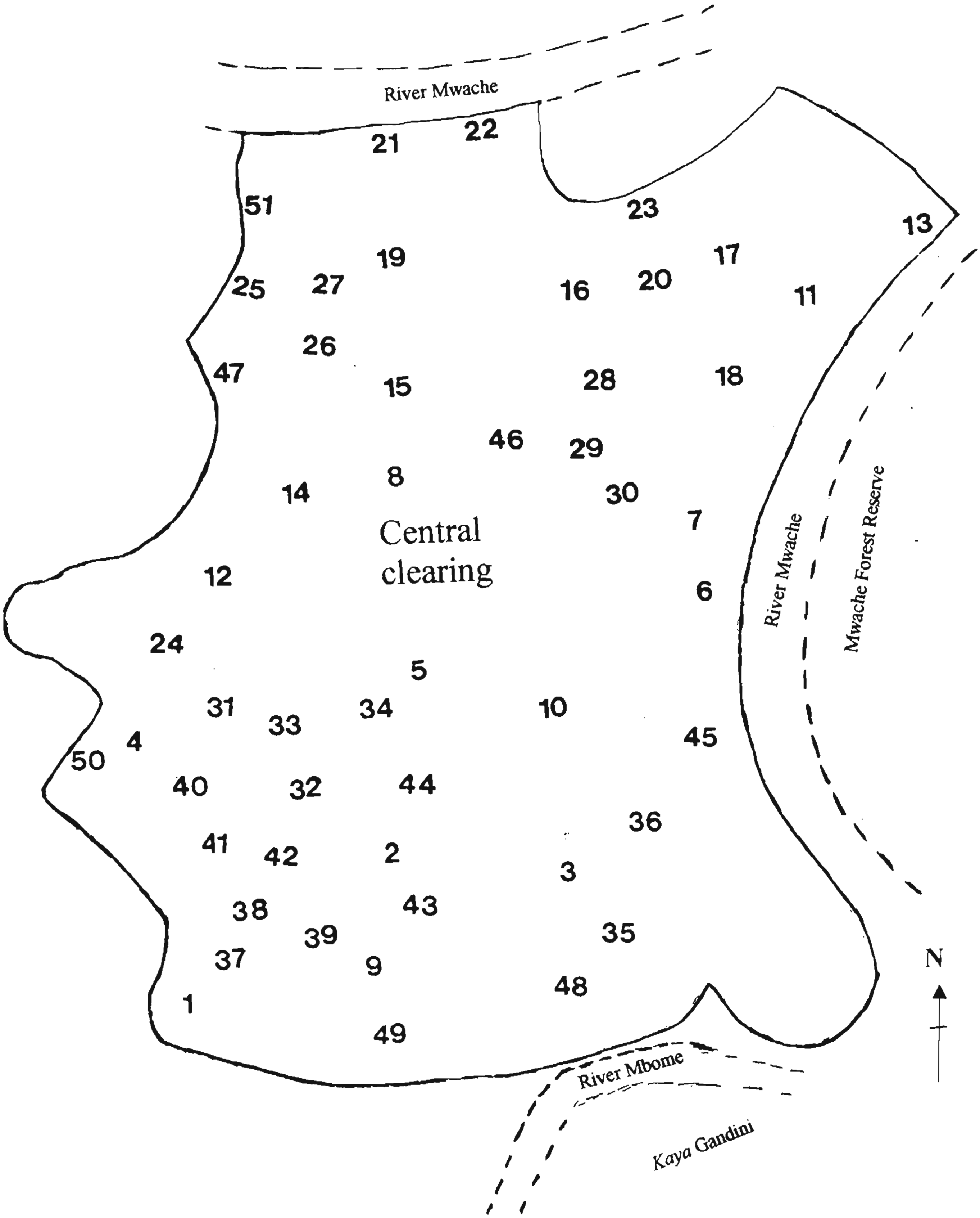

Fig. 2.1: A sketch map of *kaya* Mtswakara indicating the approximate positions of relevés established in the *kaya*

Table 2.1: General description of the individual relevés sampled in *kaya* Mtswakara.

Date	Relevé number	Sub-locality	Physiognomic category	Gradient (X°)	Relevé size (m)	Latitude	Longitude	Altitude (m)	T layer (% cover)	t layer (% cover)	S layer (% cover)	H layer (% cover)	Species richness
16-Jun-98	1	*Huernia* site	*Brachystegia*	5	20 x 10	39° 30. 865	4° 00.869	111	0	15	20	60	39
16-Jun-98	2	Chidongo water point	*Brachystegia*	10	20 x 10	39° 31.004	4° 00.823	126	0	20	25	65	18
17-Jun-98	3	Garama's former farm	*Brachystegia*	5	20 x 10	39° 31.210	4° 00.944	-	40	10	45	80	32
17-Jun-98	4	Chiphaloni	*Brachystegia*	5	20 x 10	39° 31.183	4° 00.634	222	0	70	20	35	32
18-Jun-98	5	Malatani, nr Tsanvulani	*Brachystegia*	5	20 x 10	39° 31.325	4° 00.701	-	0	40	45	65	23
18-Jun-98	6	Uzioni, near Tsanvulani	*Cynometra*	10	20 x 10	39° 31.384	4° 00.476	-	30	40	70	90	28
20-Jun-98	7	Matukutukuni/Tsanvulan	*Cynometra*	20	20 x 10	39° 31.384	4° 00.476	-	0	80	75	30	38
20-Jun-98	8	East of Mtswkara Hill	Grassland	10	20 x 10	39° 31.311	4° 00.315	66	0	0	40	80	22
21-Jun-98	9	Kauze 2	*Brachystegia*	5	20 x 10	39° 30.877	4° 00.715	117	0	20	60	85	30
21-Jun-98	10	Garama's former farm	*Julbernadia*	5	20 x 10	39° 31.310	4° 00.818	60	25	65	80	70	42
16-Sep-98	11	Near Balozi's fish traps	Bushland	15	20 x 10	39° 31.734	4° 00.112	18	0	25	80	80	53
16-Sep-98	12	Cleared, near Ndosho's farm	Grassland	20	20 x 10	39° 31.224	4° 00.440	144	0	5	35	90	31
17-Sep-98	13	Malatani, far NE tip	Grassland	5	20 x 10	39° 32.005	3° 59.831	3	0	5	85	90	53
17-Sep-98	14	SE foot of Mtswakara hill	*Cynometra*	20	20 x 10	39° 31.124	4° 00.301		50	60	80	90	38
19-Sep-98	15	Near Central Clearing	*Cynometra*	10	20 x 10	39° 31.427	4° 00.160	-	70	40	80	60	48
20-Sep-98	16	Along Balozi/ Mwatela foot-path	*Julbernadia*	10	20 x 10	39° 31.550	4° 00.124	-	0	35	85	40	50
22-Sep-98	17	Balozi/ Mwatela fishing site path.	*Julbernadia*	10	20 x 10	39° 31.650	4° 00.930	-	0	60	85	90	71
23-Sep-98	18	Towards Mwatela's fisihing site route	*Julbernadia*	25	20 x 10	39° 31.548	4° 00.150	8	0	60	90	70	57
24-Sep-98	19	Northern patch, foot-path to Mbome	*Cynometra*	40	20 x 10	39° 31.430	4° 00.152		30	25	75	40	45
14-Oct-98	20	Along route to fishing site (Mwatela/Mbovu's)	*Julbernadia*	30	20 x 10	39° 31.590	4° 00.163	-	0	70	85	40	57
18-Nov-98	21	Northern Mtswakara hill, near river bed	*Cynometra*	30	20 x 10	39° 31.384	3° 59.977		0	40	70	30	49
18-Nov-98	22	North of Mtswakara hill, (east of 21)	*Cynometra*	30	20 x10	39° 31.544	4° 00.036		5	15	60	80	32
18-Nov-98	23	North of Mtswakara hill, (east of 22)	*Cynometra*	40	20 x 10	39° 31.698	4° 00.070		0	20	60	75	40
15-Dec-98	24	Near the Chiphaloni plot	*Julbernadia*	10	20 x 10	39° 31.178	4° 00.569	315	0	40	60	30	47
15-Dec-98	25	NW Mtswakare hill	*Cynometra*	25	20 x 10	39° 31.238	4° 00.183	-	5	30	70	40	47
15-Dec-98	26	Near central clearing	*Cynometra*	5	20 x 10	39° 31.332	4° 00.142	-	5	10	80	30	41
15-Dec-98	27	West- Mtswakara hill, route to fishing zone	*Cynometra*	20	20 x 10	39° 31.313	4° 00.130		20	30	80	40	42
16-Dec-98	28	Off route before right turn to plot 8	Cynometra	40	10 x 10	39° 31.417	4° 00.172		0	40	60	40	36
16- Dec-98	29	Bi-pass to fishing sites (Mwatela/Ndosho's)	Cynometra	10	20 x 10	39° 31.377	4° 00.330	-	0	40	60	30	33
16-Dec-98	30	Bi-pass to fishing site (Mwatela/Ndosho's)	Julbernadia	25	20 x 10	39° 31.347	4° 00.331	225	0	60	70	30	36
16-Dec-98	31	Rout to Garama's former farm	*Brachystegia*	5	20 x 10	39° 31.204	4° 00.593	-	0	10	35	10	36
16-Dec-98	32	Along route to Garama	Termite mound	25	10 x 10	39° 31.191	4° 00.659	243	0	60	80	10	47
17-Dec-98	33	Along route to Garama	Termite mound	30	10 x 8	39° 31.260	4° 00.720	-	0	20	60	10	37
17-Dec-98	34	Along route to Garama	*Brachystegia*	5	20 x 10	39° 31.252	4° 00.721	-	0	20	30	5	30
17-Dec-98	35	Next to Garama plot	Termite mound	35	10 x 10	39° 31.259	4° 00.893	-	0	30	70	10	39
17-Dec-98	36	Garama/Chidongo route.	Termite mound	20	10 x 10	39° 31.166	4° 00.913	246	0	60	80	40	50
17-Dec-98	37	North of Huernia plot	*Julbernadia*	0	20 x 10	39° 30.828	4° 00.618	162	0	60	75	40	43
18-Dec-98	38	Far north of Huernia plot	*Julbernadia*	0	20 x 10	39° 30.858	4° 00.576	105	5	75	70	40	48
18-Dec-98	39	South of Chidongo	Termite mound	20	10 x 10	39° 30.954	4° 00.686	129	0	0	80	40	36
18-Dec-98	40	Near 2nd *Huernia* site	Termite mound	40	10 x 10	39° 31.171	4° 00.603	231	0	40	80	30	39
18-Dec-98	41	By-pass Garama/Chidong	*Brachystegia*	15	20 x 10	39° 31.119	4° 00.712	24	0	10	30	80	14
18-Dec-98	42	By-pass Garama/chidong	*Brachystegia*	5	20 x 10	39° 31.030	4° 00.686	27	0	0	40	70	18
19-Dec-98	43	Between plots 2 and 39	*Brachystegia*	10	20 x 10	39° 30.956	4° 00.807	123	0	0	40	60	15
19-Dec-98	44	Along Chidongo-Garama route.	Termite mound	10	5 X 10	39° 31.158	4° 00.915	180	0	10	70	20	
19-Dec-98	45	-	Grassland	5	20 x 10	39° 31.280	4° 00.948	-	0	20	60	70	32
19-Dec-98	46	Top hill Mtswakara	*Cynometra*	0	20 x 10	39° 31.292	4° 00.257	27	20	80	90	30	45
19-Dec-98	47	Nearr beacon 1	Wooded grassland	5	20 x 10	39° 31.097	4° 00.168	207	0	10	5	70	31
21-Dec-98	48	Mbome/ Vunvuni joint	*Cynometra*	60	20 x 10	39° 30.707	4° 00.622	3	10	0	60	40	42
21-Dec-98	49	Near Vunvuni stream	*Cynometra*	70	20 x 10	39° 30.730	4° 00.541	-	0	20	60	50	43
21-Dec-98	50	Near Ndosho's farm	Grassland	15	20 x 10	39° 31.088	4° 00.496	-	0	0	10	70	36
21-Dec-98	51	On the North West	Wooded grassland	10	20 x 10	39° 31.153	3° 59.985	258	0	20	10	40	23

Key: T layer refers to the emergent layer; t layer refers to the short tree layer; S layer refers to the shrub layer; and H layer refers to the herbaceous layer.

Table 2.2: TWINSPAN classification table for the relatively common plant species recorded in the relevés sampled in *kaya* Mtswakara

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                                 2224411  22122241113223333431   13    344434 114455
                                 132894567899576667800478236051340115924123948235701

Commiphora-Asplenium sub-community
Asplenium buttenerii             22 222 22          22       1
Commiphora edulis                  4 3     3 3     3                            3  3
Col. No. 3156                    22 22      1           1
Adiantum comorensis              222  2          2
Aloe rabaiensis                   3 22            3
Euphorbia wakefieldii             4 23            2
Pandanus rabaiensis              343         43
Abutilon zanzibarica                3333

Ricinodendron sub-community
Grandidiera boivinii             333   14334344432
Pycnocoma littoralis             3   333  3 33333  3  3
Hibiscus faulknerae                1  33  3 35333                                1
Cissus quinquangularis                22    3111
Ricinodendron heudelotii           3    4 13 3 3
Sterculia appendiculata          1   333
Commiphora eminii                     43 333
Cordia monoica                        41  3
Cryptolepis sinensis                     1  1113
Uvaria faulknerae                     34   3   4443
Thunbergia kirkii                     1 2   112
Cola minor                       1          3  34
Coffea sp.                                 3 1 3   3        3               3
Salacia sp.                                   133 3    3
Cissus sylvicola                  3          23            3

Differential species of Scorodophloeus community
Scorodophloeus fischeri          4554435433456566 3             3          3
Encephalartos hildebrantii       3134333443 34433 3    13   1
Selaginella eublepharis          222222 22 2 2   222          2
Achyranthes aspera               3332 323 2 4 222    3        1                  1 2
Rhoicissus tridentata            1 13    3333  13         3
Gyrocarpus americanus             33 3 3 3  333
Acalypha neptunica                 43333  23 1  3   3        3
Synadenium pereskiifolium        1 1   3  3 2        1
Nectropetalum kaessneri          3   34 3 34                   3
Col. No. 2417                                 3  3 3  3 4      1           1

Scorodophloeus-Hugonia Transitional species group
Euphorbia nyikae                  3    1 3 3      1  3    3 3
Sanseviera robusta                     2  2    1  22 2   2
Buxus obtusifolia                     3   3 2 3 33          3
Memecylon fragrans                    3 3  4    3333
Markhamia zanzibarica                  3     3   333          3

Ochna-Pancovia sub-community
Ochna thomasiana                              33331334 11        11    1
Pancovia golungensis                   3       34334343       1    3
Heinsia crinita                                  233 31 3     13 3           1 1
Ophrypetalum odoratum                            4 443
Acridocarpus alopecuris                          33 43 31     1
Phyllanthus kaesneri                       3      333   4
Monodora grandidieri                               3   34          3

Dobera sub-community
Carissa tetramera                                     3  444 3 3       3   45
Vitellariopsis kirkii               3                 4 3 3443             2
Dobera loranthifolia                     3 3             43443
Thespesia danis                                          433 3             3    13
Vernonia wakefieldii                 3                   3333              3
Tarenna supra axillaris                                333                  3
Strychnos panganensis                                  3   43 4    3
Strychnos madagascariensis                             33 331              3  31
Euphorbia tirucalli                                      33 4
Tricalysis ovalifolia                                3 4 3                34  3
Salvadora persica                                    3 333 3               1    1

Differential species of Hugonia community
Hugonia castaneifolia                        3 33333333331 33 3  1
Vepris eugeniifolia                 3       131 13   3  3313 3 3 3
Crossandra pungens               1       2 21   22222  22 1 2    2
Suregada zanzibariensis                    3  3 34 4  33 333
Schlechterina mitostemmatoides                 113  3311 3 313   4 1        3
Julbernardia magnistipulata                     455655561   144 63
Sclerochiton vogelii                            34343 3 4333     4

Differential species of Asteranthe community group
Asteranthe asterias              3333 4333333334443334333343333 3  4          3
Cynometra suaheliensis           334435454544344   33  3  54456              45
Cissus rotundifolia              1 1321233333 33233232213322 31   1 3        3   1
Combretum illairii               2 343  64 415354434543433 44    14 3              1
Croton pseudopulchellus          4   23 4656  343  4333 33334    34          3
Craibia brevicaudata             3 43 33543 43 453 43     3  3
Cynometra webberi                43 33  4545433 2 333       3                3
Grewia holstii                   33 3343 33 13 31333        3
Mildbraedia carpinifolia         3433 3  33313444 333   3    33               3
Sansevieria arborescens          322 232  4      23  2   22211
Capparis viminea                 33 4  3  33 31   31  33 333  1   3         33
Sansevieria kirkii                 2   2  2122 21 2 1       12
Panicum sp.                         1  224 622   2 242 22       2            12
Manilkara sulcata                      33333  143 333 4  3333 3 [illegible]
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Panicum sp.	1 224 622 2 242 22 2 12
Manilkara sulcata	33333 143 333 4 3333 3 43
Chlorophytum fillipendulum	222 1 211 11 2 1 1
Maerua triphylla	3 34 33 3 31 31 2 3
Companion species of *Asteranthe* community group	
Cissus phymatocarpa	13 1 1 13 1 1 2 2 3
Haplocoelum inoploeum	1 3 3 31 3 333 33 3 3
Psilotrichum scleranthum	42 23 1 32 33 3 33 1
Uvariodendron kirkii	3 3 3 3 1 3 33 1
Strophunthus kombe	31 333 33 3
Dorstenia hildibrandtii	12 22 1 211 1
Stylochaeton salaamicus	2 12 2 12 1 1 1 1
Dichapetalum zenkeri	3 1 33 43 3
Grewia forbesii	3 33 34 3 33 3
Commelina bracteosa	112 2 2 1 2 1
Commiphora lindensis	3 3 3 3
***Rytigynia* sub-community**	
Rytigynia celastroides	323 1 3
Phyllanthus welwitschianus	3223 3
Dichrostachys cinerea	322 4
Hymenodictyon parvifolia	3 33 122 3
***Psydrax* sub-community**	
Psydrax faulknerae	1 3 3333333
Bidens taylorii	25 222
Garcinia livingstonei	3 3 3 4
Differential species of *Brachystegia* community	
Brachystegia spiciformis	33 551345644444
Manilkara sansibarica	3 3 33333433 3334
Gutenbergia sp.	1 1 242222222 12
Blepharis maderaspatens	2 3 2 2 2 2222 2 1 132 2
Hyperthelia dissoluta	5 5233642 4126
Agathisanthemum bojeri	2 3 22 122 251 2
Murdannia simplex	22 22 1 1 11
Setaria sp.	4 4 5 2
Differential species of *Acacia* community	
Acacia etbaica	333313
Acacia mellifera	3333
Catunaregam nilotica	334 1
Hoslundia opposita	3 333311
Grewia plagiophylla	3 3 1 4333 3
Allophylus rubifolius	33 133 1
Ximenia americana	1 3 133
Cissampelos pareira	1 1211 1
Terminalia spinosa	3 3311
Bridelia cathartica	3 33
Tinnea aethiopica	1 31 33 1
Diospyros bussei	3 3 3 3 3
Aspilia mossambicensis	22 4 2
Ocimum suave	3 111
Differential species of *Hugonia* and *Brachystegia* communities	
Synaptolepis kirkii	23334233333 343333333331131 13
Ancylobotrys petersiana	133333333333333323333243313 33 1
Canthium mombazense	333333343443 2231334 111334
Monanthotaxis fornicata	344 43333 33 34 3 31
Adenium obesum	1 2 1 11221 32222323 2
Achyrothalamus marginatus	3 3 3 2 4 341 12
Thecocaris bussei	3 1 3 33333 1 1
Uvaria lucida	3 33 3 4 333 4 3 1 33
Diospyros consolatae	3333 3 1 433343313334 3
Psychotria amboniana	3 33433 32333333333333 2
Psydrax recurvifolia	334 3 333 343333334
Psydrax polhillii	1 3 33 3 33313 1 3 3
Pentarhopalopilia umbellulata	1 3311 44 1 33 333 1
Ritchiea capparoides	3 3333 3
Lamprothamnus zanguebaricus	3 123 3 1 33 3
Strychnos spinosa	33 3 33
Artabotrys modestus	3 31 1 4
Differential species of *Hugonia*, *Brachystegia* and *Acacia* communities	
Panicum maximum	12 1 4 22422 222 25344254332 22665 2
Ochna mossambicensis	3 3311113 113333133 3 11 3 131 1
Cyanotis sp. nov.	22 12 2222121112 21 2 2 2 1
Differential species of wet-dry coastal forest	
Asparagus falcatus	3 3313 133133131233 333133333 313 3 1 231
Uvaria acuminata	12 3 121313133333313331 3 3 33 23 4
Asystesia gangetica	22 2 1 2 2321222 3 223133222 2 22 2
Companion species of wet-dry coastal forest	
Kyllinga sp.	2 222 22 12 12 222 22 2 1 212
Deinbolia borbonica	1 1 1 3 1 13 3121 22
Pyrenacantha vogliana	1 1 3 3 2 1 3 33 13
Premna chrysoclada	3 3 3 133
Dalbergia boehmii	3 3 1 3 3 4 3 3
Abutilon mauritiana	3 3 3
Cyperus sp.	212 2 1 2 1 2
Acacia adenocalyx	4 3 5 3 3 3
Cynanchum gerradii	1 1 2 1 12 3 3
Microcoelia sp.	1 1 1 2 2 1 3 2
Sanseviera sp.	2 22 2 11 2 2

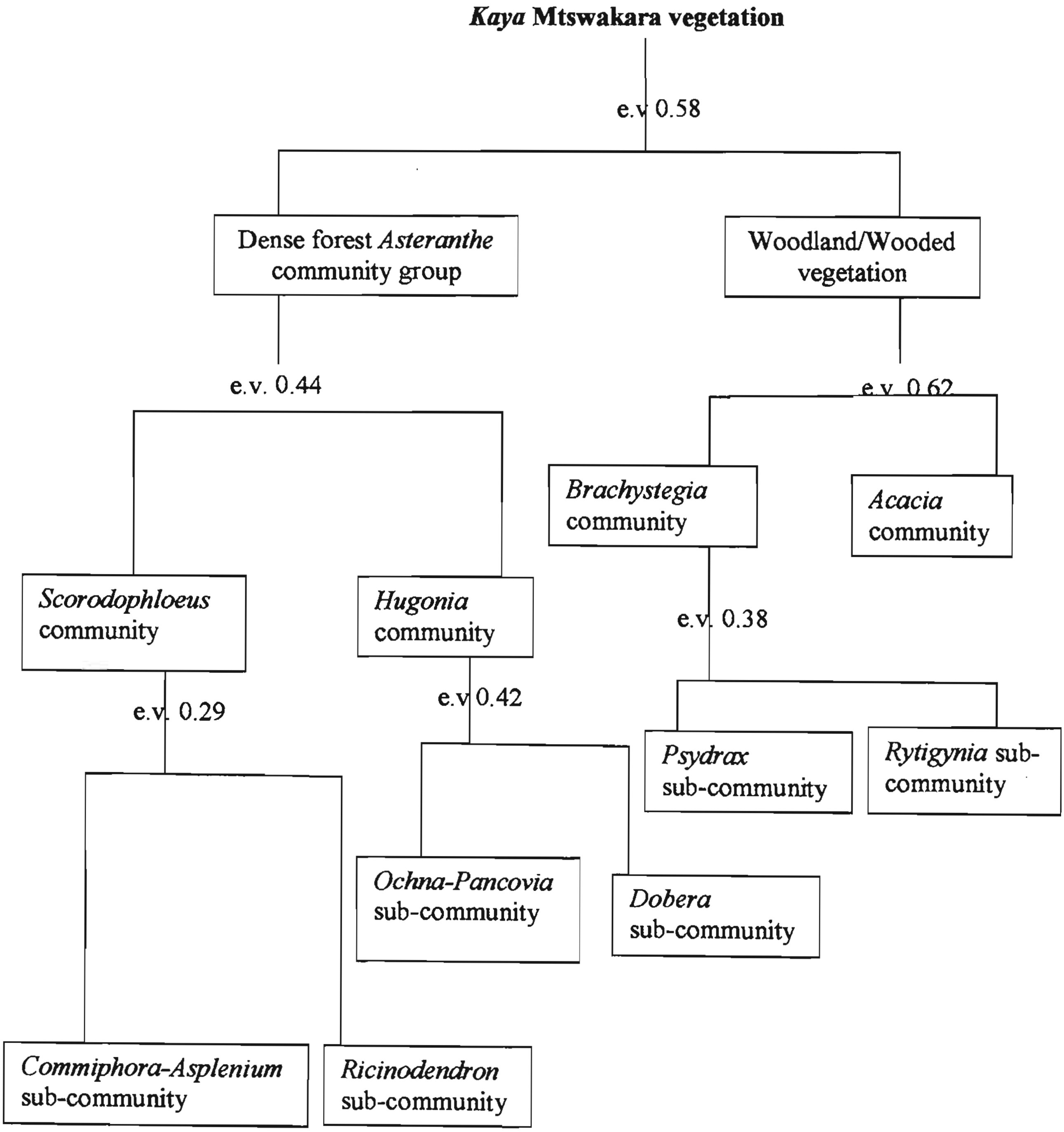
2.3.2 *Kaya* Mtswakara vegetation classification

The hierarchical classification of the data, based on TWINSPAN analysis, is presented in Figure 2.2, exhibiting the vegetation types identified in *kaya* Mtswakara. The first division (eigenvalue 0.58) separated the relatively dense canopy forest area (the *Asteranthe* community group) from the more open woodland and the wooded grassland (*Brachystegia* and *Acacia* communities respectively). The *Asteranthe* community group was then divided into two communities i.e. the *Scorodophloeus* and the *Hugonia* communities. Further divisions of these two dense canopy forest communities (the *Scorodophloeus* and the *Hugonia*) recognised four sub-communities, two in each community. The *Brachystegia* woodland community was separated from the *Acacia* wooded grassland (eigenvalue 0.62); and the *Brachystegia* woodland was further divided into two sub-communities (eigenvalue 0.38) i.e. the *Psydrax* and *Rytigynia* sub-communities.

In summary, in the vegetation classification, four plant communities and six sub-communities were identified. The four communities are: ***Scorodophloeus*** community, ***Hugonia*** community (both being relatively dense forest communities in *Asteranthe asterias* community group), the ***Brachystegia*** community (a woodland), and the ***Acacia*** community (a wooded grassland). In the *Scorodophloeus* community, the sub-communities: ***Commiphora-Asplenium*** and ***Ricinodendron*** were identified; while in the *Hugonia* community the sub-communities: ***Ochna-Pancovia*** and ***Dobera*** were identified. And in the *Brachystegia* community the sub-communities: ***Psydrax*** and ***Rytigynia*** were identified.

Although the floristic classification and relevé groups were defined up to the 25th division in the fifth cut-off level, the interpretation behind the 6th and 12th divisions, in which relevés 8 and 11 (respectively) were excluded from *Brachystegia* community were unclear. The 6th and 12th divisions had high eigenvalues (0.57 and 0.45 respectively) which indicate strong dissociation of the respective relevés sampled in the *Brachystegia* community.

Fig. 2.2: The hierarchical classification dendrogram, showing the vegetation types identified in *kaya* Mtswakara and the eigenvalues (e.v.) associated with the divisions



2.3.3 *Kaya* Mtswakara vegetation description

Kaya Mtswakara is a dry/wet coastal forest, characterised by the 'generalist' species *Asystesia gangetica, Asparagus falcatus* and *Uvaria acuminata*. Other species identified as 'generalists' were recorded across different vegetation types, but their occurrences were relatively less consistent. In the entire vegetation data set (Appendix II) about 3% of the species were generalists, occurring in 51–75% of the relevés. Most species (>60%), however, were locally rare, occurring in less than 10% of the relevés (Table 2.3).

Table 2.3: Frequencies of occurrence of species (n=317) in the 51 relevés sampled in *kaya* Mtswakara.

Percentage of the relevés	Percentage of species occurring
> 75	0
51 – 75	2.8
26 – 50	10.4
10 – 25	22.6
< 10	64.2

Table 2.4 summarises the species richness and structural characteristics of the vegetation types identified in the vegetation classification. The *Asteranthe* community group had the highest species richness, particularly the *Ochna-Pancovia* sub-community, and the lowest species richness record was for *Psydrax faulknerae* sub-community (Table 2.4). The vegetation types were considerable different in the cover of the four vegetation layers.

Emergent trees were generally rare in all vegetation types, but relatively high cover of the emergent layer (T) was recorded in the *Ricinodendron* sub-community and low cover in *Commiphora-Asplenium* and *Ochna-Pancovia* sub-communities. Emergent layer species were absent in the *Dobera* and the *Psydrax* sub-communities, as well as in the *Acacia* community.

Table 2.4: Species richness and structural characteristics of vegetation types identified in *kaya* Mtswakara (the number of species and cover percentages are means, with the standard deviation of mean given in brackets)

Community	Sub-community	Relevé No.	Range: No. of Species	No. of species/ reléve	% cover of emergent layer	% cover of short tree layer	% cover of shrub layer	% cover of herb layer
***Scorodophloeus* community**	*Commiphora-Asplenium* sub-community	5	32 – 49	41.2 (6.1)	3.0 (4.0)	19 (12.8)	62.0 (4.0)	55.0 (19.5)
	Ricinodendron sub-community	11	28 – 48	40.1 (6.2)	20.9 (21.8)	43.2 (20.9)	74.5 (8.6)	47.3 (21.8)
***Hugonia* Community**	*Ochna-Pancovia* sub-community	8	36 – 71	51.1 (10.6)	0.6 (1.7)	57.7 (12.7)	77.5 (9.7)	47.5 (19.8)
	Dobera loranthifolia sub-community	5	37 - 50	42.4 (5.7)	0	42.0 (16.0)	74.0 (8.0)	20.0 (12.6)
***Brachystegia* community**	*Rytigynia celastroides* sub-community	7	23 – 42	33.4 (6.3)	9.3 (15.2)	32.9 (23.9)	43.6 (19.9)	57.9 (24.6)
	Psydrax faulknerae sub-community	7	14 – 36	23.0 (8.8)	0	8.6 (8.3)	45.0 (19.8)	48.6 (25.7)
***Acacia* community**		6	23 – 53	34.3 (10.1)	0	10 (7.6)	34.2 (29.6)	71.7 (16.4)

Compared to other vegetation types, *Ochna-Pancovia* sub-community had the highest cover in short tree (t) layer and in the shrub (S) layer. The lowest cover in the short tree layer was recorded in *Psydrax* sub-community, and lowest cover in the shrub layer was recorded in *Acacia* community. However, within the *Scorodophloeus* and *Hugonia* communities the shrub layer had the highest cover compared to the other vegetation layers. Compared to other communities the *Acacia* community had the highest cover in the herb layer, and the *Dobera* sub-community had the lowest cover in the herb layer (Table 2.4).

A description of each of the vegetation types recognised in the classification is given below. In the relatively dense canopy forest an overall description of the *Asteranthe* community group and then a description of each of the communities and the sub-communities are given.

Asteranthe Community Group

The *Asteranthe* community group represented the physiognomic segment described as *Cynometra* and *Julbernardia* in preliminary survey, and was represented by 29 relevés. The community group occurred mostly on the northern half of the *kaya*, from the summits of the hill down to the river valleys (river Mwache) and extending from east to west, but with patches of substantially disturbed vegetation type in some parts. A stretch of the *Asteranthe* community group also occurred on the southern tip of the *kaya*, found mainly on steep slopes that run down to another river valley (river Mbome). Rock outcroppings, especially along the river valleys and on the riverbeds were common.

The *Asteranthe* community group is characterised by *Asteranthe asterias* and *Cissus rotundifolia*. *A. asterias* is a shrub of 1.5 – 8 m high, of the family Annonaceae, while *Cissus rotundifolia* is a climber 2 – 9m long, with a succulent stem and sometimes corky wings, of the family Vitaceae. In the *Asteranthe* community group the two indicator species were both non-conspicuous, and could not be casually identified as diagnostic species. Instead the tree species, *Cynometra suaheliensis*, *C. webberi*, *Scorodophloeus fischeri*, *Julbernardia magnistipulata* and *Craibia brevicaudata* were more conspicuous as they shared dominance in the emergent and canopy layers. In the relatively undisturbed areas of the *Asteranthe* community group, vegetation canopy was considerably dense with four distinct vegetation layers (the emergent, short tree, shrub and herb layers). However, the dense canopy was discontinuous, as the emergent layer was not uniformly distributed across the community types in the *Asteranthe* community group (Table 2.4). The dense canopy discontinuity was probably due to vegetation gaps rather than variations in the height of mature trees. The preferential tree species of the *Asteranthe* community group were: *Manilkara sulcata, Pancovia golungensis, Haplocoelum inoploeum, Ochna thomasiana, Cynometra suaheliensis, Craibia brevicaudata, Pycnocoma littoralis* and *Scorodophloeus fischeri*. While common shrub species include: *Vepris eugeniifolia, Croton pseudopulchellus, Maerua triphylla, Grandidiera boivinii, Encephalartos hildebrandtii* and *Acalypha neptunica*. Common climber species were: *Hugonia castaneifolia, Asparagus falcatus, Cissus phymatocarpa, Schletchterina mitostemmatoides, Combretum illairii, Capparis viminea* and *Uvaria acuminata* and common herb species: *Sclerochiton vogelii, Cyanotis* sp. nov., *Crossandra pungens, Sansevieria arborescens, S. kirkii, Panicum* sp., *Psilotrichum scleranthum, Chlorophytum filipendulum, Achyranthes aspera* and *Selaginella eublepharis*. The *Asteranthe* community group comprised two communities: the *Scorodophloeus* and the *Hugonia* communities.

Scorodophloeus Community

The *Scorodophloeus* community comprised 16 relevés, and represented the physiognomic segment defined in the preliminary survey as *Cynometra* vegetation. However, in the TWINSPAN output (Table 2.2) it enumerated that *Cynometra suaheliensis* and *C. webberi*, used for the description of the physiognomic segment, were not restricted to the *Scorodophloeus* community. The community was comparatively common in the *kaya*, and it occurred on the summits of the hills around the sacred sites and the central clearing of the *kaya*, as well as on slopes running down into the river valleys (Plate 2.1). A continuous stretch of *Scorodophloeus* community occurred on the northern half of the *kaya*, and a small stretch occurred on steep slopes of *Vunvuni* stream and river Mbome, at the southern end of the *kaya*. The *Scorodophloeus* community, especially the stretch on the northern part, was occasionally interrupted by other vegetation types (*Hugonia* and *Acacia* communities).

The indicator species for the *Scorodophloeus* community were *Scorodophloeus fischeri* and *Grandidiera boivinii*. *S. fischeri* is a tree 5-30m high with small buttresses and smooth grey bark, of the family Caesalpiniaceae. *G. boivinii* is a shrub, 1-4.5m high, in the family Flacourtiaceae. Preferential species for this community were *Encephalartos hildebrandtii, Achyranthes aspera, Acalypha neptunica, Pycnocoma littoralis,* and *Grewia holstii*. The species restricted to *Scorodophloeus* community were *Synadenium pereskiifolium, Cissus quinquangularis, Ricinodendron heudelotii, Commiphora eminii, Pandanus rabaiensis, Sterculia appendiculata* and *Abutilon zanzibaricum*.

In the *Scorodophloeus* community, the emergent layer comprised the tree species: *S. fischeri, Cynometra suaheliensis, C. webberi, Commiphora eminii, Craibia brevicaudata, Sterculia appendiculata, Combretum schumannii, Gyrocarpus americanus, Ricinodendron heudelotii, Commiphora eminii* and *Dobera loranthifolia*; and climber species: *Combretum illairii, Cissus rotundifolia* and *Rhoicissus revoilii*. Common species in the short tree layer included young individuals of the emergent layer (listed above) and the tree species: *Uvariodendron kirkii, Haplocoelum inoploeum, Cola minor* and *Pycnocoma littoralis*; and climber species: *Urera sansibarica* and *Uvaria acuminata*. The shrub layer comprised the most species, which included the young individuals of the emergent and the short tree layers, and assorted shrub and climber species. The shrub species included: *Nectropetalum kaessneri, Encephalartos hildebrandtii, Abutilon zanzibaricum, Acalypha neptunica, Euphorbia wakefieldii, Dalbergia boehmii, Croton pseudopulchellus, Asteranthe asterias, Mildbraedia carpinifolia, Vittelariopsis kirkii, Deinbolia borbonica, Vepris eugeniifolia, Ochna thomasiana, Hunteria zeylanica, Memecylon fragrans, Cyphostemma adenocaule, C. buchananii, Grandidiera boivinii, Ritchea capparoides, Anchomanes abbreviatus, Coffea sessiliflora* and *Commiphora edulis*. Also recorded was the invasive shrub species *Lantana camara*. The climber species included: *Grewia holstii, Grewia forbesii, Hibiscus altissimus, Asparagus falcatus, Vernonia aemulans, Cissus phymatocarpa, Combretum illairii, Capparis vimenea, Rhoicissus revoilii, Uvaria acuminata, Hugonia castaneifolia, Uvaria faulknerae, Salacia elegans, Ancylobotrys petersiana, Landolphia kirkii* and *Schlechterina mitostemmatoides*.

Common species of the herb layer were: *Asplenium butteneri, Psilotrichum scleranthum, Aloe rabaisensis, Sansevira* spp., *Asystesia gangetica, Plectranthus tenuiflorus, Pyrenacantha vogeliana, Dorstenia hildebrandtii, Chlorophytum suffruticosum, Achyranthes aspera Panicum* sp., *Kyllinga* sp., *Commelina bracteosa, Thilachium roseomaculatum, Selaginella eublepharis,* and the invasive species *Opuntia vulgaris*.

The *Scorodophloeus* community comprised *Commiphora-Asplenium* and *Ricinodendron* sub-communities. The *Commiphora-Asplenium* sub-community, represented by five relevés, occurred on the slopes ($\bar{x}$ = 46°) running down to the riverbanks on the southern and northern sides of the *kaya*. This sub-community represented the relatively less dense canopy area of the *Scorodophloeus* community. No indicator or preferential species were identified for this sub-community, however, the species which characterised this sub-community were: *Commiphora edulis, Adiantum comorensis, Aloe rabainsis, Euphorbia wakefieldii* and *Pandanus rabaiensis*. Invasive species, *Lantana camara* and *Opuntia vulgaris,* were also recorded in this sub-community. Although *Asplenium butteneri* was used in the syntaxa of the sub-community, this species was not restricted to the *Commiphora-Asplenium* sub-community, but showed satisfactory occurrence.

The *Ricinodendron* sub-community was represented by 11 relevés, and occurred mainly on the hilltops and on more gentle slopes ($\bar{x}$ = 18.2°) within the areas of the *Scorodophloeus* community. This sub-community represented the most dense canopy forest area of the *kaya*, and was restricted mainly to Mtswakara hill located in the northern part of the *kaya*. This sub-community is the specific vegetation type that surrounds the central clearing and other sacred sites of the *kaya*; significantly these are areas that plant resources extraction is culturally prohibited. Probably this restriction contributed to the relatively undisturbed condition of this sub-community. There was no strict indicator species identified for this sub-community, but preferential species include *Grandidiera boivinii, Pycnocoma littoralis, Hibiscus faulknerae* and *Rhoicissus revoilii*. High recruitment potentials (from seedling abundance records) of the tree species *Scorodophloeus fischeri, Craibia brevicaudata* and *Cynometra suaheliensis* were recorded.

The floristic differences between the *Commiphora-Asplenium* and *Ricinodendron* sub-communities are reflected by the absence of the following species in the *Commiphora-Asplenium* sub-community;: *Combretum schumannii, Ricinodendron heudelotii, Caesalpinia insolita, Tamarindus indica, Adansonia digitata, Inhambanella* sp., *Markhamia zanzibarica, Manilkara sulcata, Buxus obtusifolia, Thyelachium rose-emaculatum* and *Siphonochilus kirkii* all these species were recorded in the *Ricinodendron* sub-community. Also, the invasive species *Lantana camara* and *Opuntia vulgaris* recorded in *Commiphora-Asplenium* sub-community were not recorded in *Ricinodendron* sub-community, an observation that possible indicates the relatively higher disturbance level in *Commiphora-Asplenium* sub-community compared to *Ricinodendron* sub-community.

Hugonia Community

The *Hugonia* community consisted of 13 relevés, and occurred in the physiognomic segment described in the preliminary survey as *Julbernardia* vegetation and the termite mounds. These two physiognomic segments, although classified in the same community, were not co-incident geographically. The *Julbernardia* vegetation was found in the north-eastern, south-western, and the central parts of the *kaya*. Whereas the termite mounds were found in the southern part of the *kaya*, in an area occupied by the woodland vegetation. A conspicuous feature of the *Hugonia* community was the infrequent presence of the emergent layer, recorded only in <8% of the representative relevés, and occurred at very low cover (5%).

The indicator species for the *Hugonia* community were *Sclerochiton vogelii* and *Hugonia castaneifolia*. *S. vogelii* is a scandent shrub 1-4m high, a member of family Acanthaceae, and in Kenya is restricted to the coastal area. *H. castaneifolia* is a climber, 1-7m long, with spirally coiled hooks. This species is a member of family Linaceae. Preferential species for this community were: *Julbernardia magnistipulata, Suregada zanzibariensis, Ochna thomasiana, Heinsia crinita, Pancovia golungensis, Schlechterina mitostemmatoides* and *Crossandra pungens*. Although the emergent layer (>15m high) was not common in the *Hugonia* community, the short tree layer (5-15m high) was common (recorded in all relevés). The common tree species in the short tree layer included: *Dobera loranthifolia, Cynometra suaheliensis* and *J. magnistipulata*; the succulent shrub *Euphorbia nyikae*, and the climber *H.*

castaneifolia. In the *Hugonia* community the shrub layer was the most represented in both the cover and species richness. The species recorded in the shrub layer included young individuals of the short tree layer, a range of shrub species (including the invasive *Thespesia danis*) and climber species.

The *Hugonia* community comprised two sub-communities: the *Ochna-Pancovia* and the *Dobera* sub-communities. The *Ochna-Pancovia* sub-community represented the physiognomic segment described in the preliminary survey as *Julbernardia* vegetation. A common observation in this sub-community was the signs of recent disturbance particularly through plant resource extraction (Plate 2.2) which mostly affected canopy tree species, e.g. *Julbernardia magnistipulata*. This probably encouraged the creation of vegetation gaps in the sub-community which led to the observed high cover in the shrub layer. No indicator species was identified for this sub-community, but the preferential species were: *Ochna thomasiana, J. magnistipulata, Heinsia crinita* and *Pancovia golungensis*. Other species that showed considerable restriction to this sub-community were: *Ophrypetalum odoratum, Acridocarpus alopecuris, Phylanthus kaesnerii* and *Monodora grandidiera*. The most common species in the short tree layer was *J. magnistipulata* and the climber species *Hugonia castaneifolia*. Relatively, high recruitment of the tree species *J. magnistipulata, P. golungensis* and *Cynometra suaheliensis*, and low recruitment of *Craibia brevicaudata, Manilkara sulcata* and *Cynometra webberi* were recorded.

The *Dobera* sub-community represented the termite mounds. The mounds were different in size (50 - 200m^2) and height (2 – 5m) and can be, perhaps, best described as randomly clustered. The floristic variation between these termite mounds and the surrounding *Brachystegia* woodland was distinct. A common observation in the areas of the termite mounds was timber extraction, which particularly concerned *C. suaheliensis*, and this seemed to be a major factor affecting the tree canopy (it had low cover in the short tree layer and was absent from the emergent layer) in the mounds (Table 2.4). Although strict indicator and preferential species for this sub-community were not identified, the most common species were: *Carissa tetramera, Vitellariopsis kirkii, Salvadora persica, Dobera loranthifolia, Thespesia danis* and *Vernonia wakefieldii*. The most common tree species in the short tree layer were: *C. suaheliensis* and *D. loranthifolia*. A potentially invasive species *Thespesia danis* was also recorded in that layer. Relatively, a high recruitment of tree species *C. suaheliensis*, and low recruitment of *C. webberi, J. magnistipulata* and *M. sulcata* were recorded.

Brachystegia Community

The *Brachystegia* community coincided with the physiognomic segment described as *Brachystegia* woodland in the preliminary survey. This community occurred extensively and continuously in the southern part of the *kaya*, interrupted by the termite mound clusters (described above) which created vegetation clumps that were very distinct from the woodland vegetation. In the *Brachystegia* community both the emergent and the short tree layers were not consistently present, and where these layers did occur the tree crowns were not interlocking. This created a generally open woodland vegetation (Plate 2.3). The indicator species for this community were: *Brachystegia spiciformis* and *Manilkara sansibarensis*. *B. spiciformis*, of family Caesalpiniaceae, is a tree of 6-21m high, the bark is rough and grey-brown and it has a rounded or flat crown in older trees. *M. sansibarensis*, a tree of 6-25m in height, sometimes with slightly buttressed base and fluted bole, has a light grey and grooved bark, and is a member of the family Sapotaceae. In the *Brachystegia* community *B. spiciformis* is very conspicuous, and can easily be picked out by eye as an indicator species, but *M. sansibarensis* is not as conspicuous and could be easily missed by eye as an indicator species for the community. In Kenya both *B. spiciformis* and *M. sansibarensis* is restricted to the coastal area. There were high densities of *Uapaca nitida* localised in the ridge along the *Chidongo* stream within the *Brachystegia* community. In that area *U. nitida* was conspicuous enough to be identified visually as an indicator species, but its distribution in the entire *Brachystegia* community was not uniform enough to qualify as a characteristic species. Preferential species for this community were: *Gutenbergia sp.* and *Hyperthelia dissoluta*.

The *Brachystegia* community comprised *Rytigynia* and *Psydrax* sub-communities. The *Rytigynia* sub-community was characterised by the exclusive presence of *Rytigynia celastroides* and *Phyllanthus welwitschianus*, and relative absence of *Psydrax faulknerae*. In this sub-community an invasive species, *Triumfetta rhomboidea*, was recorded. The *Psydrax* sub-community was characterised by the presence of *P. faulknerae* and absence of *R. celastroides* and *P. welwitschianus*. An aggressive exotic species *Thespesia danis* was recorded in the *Psydrax* sub-community. A high recruitment of *Brachystegia spiciformis* was recorded in both sub-communities, but the seedlings were found in discontinuous clumps, an observation that could not be immediately explained. From the ground-based sampling methods used in this work, the spatial distribution of these sub-communities in the field was not clear.

Acacia Community

The *Acacia* community represented the substantially disturbed areas (wooded grassland physiognomic segment), mainly found on the edges of the *kaya*. Based on the field observations and historical information, this community was strongly associated with physical activities such as clearing and cultivation, burning and grazing. The impacts of these activities were depicted by the absence of emergent layer, poor representation of the short tree layer, relatively low cover of the shrub layer and a very high cover of the herb layer (Table 2.4 and Plate 2.4).

The indicator species of the *Acacia* community were: *Acacia etbaica, Grewia plagiophylla* and *Hoslundia opposita*. *A. etbaica* is a tree, 2-10m high, with a round or, in older trees, a flat crown. The bark is reddish grey to dark grey, and smooth or fissured. The spines, occur in pairs at the nodes, and are of two types: small re-curved measuring 7mm, or long measuring 6cm. This species is a member of the family Mimosaceae. *G. plagiophylla* is a shrub, 2-7.5m high, with a grey fissured bark. *H. opposita* is a shrub, 0.5-3m high, and a member of the family Labiatae. There were no preferential species identified for this community. However, the common tree species recorded in the short tree layer were: *Acacia mellifera* and *A. etbaica*. Infrequent records of tree species *Terminalia spinosa, Dalbergia melanoxylon* and *Ziziphus mucronata* were made. The common species in the herb layer were: *Agathisanthemum bojeri, Asystesia gangetica, Panicum maximum, Panicum sp.* and *Blepharis maderaspatensis*.

2.4 RESULTS: *KAYA* FUNGO VEGETATION

2.4.1 Introduction

Between March and May (1999), 54 relevés were sampled in *kaya* Fungo (Fig.2.3). Table 2.5 gives the general descriptions of the 54 relevés. A total of 280 taxa representing 213 genera in 74 families were recorded from the 54 relevés. These taxa represented 35 tree species, 125 shrubs species, 73 herbaceous species, 43 climbers and 3 epiphytes. The TWINSPAN classification for the most common occurring species (i.e. recorded in at least three relevés) is presented as Table 2.6, and the complete data set for all species is presented in Appendix III.

2.4.2 *Kaya* Fungo vegetation classification

The hierarchical classification of the vegetation types is summarised as a dendrogram in Figure 2.4. In the classification the first division (eigenvalue 0.58) separated the relatively high canopy vegetation (>10m) from the low canopy vegetation (<10m). A further division of the relatively high canopy vegetation (eigenvalue 0.46) separated the relatively dense canopy vegetation from the open canopy woodland (*Uvariodendron* and *Brachtsegia* communities respectively). The dense canopy community (*Uvariodendron community)* was further sub-divided into *Grandidiera* and *Uvariodendron senso stricto* sub-communities. In a division of the low canopy vegetation, an *Acacia robusta* community was separated from an undefined wooded vegetation (eigenvalue 0.44). The *Acacia robusta* community was further divided into *Acacia reficiens* and the *Acacia robusta senso stricto* sub-communities (eigenvalue 0.28). The *Acacia reficiens* sub-community was further sub-divided into grass-dominated (*Chloris roxburghiana*) and shrub-dominated (*Dalbergia melanoxylon*) stages (eigenvalue 0.31).

In summary, three plant communities were identified, the ***Uvariodendron* community** (a mixed forest community), the ***Brachystegia* community** (woodland community), and the ***Acacia robusta* community** (a shrubby thicket community). The *Uvariodendron* community comprised ***Grandidiera*** and ***Uvariodendron senso stricto*** sub-communities. The *Uvariodendron senso stricto* **sub-community** comprised ***Hunteria*** and ***Salacia* stages**. The *Salacia* stage consisted of three sub-stages, the ***Blepharespermum,*** the ***Haplocoelum*** and the ***Excoecaria*** sub-stages.

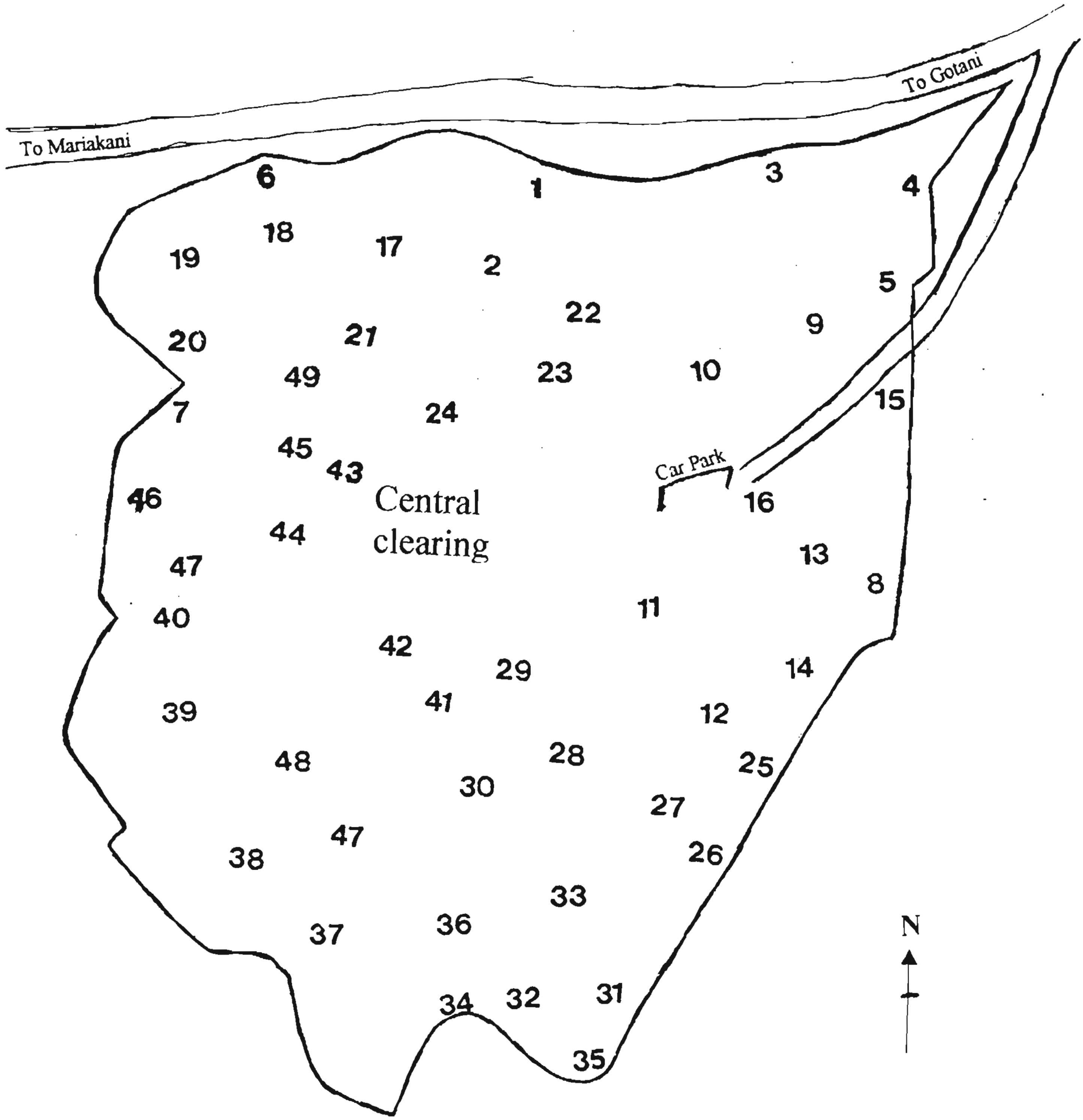


Fig. 2.3: A sketch map of *kaya* Fungo indicating the approximate positions of relevés sampled in the *kaya*

Table 2.5: General description of the individual relevés established in *kaya* Fungo.

Date	Relevé number	Sub-locality	Physiognomic category	Relevé size (m)	Latitude	Longitude	Altitude (m)	T layer (% cover)	t layer (% cover)	S layer (% cover)	H layer (% cover)	Species richness
04-Mar-99	1	Near the swept bridge	Bushland	10 x 10	39° 30.990	3° 47.730	204	0	0	70	50	22
04-Mar-99	2	South of Plot 1	*Acacia*	20 x 10	39° 30.975	3° 47.793	180	0	0	80	60	17
04-Mar-99	3	Near beacon 1	*Acacia*	20 x 10	39° 31.243	3° 47.662	336	0	0	70	60	29
04-Mar-99	4	Along tsangalaweni track	*Acacia*	20 x 10	39° 31.281	3° 47.664	276	0	0	40	70	16
18-Mar-99	5	Near beacon 57	*Acacia*	20 x 10	39° 31.249	3° 47.765	-	0	0	70	40	27
18-Mar-99	6	Near beacon 21	Bushland	20 x 10	39° 30.340	3° 47.726	222	0	10	30	70	41
24-Mar-99	7	Near beacon 18	*Acacia*	20 x 10	39° 31.313	3° 48.080	-	0	0	35	80	40
24-Mar-99	8	Near beacon 53	*Acacia*	20 x 10	39° 31.189	3° 48.284	81	0	0	60	80	36
25-Mar-99	9	Near beacon 54	Bushland	20 x 10	39° 31.197	3° 48.044	405	0	0	50	80	40
25-Mar-99	10	Towards oar park	Bushland	20 x 10	39° 31.144	3° 48.178		0	0	60	80	49
25-Mar-99	11	Hilly site, eastern end	Bushland	20 x 10	39° 31.065	3° 48.331		0	40	70	60	43
25-Mar-99	12	Near beacon 40	Mixed Forest	20 x 10	_	_	_	0	30	80	40	48
26-Mar-99	13	Near water point	Mixed Forest	20 x 10	_	_	_	0	30	80	40	49
26-Mar-99	14	South of plot 13	Mixed Forest	20 x 10	_	_	_	10	30	80	40	43
26-Mar-99	15	Left of track to Tsangalaweni	Bushland	20 x 10	39° 31.207	3° 48.085	378	0	0	40	60	35
26-Mar-99	16	Near Tsangalaweni	Bushland	20 x 10	39° 31.329	3° 48.328	-	0	20	40	60	46
27-Mar-99	17	Near dam site	Bushland	20 x 10	39° 31.022	3° 47.841	-	0	0	70	80	51
27-Mar-99	18	Near Bani's former farm	Bushland	20 x 10	39° 30.730	3° 47.802	171	0	10	80	60	49
27-Mar-99	19	_	Bushland	20 x 10	39° 30.532	3° 47.826		0	0	60	40	41
27-Mar-99	20	Western end of kaya	Bushland	20 x 10	39° 30.507	3° 47.922	-	0	0	60	40	30
28-Mar-99	21	_	Bushland	20 x 10	39° 30.544	3° 47.963	138	0	0	60	40	26
28-Mar-99	22	"Bush-pigs stream site"	Bushland	20 x10	39° 30.663	3° 47.925	189	0	0	50	40	38
28-Mar-99	23	West of central clearing	Mixed Forest	20 x 10	39° 30.717	3° 48.067		0	30	60	40	47
28-Mar-99	24	Next to river valley, near Central Clearing	Mixed forest	20 x 10	39° 30.623	3° 48.084	_	0	10	80	20	43
30-Mar-99	25	Near Mungwari farm	Mixed Forest	20 x 10	39° 31.160	3° 48.032	-	0	5	90	20	36
30-Mar-99	26	Eastern, near *Tamarindus*	Bushland	20 x 10	39° 30.869	3° 48.403	153	0	0	30	90	29
02-Apr-99	27	_	Bushland	20 x 10	39° 30.823	3° 48.380		0	30	80	40	45
02-Apr-99	28	Near *Paveta linerifolia*	Mixed Forest	20 x 10	_	_		0	60	80	30	51
02-Apr-99	29	Central Clearing entrance from West	Mixed Forest	20 x 10	39° 30.778	3° 48.404	-	0	60	90	30	46
02-Apr-99	30	Near big *Dobera* tree	Mixed Forest	20 x 10	39° 30.657	3° 48.360	_	0	70	80	30	40
28-Apr-99	31	Near beacon 45	Bushland	20 x 10	_	_	-	0	0	80	20	38
28-Apr-99	32	Elephant-ear fern site	Mixed Forest	20 x 10	39° 30.671	3° 48.642	_	0	5	60	10	22
28-Apr-99	33	West of plot 32	Mixed Forest	20 x 10	39° 30.631	3° 48.532	-	0	5	70	15	37
28-Apr-99	34	Near beacon 40	Grassland	20 x 10	39° 30.547	3° 48.566	-	0	0	0	60	25
28-Apr-99	35	Near beacon 42	Bushland	20 x 10	39° 30.745	3° 48.655	246	0	15	10	70	47
02-May-99	36	_	Mixed Forest	20 x 10	39° 30.725	3° 48.477	_	0	50	70	5	40
02-May-99	37	Near beacon 31	Bushland	20 x 10	39° 30.447	3° 48.536	_	0	30	80	60	47
02-May-99	38	Near beacon 29	Mixed Forest	20 x 10	39° 30.297	3° 48.578	63	0	40	90	50	52
02-May-99	39	Southern side/ Julbernadia area	*Julbernadia* forest	20 x 10	39° 30.300	3° 48.479	_	0	60	40	70	48
02-May-99	40	Near "chisimani"	Mixed Forest	20 x 10	39° 30.234	3° 48.384	_	0	10	80	30	43
03-May-99	41	Close to CC from east	Mixed Forest	20 x 10	_	_	_	20	15	70	40	43
03-May-99	42	Bee-hive site at *Dobera* tree	Mixed Forest	20 x 10	_	_	_	10	30	60	10	35
03-May-99	43	SW side of CC	Mixed Forest	20 x 10	_	_	_	60	30	90	30	43
03-May-99	44	*Craibia-Julbernardia*, site of Nvuje (Scutia)	*Julbernadia* forest	20 x 10	39° 30.624	3° 48.236	_	10	60	80	20	37
04-May-99	45	Out-bound to Gogoreruhe	Mixed Forest	20 x 10	39° 31.468	3° 48.165	-	0	60	80	60	63
04-May-99	46	Near beacon 19	Bushland	20 x 10	39° 30.328	3° 48.144	198	0	0	10	80	42
04-May-99	47	Near beacon 22	Bushland	20 x 10	39° 30.321	3° 48.340	129	0	0	15	80	27
04-May-99	48	Near beacon 29	*Julbernadia* forest	20 x 10	39° 30.437	3° 48.480	_	20	60	40	80	55
05-May-99	49	Near Mvirya ya tsini	Mixed Forest	20 x 10	39° 30.709	3° 48.112	-	10	40	70	20	49
05-May-99	50	Mirihi -ya Kirahu	*Brachystegia* woodland	20 x 10	39° 31.089	3° 49.806	-	5	10	40	80	67
05-May-99	51	Mirihi -ya Kirahu	*Brachystegia* woodland	20 x 10	39° 31.131	3° 49.906	264	15	20	60	40	72
05-May-99	52	Mirihi -ya Kirahu	*Brachystegia* woodland	20 x 10	39° 31.195	3° 49.947	219	5	10	60	80	57
05-May-99	53	Mirihi -ya Kirahu	*Brachystegia* w/land	20 x 10	39° 31.168	3° 49.817	243	5	10	40	60	56
05-May-99	54	Mirihi -ya Kirahu	*Brachystegia* woodland	20 x 10	39° 31.044	3° 49.647	240	5	5	60	80	57

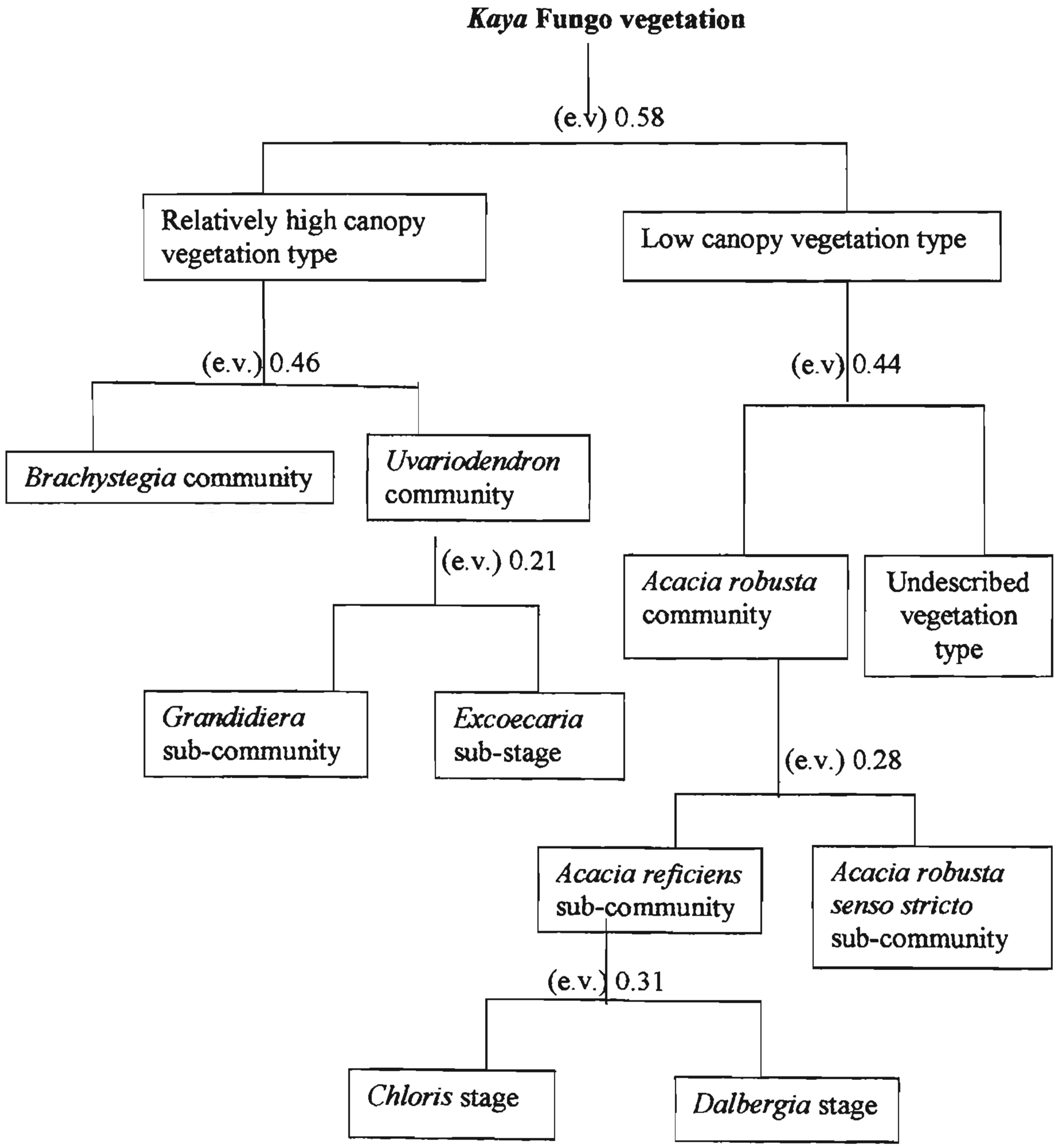
Key: T layer refers to the emergent layer; t layer refers to the short tree layer; S layer refers to the shrub layer; and H layer refers to the herbaceous layer

Table 2.6: TWINSPAN classification table for the relatively common species recorded in the relevés sampled in *kaya* Fungo

```
                              555533422443344411233123322         111111222233144445
                              123489034342751224903381657612473589057896012645176890

Differential species of Brachystegia community
Brachystegia spiciformis      4443                                                 3
Murdannia simplex             2222              2   2                  2         1
Psychotria amboniana          3343     3   3             1          3  1           4
Psydrax faulknerae            3333                       3                         2
Vitex mombassae               4343                       3                        2
Achyranthes aspera            2222 3
Cyperus sp.                   222         2              2       2
Pentas bussei                 33 23  3                                          1  4
Ormocarpum kirkii             3 33                                                 2
Acridocarpus zanzibaricus      332
Canthium kilifiensis           332                                                1
Eulophia speciosa             22 2
Gonatopus boivinii            1111                  1
Oxygonum sp.                  2222
Uvaria faulknerae             343
Bulbophyllum maximum          2 22                       2
Adenium obesum                2211                                           1 2   2
Abrus precatorius              111                                    2            1
Triumfetta rhomboidea          222                       2                      2
Thecocaris bussei             2322
Solenostemon latifolius       222                                      2 2

Companion species of Brachystegia community
Synaptolepis kirkii           122313 2              2   13                     2
Julbernardia magnstipulata    3 4 653                                            33
Monanthotaxis fornicata       333 34            1
Oxyanthus zanguebaricus        3 35 3                                  3
Tabernaemontana elegans         1333  1 3           3    3                       3

Grandidiera sub-community
Grandidiera boivinii              3333433   331  3
Acalypha neptunica                333  3    333 3   33     3                 1
Craibia brevicaudata               33 465    334 63
Asteranthe asterias               3 4 1  331  43 1                            3

Hunteria seral stage
Col. No. 3679                       3 112     1    1                               4
Hunteria zeylanica               3   3 34   3 3                                    1

Blepharispermum sub-stage
Blepharispermum zanguebaricum            64544   34    4
Vitex strickeri                   3     3 3133 3     31         3   1  1  3   3
Ruellia sp.                              22322     2 2    2                  2 2   4

Haplocoelum sub-stage
Haplocoelum foliolosum                    3 2 33333 4                         3
Euphorbia tirucalli                       2    323234                            1
Cyanotis sp. nov.                             2  212 1                           3 4

Excoecaria sub-stage
Excoecaria madagascariensis              1         343323                         2
Ipomoea shupangensis          1    1             2 11  213

Salacia seral stage
Salacia sp.                            33  3333313313334
Psilotrichum scleranthum                 2222 222222 2222  3      2  23       43
Dombeya taylori                           3 3 313334 33 3                      1 2
Polysphaeria parvifolia       34          23  313 3433334           3 4 4333

Uvariodendron senso stricto sub-community
Croton pseudopulchellus             3331 3434433444545445
Cola minor                            3323333334333433333
Manilkara sulcata             4      43 33343343 33334343         3           4 1  3
Cissus rotundifolia                 2231  212  21  11 1 1       3    32  3   2
Sansevieria arborescens         1    2222 122  3 2 11  22
Pellaea doniana               2  2  2 2   1   212 12213 2
Commiphora eminii                    3343  133 44  35

Differential species of Uvariodendron community
Uvariodendron kirkii              33334434343435535545444         3
Combretum schumannii             34333443  43333343334343                      3
Eugenia capensis                3  3 2333 1 43  433333435                       1 4
Haplocoelum inoploeum         3  33433333 3331  33 344333       3 3   1   31 31
Encephalartos hildebrandtii       333 322 3 32 121 121 12           1
Hugonia castaneifolia         3   233   1  3  1123323 312
Anchomanes abbreviatus            1 1 212   2 112212 112          1
Monodora grandidieri          3   33333   34        3                        3 1   3
Strophanthus kombe                3   232   23    3333                          1
Toddaliopsis sansibarensis        33 33 3  33 3333 433
Tiliacora funifera            1   3    22  2  1   2                             2  2

Differential species of Brachystegia and Uvariodendron communities
Uvaria acuminata              4334 3223323432313425444333               3     3
Ochna thomasiana              3233 3333 31333333 34444434
Euphorbia nyikae              3332 1  1 3 13 3  33 31 1 1                     3 2313
Acacia adenocalyx              33   3 133 33232332 1  1 3         1          2   133
Canthium mombazense             33 3 33  333  334 4334433               3     3  3
Afzelia quanzensis             3 3434  4   5    4  4  4
Commelina sp.                 222212   2        2  22  2         2   1    1212
Heinsia crinita               33 335433 3     1     34 33
Gossypioides kirkii           331313 1  1     1     2   2
Sansevieria kirkii            2 223 12    21       2   2               2      2
```

Dalbergia melanoxylon	31111333 3 1
Agathisanthemum bojeri	2222 2 2222223242 2 2
Diospyros bussei	3 3 43 33133333 31 1
Hoslundia opposita	3 3 231333 41 113
Lantana camara	3 1 333343543 3 33 22
Catunaregam nilotica	1 2 133231333 33 3 2
Eragrostis superba	2 22 2222222 22 2
Harrisonia abyssinica	33 33 3 3
Sterculia rhynchocarpa	3 3 1 333 22
Zanthoxylum challybeum	11 33 3 3
Acacia reficiens sub-community	
Acacia reficiens	1643555 4233 433
Acacia zanzibarica	53333333323 3 1 13
Indigofera sp.	1 2
Terminalia spinosa	3 33141 433 3 3
Erythrocephalum minus	22 1 1 13 1 344
Ximenia americana	33 3 3 1 3 3 2
Manilkara mochisa	3 3 3 34 4 2 2
Salvadora persica	3 13 3 3 332 33 3
Flueggea virosa	3 33 1 13 33
Grewia densa	3 333343 333334 3 3 1
Tragia furialis	11 111 12 3 2 2
Sporobolus fimbriatus	2 2 222 2 22 1
Commiphora africana	33333 1 1 1 3
Lannea schweinfurthii	1 3 11 31 3 11 3 1 222
Dichrostachys cinerea	3 3 332 33 3 333
Acacia robusta senso stricto sub-community	
Lamprothamnus zanguebaricus	3 1 3 1 3 2313 324333342 2 5
Thespesia danis	3 1 3 433 5334334543323
Croton talaeporos	3 3 3 3 3 3 33 3 3 24 31
Hyperthelia dissoluta	5 1 2 22 322 22
Premna chrysoclada	3 3 3433 3 333 1 2
Maerua sp.	3 3323
Acacia mellifera	3 124 11
Differential species of *Acacia robusta* community	
Acacia robusta	3 133 3444 33333333 4324 3
Bridelia cathartica	3 13333 3333 3 33 3 112
Vernonia hildebrandtii	3 2 2 332 333223 4 233222 22
Allophylus rubifolius	3 2 113 433 3333334 23
Commiphora edulis	3 3 4 3 3 3 33 31 3
Pentarhopalopilia umbellulata	3 1 1 1 1 3 4 3 31
Indigofera sp.	2 232 43 3 1 13 33 4 3
Cissampelos pareira	1 23 11 2 2 1 111
Companion species of *Acacia robusta* community	
Maerua grantii	1 3 1 1 1 4
Cycnium veronicifolium	122 21
Melhenia velutina	1 2 11 1 2 1
Zehneria pallidinervia	31 1 1 12 22
Companion species of Undetermined vegetation type	
Ophrypetalum odoratum	34 222
Manilkara sansibarensis	433 4 3 3 3 1313
Adenia gummifera	1 1 1 2 234
Capparis sp.	1 133
Quisqualis littorea	233
Differential species of *Brachystegia* and *Acacia robusta* communities	
Cyperus niveus	2222222 2 1 2 22 1 222 2 22
Blepharis maderaspatensis	22223 2 2 1 3 2 2222 2 2 33 3
Pyrenacantha vogeliana	1131 1 1 3 331
Differential species of *Uvariodendron* and *Acacia robusta* communities	
Grewia forbesii	334 33 333 3 33 4 3 4 43133 33 54
Acalypha fruticosa	33 4 53 3 31 43 1 33
Capparis viminea	3 3 3 1 11 1 3 3 3 1 23 3
Hibiscus micranthus	13 3 12433 32 1 2 1 1 3 1
Carissa tetramera	33 3 4 4 434 3 3243 22 2
Grewia stuhlmannii	44 3 3 3 333 3
Diospyros loureiriana	33 3 3 3 3 3 1 1 5 1 2
Grewia truncata	4 3 4 3 3 3
Cola sp.	3 21 3 3
Sideroxylon inerme	3 3 3 3 1 3
Differential species of semi-arid coastal forest	
Panicum maximum	222222232 222222111222222 2 3 2 2 222 2 22
Ancylobotrys petersiana	2411333 33 1 3121122 3 3 1 3 13 23
Ochna mossambicensis	1332 11 1 2 4 1 3 3 1 11
Abutilon zanzibaricum	2 222 33 3122 3 23 2 1212322 2 1221 2
Grewia plagiophylla	3 33 3 3 33 3 313 443 3 33 3313 334 4
Companion species of semi-arid coastal forest	
Siphonochilus kirkii	22 2 2 2 2 2 2 3
Commiphora lindensis	33 1 3 1 3 3 33331 1
Deinbolia borbonica	31 3 1 1 13 1 3 3 333 2
Cissus phymatocarpa	2 22 1 322 2 222 232 2233 2 3
Celosia hastata	3 3541 2 322 3 1 3 3 3 2
Cordia faulknerae	3 4 3 3 1 1 33 31 3
Rhoicissus tridentata	3 33 3 22 2
Asparagus sp.	2 1 1 1 11 1 1 112
Suregada zanzibariensis	33 3 3 3 1 33 3 2
Asystasia gangetica	22 2 3 42 22 2 1

Fig. 2.4: The hierarchical classification dendrogram, showing the vegetation types identified in *kaya* Fungo and the eigenvalues (e.v.) associated with the divisions



The ***Acacia robusta*** community comprised ***Acacia reficiens*** and ***Acacia robusta senso stricto*** sub-communities. Within the ***Acacia reficiens*** sub-community there was a grass species dominated and a shrub species dominated stages, i.e. *Chloris* and *Dalbergia* stages. The undescribed vegetation did not constitute a definable species grouping, but based on the eigenvalue of the division separating it (0.44), it was regarded as an independent vegetation type.

2.4.3 *Kaya* Fungo vegetation description

Kaya Fungo is in a semi-arid area, characterised by frequent prolonged dry conditions. The *kaya*, therefore, constituted a coastal dry forest. Species that occurred commonly in the different vegetation types of the *kaya*, i.e. the generalist species included: *Panicum maximum, Ancylobotrys petersiana, Abutilon zanzibaricum, Grewia plagiophylla* and *Cissus phymatocarpa*. The other species that also showed distribution across different vegetation types, were rare. Over 50% of the species recorded in the *kaya* were locally rare, occurring in less than 10% of the total relevés, while 1% of the species were generalists occurring in >51% relevés, but no species occurred in more than 75% of the relevés (Table 2.7).

Table 2.7: Frequencies of occurrence of species (n=317) in 51 relevés sampled in *kaya* Fungo.

Percentage of the relevés	Percentage of the species occurring
> 75	0%
51 – 75	1%
26 – 50	15%
10 – 25	28.7%
< 10	55.2%

Comparatively, among the vegetation types in *kaya* Fungo, the highest species richness was recorded in the *Brachystegia* community, and the lowest species richness was recorded in the grass-dominated vegetation, the *Chloris* stage (Table 2.8). Generally the cover of the emergent layer was low (<10%) in the whole *kaya*, with highest cover recorded in the undescribed wooded vegetation type, followed by *Brachystegia* community (Table 2.8). This observation was contrary to expectation, because from visual observation the relatively dense canopy vegetation type, *Uvariodendron* community, was predicted to show the highest cover of emergent layer. The emergent layer was absent in *Acacia robusta* community.

Table 2.8: Species richness and structural characteristics of vegetation types identified in *kaya* Fungo (the number of species and cover percentages are means, with the standard deviation of mean given in brackets)

Community	Sub-community/ stage	Relevé No.	Range: No. of spp	No. of species per relévе	Percentage cover of emergent layer	Percentage cover of short tree layer	Percentage cover of shrub layer	Percentage cover of herb layer
Brachystegia community		4	56 – 72	60.5 (7.7)	7.5 (5.0)	11.3 (6.3)	55.0 (10.0)	60.5 (7.7)
Uvariodendron community	*Grandidiera sub-community*	17	22 – 63	43.4 (8.5)	6.5 (15.0)	33.8 (21.4)	74.7 (13.3)	35.0 (17.7)
	Uvariodendron senso stricto sub-community	20	22 – 51	42.7 (8.1)	3.5 (6.7)	31.3 (22.0)	76.0 (8.8)	30.5 (15.5)
***Acacia nilotica* community**	***Acacia reflciens* sub-community**							
	Chloris roxburghiana stage	5	16 – 41	27.2 (12.4)	0	2.0 (4.5)	51.0 (22.5)	66.0 (11.4)
	Dalbergia melanoxylon stage	7	27 – 51	38.1 (9.2)	0	0	60.0 (11.5)	68.6 (15.7)
	Acacia ***nilotica senso stricto*** **sub-community**	12	26 – 51	37.4 (9.1)	0	2.8 (6.3)	50.6 (22.1)	61.3 (17.5)
Undetermined wooded vegetation unit		4	42 – 67	53.3 (10.6)	8.8 (8.5)	27.5 (27.5)	40.0 (24.5)	65.0 (30.0)

Compared to other vegetation types, the sub-communities in the *Uvariodendron* community had the highest cover in the short tree and in the shrub layers. Low abundance covers of short tree and of shrub layers were recorded in the sub-communities of the *Acacia robusta* community. In all the vegetation types, except for *Uvariodendron* community, the highest cover was recorded in the herb layer. But between vegetation types, the highest cover in the herb layer was recorded in the shrub dominated *Dalbergia* stage, and there was considerable high cover of the herb layer in the grass-dominated *Chloris* stage and in the *Brachystegia* community (Table 2.8).

A general description of each vegetation type identified in *kaya* Fungo is given below.

Brachystegia Community

The *Brachystegia* community comprised four relevés, and represented the physiognomic segment described in the preliminary survey as *Brachystegia* woodland, exclusively located at Mirihi-ya-Kirao. The *Brachystegia* community was characterised by scattered trees, mainly *Brachystegia spiciformis*, in relatively dense shrub clumps, and dominated by herbaceous vegetation. Most of the mature *B. spiciformis* trees had been logged for charcoal making (Plate 2.5). The indicator species for *Brachystegia* community were *B. spiciformis, Murdannia simplex, Psychotria amboniana, Psydrax faulknerae, Vitex mombassae* and *Achyranthes aspera*. *B. spiciformis* is a tree, 6-21m high, with a rounded crown or flat (in older trees), and rough grey-brown bark. This species is a member of the family Caesalpiniaceae. *M. simplex* is a herb, >1m high, and a member of the family Commelinaceae. *P. amboniana* is a shrub, 0.5-3m high, a member of the family Rubiaceae. *P. faulknerae* is a shrub, sometimes scandent, 3-5m high, a member of the family Rubiaceae. *Vitex mombassae* is a shrub, 1.8-6m high, and a member of the family Verbenaceae. In Kenya, *B. spiciformis, P. amboniana* and *V. mombassae* are restricted to the coastal area. *A. aspera* is a herb, and a member of the family Amaranthaceae. Preferential species for the *Brachystegia* community include *Cyperus* sp., *Pentas busse,* and *Ormocarpum kirkii*. The tree species in the emergent layer was exclusively *B. spiciformis*. In the short tree layer, the tree species occuring were: *B. spiciformis, Manilkara sansibarensis, Afzelia quanzensis* and *Julbernardia magnistipulata*. The epiphytic species, *Vanilla roscheri* was also recorded in the short tree layer.

Uvariodendron Community

This community represented the relatively dense canopy forest area of *kaya* Fungo, a physiognomic segment identified in the preliminary survey as mixed forest. The indicator species for *Uvariodendron* community were: *Uvariodendron kirkii, Combretum schumannii, Croton pseudopulchellus* and *Cola minor*. *U. kirkii* is a shrub, 2-12m high, occasionally scandent, with a dark grey to black bark. *U. kirkii* is a member of the family Annonaceae. *C. schumannii* is a tree, 3-20m high, with a brown bark that peels or flakes to show a paler under-bark. This species is a member of the family Combretaceae. *C. pseudopulchellus* is a shrub, 1-6m high, with a brown or pale brown rough bark. This species is a member of the family Euphorbiaceae. *C. minor* is a tree, 3-12m high, with a light green bark, and is a member of the family Sterculiaceae. In Kenya both *U. kirkii* and *C. minor* are restricted to the coastal area. Preferential species for this community were: *Dombeya taylorii, Pellaea doniana, Salacia* sp., *Anchomanes abbreviatus, Ochna thomasiana, Loeseneriella africana, Commiphora eminii, Eugenia capensis, Sansevieria arborescens, Toddaliopsis sansibarensis, Encephalartos hildebrandtii, Grandidiera boivinii, Hugonia castaneifolia, Coffea sessiliflora, Acalypha neptunica, Canthium mombazense, Manilkara sulcata,Cussonia zimmermannii, Acacia adenocalyx, Haplocoelum inoploeum, Heinsia crinita, Monodora grandidieri* and *Psilotrichum scleranthum*.

Uvariodendron community comprised *Grandidiera* and *Uvariodendron senso stricto* sub-communities. The *Grandidiera* sub-community comprised the dense canopy mixed forest ares, characterised by frequent occurrence of emergent and short tree layers. The *Grandidiera* sub-community also included the physiognomic segment identified as the *Julbernardia* vegetation in the preliminary survey. No indicator species were identified for this sub-community, but the preferential species were: *Grandidiera boivinii, Acalypha neptunica, Craibia brevicaudata and Asteranthe asterias*. The common tree species in the emergent and short tree layers were: *Afzelia quanzensis, Combretum schumannii, Cussonia zimmermannii, Dobera loranthifolia, Commiphora eminii, Diospyros bussei, Cola minor, Manilkara sulcata* and *Julbernardia magnistipulata*. Conspicuous climber species in the emergent and short tree layers were: *Strophanthus kombe* and *Urera sansibarica*, and the shrub species *Euphorbia nyikae*, and a scandent shrub species *Grewia forbesii*. The invasive species *Lantana camara* was also recorded in this sub-community. A high recruitment of the tree species *J.*

magnistipulata (restricted to few relevés), *C. brevicaudata* and *C. minor*; and low recruitment of *C. schumannii, M. sulcata* and *Tabernaemontana elegans* were recorded.

The *Uvariodendron senso stricto* sub-community represented the physiognomic segment described as mixed forest in the preliminary survey. The exclusion of the *Julbernardia* vegetation from this sub-community was the main floristic difference to the *Grandidiera* sub-community described above. The indicator species for the *Uvariodendron senso stricto* sub-community were: *C. minor, C. pseudopulchellus* and *M. sulcata*.

The *Uvariodendron senso stricto* sub-community comprised *Hunteria zeylanica* and *Salacia* stages. The *Salacia* stage comprised *Blepharespermum, Haplocoelum* and *Excoecaria* sub-stages. The *Excoecaria* sub-stage was characterised by the strong absence of the dominant tree species: *C. brevicaudata, J. magnistipulata* and *C. minor*, and by dominance of climber species which over-grew on other plant species, particularly inhibiting the growth of a herb layer (Plate 2.6).

The *Brachystegia* and *Uvariodendron* communities were related through the sharing of: *Uvaria acuminata, Ochna thomasiana Euphorbia nyikae, Acacia adenocalyx, Canthium mombazense, Afzelia quanzensis, Heinsia crinita, Gossypoides kirkii, Sansevieria kirkii, Loeseneriella africana, Cissus sylvicola, Coffea sessiliflora, Cussonia zimmernnii, Stylochiton salaamicus, Synaptolepis kirkii, Julbernardia magnistipulata, Monanthotaxis fornicata, Oxyanthus zanguebaricus* and *Tabernaemontana elegans*. However, on the ground the *Brachystegia* community was found in a different forest area (Mirihi-ya-Kirao) to the *Uvariodendron* community (which was found in the main *kaya* Fungo forest).

Acacia robusta Community

The *Acacia* community represented the physiognomic segment identified as *Acacia* thicket and scrubland during the preliminary survey. This community was found all round the periphery of the *kaya*, forming a gradual transition from the cultivated farmlands to the *kaya* 'forest' area. The indicator species for this community was *Acacia robusta*, a tree 4.5-20m high, with a flat crown and a smooth or fissured dark grey brown bark. This species has paired spines at the nodes, which are straight or nearly so, measuring up to 9cm long on older wood, and 3-7 mm on young branches. This species is a member of the family Mimosaceae. The *Acacia* community comprised *Acacia reficiens* and *Acacia robusta senso stricto* sub-communities.

Acacia reficiens sub-Community

The *Acacia reficiens* sub-community represented the physiognomic segment identified as *Acacia* thicket in the preliminary survey, constituting of areas mostly dominated by *Acacia* species (Plate 2.7). The sub-community is found on the forest periphery, especially on the northern and eastern edges of the *kaya*, extending continuous outside the *kaya* area. The indicator species for the *Acacia reficiens* sub-community were: *Acacia reficiens* and *Acacia zanzibarica*; while the preferential species were: *Dalbergia melanoxylon, Agathisanthemum bojeri, Diospyros bussei, Hoslundia opposita, Indigofera longimucronata, Terminalia spinosa, Grewia densa, Erythrocephalum minus* and *Salvadora persica*. The *Acacia reficiens* sub-community comprised the *Chloris* stage and the *Dalbergia* stage.

The *Chloris* stage is a grass-dominated area of the *Acacia reficiens* sub-community (Plate 2.8). The stage was characterised by the notable absence of emergent and short tree layers, but signs of recent fire incidences e.g. sprouting from burnt mother plants, were common. It was believed that this stage was a product of fire. The indicator species for this stage was *Chloris roxburghiana*, a Graminoid species. No preferential species were identified, but *Enteropogon sechellensis* was common in this stage. Other Graminoid species recorded in the *Chloris* stage included: *Chloris* sp., *Dactyloctenium geminatum, Eragrostis superba* and *Cenchrus ciliaris*; and a forb *Cycnium tubulosum ssp tubulosum*.

The *Dalbergia* stage is dominated by shrub species. The indicator species of this stage is *Dalbergia melanoxylon*, a shrub species 1-11m high, often with many branches and clustered branchlets at the nodes that are partly spine-tipped. The bark is pale grey, and in older trees it is fissured or flaking. Preferential species of this stage are: *Diospyros bussei, Hoslundia opposita* and *Agathisanthemum bojeri*. Although tree species *Terminalia spinosa, Zanthoxylum chalybeum, Lannea schweinfurthii, Diospyros squarrosa, Tamarindus indica* and *Croton talaeporos*, were recorded in this stage, but mostly as a shrub layer. The emergent layer was absent and the short tree layer was not common. The invasive species *Lantana* *camara* and *Thespesia danis*, and the alien shrub species *Thevetia peruviana* were recorded in this stage. This stage is probably a later seral stage to the *Chloris* stage, in which the vegetation has regenerated after fire.

Acacia robusta senso stricto sub-Community

The *Acacia robusta senso stricto* sub-community share most floristic components with the *Acacia reficiens* sub-community. However, *Maerua* sp. and *Acacia mellifera* were restricted to the *Acacia robusta senso stricto* sub-community; and the *Chloris* stage is not part of *Acacia robusta senso stricto* sub-community. The character species of *Acacia robusta senso stricto* sub-community are: *Lamprothamnus zanguebaricus* and *Thespesia danis*, while the preferential species are: *Croton talaeporos, Hyperthelia dissoluta* and *Premna chrysoclada*.

Undescribed Vegetation type

This vegetation type, was considered as a separate community only on the basis of the eigenvalue of the division (eigenvalue = 0.44), thus it could be a different community or it could be a unit of the *Acacia* community. The vegetation type was represented by four relevés, which were mainly on the forest edge, and showed signs of recent burning incidences (within the last 1-3 months) and grazing activities. Whether this vegetation type was a transitional stage between *Chloris* and *Dalbergia* stages, or a complete different community was not clear. No indicator nor preferential species for the vegetation type were identified, but *Manilkara sansibarensis* frequently occurred. The vegetation type was characterised by the absence of diagnostic species of the other vegetation types within the *Acacia* community, i.e. *Acacia robusta, Acacia reficiens, Acacia zanzibarica, Dalbergia melanoxylon, Agathisanthemum bojeri* or *Chloris roxburghiana*.

Plate 2.1: A section of the *Scorodophloeus* dense forest community on the hilltop of Mtswakara hill, in *kaya* Mtswakara (Photo taken in September 1998)

Plate 2.2: Extraction of dominant canopy tree species, *Julbernardia magnistipulata*, (for hand-hoe handles) from *kaya* Mtswakara. (Photo taken in October 1998)

Plate 2.3: Rocky ground surface of the *Brachystegia* woodland community in *kaya* Mtswakara. (Photo taken in December 1998)

Plate 2.4: A section of the *Acacia* wooded grassland community in *kaya* Mtswakara, bordering the dense forest area at the background. (Photo taken in December 1998)

Plate 2.5: Signs of charcoal making activities (on the foreground) and a coppicing *Brachystegia spiciformis* tree at the background, in the *Brachystegia* woodland community at Mirihi-ya-kirao (near *kaya* Fungo) (Photo taken in May 1999)

Plate 2.6: A section of the *Excoecaria* sub-stage (in *kaya* Fungo), in which the dominance of climber species has an inhibition effect over the herbaceous layer (Photo taken in April 1999)

Plate 2.7: A section of the *Acacia reficiens* sub-community, in *kaya* Fungo. (The *Acacia reficiens* was commonly debarked and used as tying material). (Photo taken in May 1999)

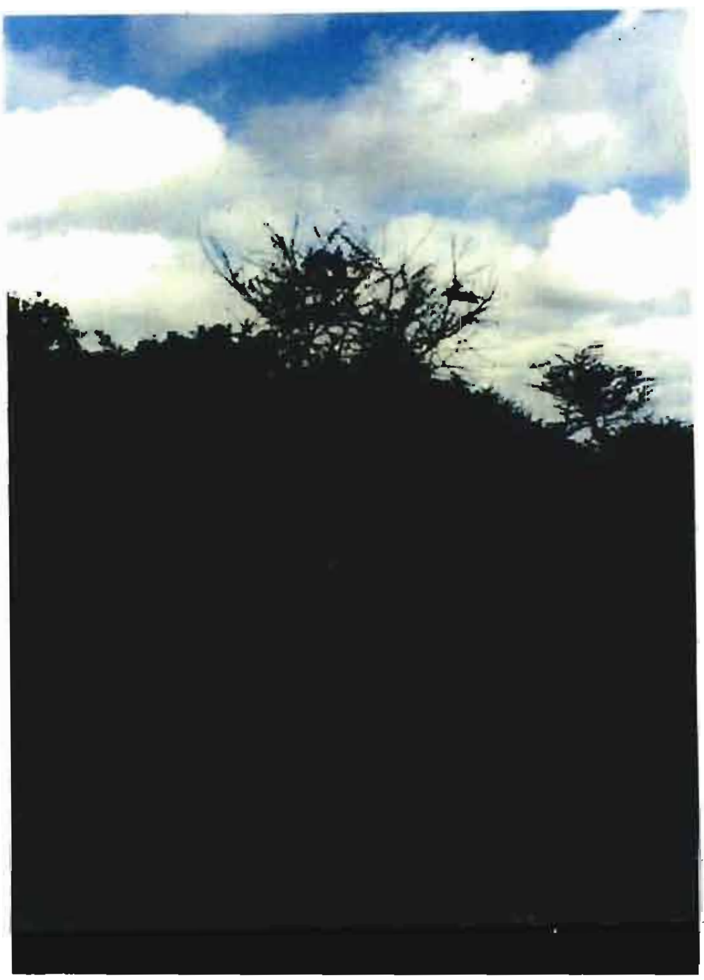


Plate 2.8: A section of the *Chloris* stage (in *kaya* Fungo) illustrating dominance of *Chloris roxburghiana* in the stage. (Photo taken in May 1999).

2.5 DISCUSSION

In this discussion, the vegetation types identified in *kayas* Mtswakara and Fungo were related to vegetation types with similar floristic components described by other authors in previous studies. Common and different floristic elements in the vegetation types within and between the two *kayas* were also compared. The discussion which follows considers the relatively dense canopy forests, woodland, thicket/bushland and wooded grassland areas as the main vegetation types.

2.5.1 Dense Canopy Forest

The *Asteranthe* community group in *kaya* Mtswakara was found on sites ranging from gentle undulating topography to steep slopes (70°), running into the river valleys on all aspects. This community group fits the description of 'Zanzibar-Inhambane undifferentiated forest' by White (1983). The floristic components of this community group also suit the description of the 'Dry forest' type described by Hawthorne (1993). Although Hawthorne (1993) identified four types of dry forest, the *Asteranthe* community group best matched the *Cynometra webberi-Scorodophloeus fischeri* type identified by the dominance of evergreen Caesalpinioid. In that vegetation type Hawthorne (1993) observed that the Caesalpinioid 'dominants' (*Cynometra suaheliensis, C. webberi, Craibia brevicaudata, Scorodophloeus fischeri* and *Julbernardia magnistipulata*) were found with many of their saplings. Hawthorne (1993) argued that the Caesalpinioid saplings tolerate the parental shade. In this study, similar observation i.e. abundant Caesalpiniod saplings, particularly of *Craibia brevicaudata* and *Scorodophloeus fischeri*, was made. In the relevés *Manilkara sulcata* was recorded but was not a dominant species, which is also similar to the observations of Hawthorne (1993).

The floristic aspects of the *Asteranthe* community group were also similar to those of the '*Manilkara-Diospyros* lowland dry forest', particularly the sub-type '*Cynometra-Manilkara/Croton* dry evergreen forest' described by Mamoow (1960). Vegetation types with similar features to *Asteranthe* community group were identified in *kayas* Kambe and Ribe by Hawthorne *et al.* (1981). Those authors referred to that plant association as 'the slope flora'. The *Asteranthe* community group was also similar to the 'evergreen dry forest' described by

Dale (1939). According to Hawthorne (1993), Dale's 'evergreen dry forest' is physiognomically similar to 'Black-barked *Manilkara* forest' of Boni described by Rawlins (1957) and Watson (1957); and is part of the 'Bushland and Thicket' of Gillman (1949) and the 'Coastal High Grass-bush' of Edwards (1956) mentioned as a transition to semi-desert vegetation. Although both *Scorodophloeus* and *Hugonia* communities were not directly similar to the floristic features of communities identified by Schmidt (1991) in the Shimba Hills, some of the important floral elements in these communities were recorded as important elements in the *Isolana cauliflora* community in that study.

Even within the relatively dense canopy areas of the *Asteranthe* community group, consistent lateral contact of tree crowns was absent, and there were considerable variations in the vertical stratification in the vegetation. The *Ricinodendron* sub-community, found on the summits of the hills, and close to the central clearing, had the most dense canopy (Table 2.4, Plate 2.1). While the *Ochna-Pancovia* and *Dobera* sub-communities had a relatively open canopy, with strong indications that the canopy had been disturbed by physical activities, particularly timber extraction which mainly targeted the canopy tree species. Although in the *Commiphora-Asplenium* sub-community there were no signs of recent disturbance, it is possible that extensive timber extraction had occurred in the distant past but its effects on the vegetation structure have been maintained and are observable today. On the assumption that high canopy density is associated with low disturbance, the relatively dense canopy in the *Ricinodendron* sub-community could be partly attributed to its proximity to the sacred sites on which plant resource collection has been culturally prohibited (Mwayaya, pers. comm.).

Although some species were shared between the sub-communities in the *Scorodophloeus* community and in the *Hugonia* community, other species were restricted to the sub-communities (Table 2.9). And while some species were shared between the *Scorodophloeus* and *Hugonia* communities, there were species largely restricted to each of these communities (Table 2.10).

Table 2.9: Plant species largely restricted to the different sub-communities of *Scorodophloeus* and *Hugonia* communities

Scorodophloeus community		**Hugonia community**	
***Commiphora-Asplenium* sub-community**	***Ricinodendron* sub-community**	***Ochna-Pancovia* sub-community**	***Dobera loranthifolia* sub-community**
Commiphora edulis	*Cola minor*	*Pancovia golungensis*	*Vernonia wakefieldii*
Aloe rabaiensis	*Cissus quinquangularis*	*Ophrypetalum odoratum*	*Dobera loranthifolia*
Euphorbia wakefieldii	*Hibiscus faulknerae*	*Phyllanthus kaesnerii*	
Adiantum comorensis	*Ricinodendron heudelotii*	*Monodora grandidiera*	
Coll. No. 3156			

Table 2.10: Plant species largely restricted in the *Scorodophloeus* and *Hugonia* communities

Scorodophloeus community	**Hugonia community**
Grandidiera boivinii	*Hugonia castaneifolia*
Scorodophloeus fischeri	*Suregada zanzibarica*
Encephalartos hildebrandtii	*Schlechterina mitostemmatoides*
Selaginella eubleferens	*Julbernardia magnistipulata*
Achyranthes aspera	*Sclerochiton vogelii*
Rhoicissus revoilii	
Gyrocarpus americanus	
Acalypha neptunica	

A vegetation type in *kaya* Fungo with floristic components and structural characteristics very similar to those of the *Asteranthe* community group of *kaya* Mtswakara was the *Uvariodendron* community. The *Uvariodendron* community had similar floristic aspects to "*Manilkara-Diospyros* lowland dry forest" on shale soil (shale flora) described by Moomaw (1960). Also it matched the floral aspects of the "Savanna Woodland" described by Dale (1939) and "Scrub forest" by White (1983). The *Uvariodendron* community was found between the *Acacia* community, which probably led to the description by Robertson (1984) as a *Brachystegia-Afzelia-Julbernardia* Woodland, verging on *Manilkara-Diospyros* wooded grasslands, close to semi-arid bushland of Taru Desert. It is believed that the *Uvariodendron* community at one time occupied a larger area compared to its current distribution (Moomaw 1960, Hawthorne 1993). Its remnants occupy a narrow belt between *Acacia-Euphorbia* Thorn-bushland and *Brachystegia* woodland (Moomaw 1960). The *Uvariodendron* community covered most of *kaya* Fungo forest area, with different levels of disturbance and canopy discontinuity. The observed discontinuity, again was likely to have resulted from timber extraction, where particularly the canopy tree species were selected and therefore affected.

Removal of the canopy tree species allows for light penetration that favours invasion of the forest areas by light-loving shrub species, The shrub species, most of which are invasive or have aggressive recruitment strategies, take advantage of the higher light levels in the gaps. Such shrub species include: *Acalypha fruticosa, Mildbraedia carpinifolia* (Hawthorne *et al.* 1981), *Thespesia danis, Grewia plagiophylla, Lantana camara* (Luke, pers. comm.) and *Opuntia vulgaris*.

Most climber species are also favoured by disturbance (Hawthorne *et al.* 1981; Vázquez & Givnish 1998) due to an advantage in mobility with which the climber species invade and exploit the ephemeral openings (Givnish 1984; 1995). The climber species are structural parasites that gain a competitive edge by allocating relatively little photosynthate to support tissue to achieve increase in height (Vázquez & Givnish 1998). To be successful, some shrub species attempt to acquire both erect and climbing forms (Hawthorne *et al.* 1981). Based on this assumption, and as a first analysis, vegetation types with relatively high disturbance level could be expected to contain a small number of tree species, and relatively more shrub and climber species. The different plant life-forms recorded in the *Asteranthe* community group concur with this expectation and the field observations, that the *Ricinodendron* sub-community is the least disturbed and the *Dobera loranthifolia* sub-community the most disturbed (Table 2.11). The vegetation structure of *Ricinodendron* sub-community (relatively high cover in emergent and short tree layers) compared to other vegetation types in *Asteranthe* community groups (Table 2.4), also supports the argument that there is a relatively low level disturbance in the area close to the central clearing and traditional sacred points.

Table 2.11: Number of tree, shrub, climber species and epiphytes recorded in the different vegetation types in the *Asteranthe* community group

Vegetation type	No. of tree species	No. of shrub species	No. of climber species	No. of epiphytes
Ricinodendron sub-community	27	38	28	1
Commiphora-Asplenium sub-community	15	33	18	2
Ochna-Pancovia sub-community	20	59	20	4
Dobera loranthifolia sub-community	10	44	25	1

Although progressive variations from one sub-stage to another were not easy to pick up in the field, the general distribution of the relevés representing the sub-stages recorded in the *Uvariodendron* community in *kaya* Fungo, were noted to be gradual from near the central clearing to the forest periphery. Visually, the floristic trends in this pattern changed from a relatively dense canopy forest area to a shrub-area. This led to the assumption that disturbance was more prevalent towards the periphery. If the assumption was true, it was anticipated that the recorded life-forms of the floristic elements, and the vegetation structures of the sub-stages would show variations that indicate some ranking along the central-to-periphery axis. The patterns illustrated by the variations in recorded life-forms (the number of tree, shrub and climber species) (Table 2.12) and the vegetation structures (Table 2.13) of these sub-stages did not support the assumption. The hypothesis that within the dense canopy area, the forest structure of *kaya* Fungo gradually deteriorates from near the central clearing (where most sacred spots are located, and relatively far from settlements) towards the periphery is, therefore, rejected.

Table 2.12: Number of tree, shrub, climber species and epiphytes in different stages in the *Uvariodendron* community (arranged in order from the central to the periphery of the forest).

Vegetation type	No. of tree species	No. of shrub species	No. of climber species	No. of epiphytes
Hunteria zeylanica sub-stage	13	42	19	0
Blepharespermum zanguebaricus sub-stage	15	47	17	2
Haplocoelum foliolosum sub-stage	14	45	12	1
Excoecaria madagascariensis sub-stage	12	46	18	1

Table 2.13: Vegetation structure of different *Hunteria* stage and sub-stages of *Salacia* stage in the *Uvariodendron* community *kaya* Fungo (standard deviation of mean in brackets; vegetation types arranged in distribution order from central area towards forest periphery

Vegetation type	Emergent layer	Short tree layer	Shrub layer	Herb layer	Species richness
Hunteria zeylanica stage	17.5 (28.7)	32.5 (20.6)	77.5 (12.6)	27.5 (9.6)	42.5 (4.1)
Blepharespermum sub-stage	6.0 (8.9)	28.0 (20.8)	70.0 (10.0)	36.0 (25.1)	42.0 (15.1)
Haplocoelum sub-stage	4.0 (8.9)	39.0 (26.1)	80.0 (7.0)	31.0 (10.3)	42.8 (4.4)
Excoecaria sub-stage	0.8 (2.0)	33.3 (20.7)	76.7 (5.2)	29.2 (14.3)	43.2 (6.1)

The dense canopy forest areas in the two *kayas* showed considerable similarities, with most of the floristic elements being shared. However, there were marked differences between the areas supporting dense canopy vegetation in the two *kayas*. The dense forest in *kaya* Mtswakara is found on the hills and steep slopes, while in *kaya* Fungo the dense forest area is on a relatively flat area. The difference in topography is probably one of the main causes leading to the floristic composition variations in the two *kayas*. The dense forest areas in *kaya* Mtswakara were considerably more intact, especially the *Ricinodendron* sub-community, with a relatively high cover in the emergent and the short tree layers compared to 'similar' vegetation types in *kaya* Fungo (Table 2.4; 2.8). Also a higher species richness was recorded in *kaya* Mtswakara (*Ochna-Pancovia* sub-community) than in *kaya* Fungo, although in most of the vegetation types the species richness was about same in the two *kayas*.

Most of the taxa recorded in the dense forest communities of the two *kayas* were shared, but some were not. Some of the species that were not shared within the dense forest communities of the two *kayas* were recorded in other vegetation types. Therefore, absence of a species in the dense forest community here does not indicate complete absence of that species in a particular *kaya*. In this comparison, only the relatively common species (based on records made in this study) have been used. The list of species not shared between the dense forest communities of the two *kayas* is given in Table 2.14, and suggests that there were more species restricted to the dense forest communities in *kaya* Mtswakara than in *kaya* Fungo. However, some species that were restricted in the dense canopy communities in *kaya*

Mtswakara, were widely distributed in *kaya* Fungo. These included: *Abutilon zanzibaricum*, *Suregada zanzibarica* and *Cissus phymatocarpa*.

Table 2.14: Species not shared between dense forest areas in *kayas* Mtswakara and Fungo

Non-shared taxa recorded in Mtswakara	**Non-shared taxa recorded in Fungo**	**Comments**
Cynometra suaheliensis	*Afzelia quanzensis*	
Cynometra webberi,	*Tabernaemontana elegans*	
Ricinodendron heudelotii	*Combretum schumannii*	*C. schumannii* was less common in Mtswakara
Caesalpinia insolita	*Commiphora eminii*	
Sterculia appendiculata	*Cussonia zimmermannii*	
Pancovia golungensis	*Dombeya taylorii*	
Dichapetalum zenkeri	*Toddaliopsis sansibarensis*	
Thespesia danis		*T. danis* was in *Brachystegia* woodland in Fungo
Maerua triphylla	*Canthium mombazense*	*C. mombazense* was in *Brachystegia* (in Fungo)
Pycnocoma littoralis	*Vitex strickeri*	
Pandanus rabaiensis	*Excoecaria madagascariensis*	
Aloe rabaiensis	*Oxyanthus zanguebaricus*	
Synadenium pereskiifolium	*Polysphaeria parvifolia*	*Synadenium pereskiifolia* is less common in Fungo
Nectropetalum kaesnerii	*Eugenia capensis*	
Buxus obtusifolia	*Ruellia* sp.	
Cordia monoica	*Gossypioides kirkii*	
Markhamia zanzibarica	*Acacia adenocalyx*	
Euphorbia wakefieldii	*Loeseneriella africana*	
Vepris eugeniifolia	*Laportea lanceolata*	
Acridocarpus alopecuris	*Ipomoea shupangensis*	
Rhoicissus revoilii	*Tiliacora funifera*	
Uvaria faulknerae	*Pellaea doniana*	
Memecylon fragrans	*Platycerium alcicorne*	*P. alcicorne* was recorded in only one relevé in Fungo
Sanseviera robusta	*Diospyros loureiriana*	*D. loureiriana* was less common in Mtswakara
Bulbophyllum maximum	*Grewia truncata*	
Aerangis kirkii	*Grewia forbesii*	
Angraecum cultriforme	*Grewia stuhlmannii*	
Oeceoclades saundersiana		
Adiantum comorensis		
Asplenium buetteneri		
Dorstenia hildebrandtii		
Cholorophytum fillipendulum		
Sclerochiton vogelii		
Selaginella eubleferens		

2.5.2 Woodland vegetation

In *kaya* Mtswakara, the *Brachystegia* community constituted of a continuous stretch in the gentle undulating parts of the forest, but with a distinct absence along the steep slopes that run into the river valleys and streams. In these areas, where the *Brachystegia* community was absent, the *Commiphora-Asplenium* sub-community (*Scorodophloeus* community) was recorded. This suggests the species found in the *Brachystegia* community are not adapted to steep slopes. The species of the *Brachystegia* community were similar to '*Brachystegia-Afzelia* lowland woodland' described by Mamoow (1960). Dale (1939) identified a similar plant association as 'Savanna woodland' or 'Mrihi' (a vernacular name for *Brachystegia spiciformis* in the *Midzichenda* dialects). The presence of *Brachystegia spiciformis* and *Uapaca nintida* in the *Brachystegia* community indicates its typical similarities with the 'Miombo' woodland in Central Africa (Moomaw 1960). The *Brachystegia* communities in the *kayas* can be said to form the northernmost extension of 'Miombo' woodland vegetation (Hoeft pers. comm.). According to Moomaw (1960) a vegetation similar to 'Miombo' was identified as 'Woodland' by Gillman (1949), and as 'Dry forest' by Shantz & Marbut (1923). White (1983) described a similar vegetation type as 'Zanzibar-Inhambane transition woodland', found in the Shimba Hills, Arabuko-Sokoke and Witu forests, on the Kenya Coast. The '*Markhamia zanzibarica*' vegetation described as a sub-community of the '*Manilkara discolor*' community by Schmidt (1991) has close similarities to the *Brachystegia* community identified in this study.

Moomaw (1960) and White (1983) noted that *Brachystegia* community was a successional phase in some areas, but forms a stable vegetation type in others. According to Moomaw (1960) the *Brachystegia* vegetation remnants at the Kenya Coast are scattered and of limited extent, with well developed stands in the north at Marafa, Garashi and around Mangea hill. In the south, a broad band of the forest extends from north of Bamba to Gotani (near *kaya* Fungo), at Sokoke forest, on Mwache forest (near *kaya* Mtswakara), on the slopes of the Shimba Hills and Dzombo hill (Moomaw 1960). Hawthorne (1993) identified related woodland as forested phases on the coastal plateau between Dar es Salaam and the Pungu Hills, in Tanzania, and defined them as *Baphia-Hymenaea* and *Dialium-Baphia* successional phases. However, these phases included many 'southern' species that cannot be matched with those in the Kenyan forests (Hawthorne 1993).

In *kaya* Fungo, the *Brachystegia* community was found on a neighbouring forest patch (*Mirihi-ya-Kirao*), and was totally absent in the main *kaya* forest. The local name for the site was literally derived from the presence of the *Brachystegia spiciformis* (*mirihi*). This *Brachystegia* community comprised woodland vegetation similar in many aspects to the *Brachystegia* community identified in *kaya* Mtswakara. The physical differences between the *Brachystegia* communities in the two *kayas* included the presence of termite mounds, and outcropping sandstone rocks breaking into sandstone pebbles, on undulating land in *kaya* Mtswakara; conditions that were absent in *kaya* Fungo. The species richness (number of species per 10x20m relevé) in the *Brachystegia* community in *kaya* Fungo was about twice that of *kaya* Mtswakara. Despite the high species richness recorded in *kaya* Fungo (which was based on four sample plots), in *kaya* Mtswakara the *Brachystegia* community had more species that were not shared between the two communities. Plant taxa that were not shared by the two *Brachystegia* communities are listed in Table 2.15. The vegetation structures of the two *Brachystegia* communities were similar, except that the short tree layer in *kaya* Mtswakara was considerable higher than in Fungo.

2.5.3 Thicket and wooded vegetation

The *Acacia* community was the least common vegetation type in *kaya* Mtswakara, and it comprised of floristic aspects close to those of *Acacia* thorn-bushland described by Moomaw (1960). The community was associated historically with activities such as clearing for farming, burning, and grazing, and formed an extensive wooded grassland (Plate 2.4). Although the *Acacia* community in Mtswakara represented a comparatively small area of the *kaya* forest at the time of this survey, the ongoing burning activities are likely to open up the dense canopy forest and promote the spread of the *Acacia* community.

The floristic aspects of the *Acacia* community identified in *kaya* Fungo conformed to the *Acacia-Euphorbia* (*Acacia* Thorn-bushland) described by Moomaw (1960). According to Moomaw (1960) the vegetation type is the same as that of the 'Thorn forest/*Acacia* desert grass savanna' described by Shantz & Marbut (1923), '*Acacia-Themeda*' by Edwards (1956), 'Xerophilous open woodland' by Pichi-Sermolli (1957), 'Scrub thornland' by Dale (1939), 'Dry *Acacia* bush' by Watson (1957) and 'Hinterland vegetation' by Allen (1949). This vegetation type had dominant floral elements close to those of the 'Somali-Maasai Scrub Forest' described by White (1983).

Table 2.15: Species not shared between *Brachystegia* communities in *kayas* Mtswakara and Fungo

Non-shared taxa recorded in Mtswakara	**Non-shared taxa recorded in Fungo**	**Comments**
Hyperthelia dissoluta	*Oxyanthus zanguebaricus*	*Hyperthelia dissoluta* was recorded in *Acacia* community in Fungo
Achyranthes marginatus	*Achyranthes aspera*	*Achyranthes aspera* was recorded in dense forest in Mtswakara
Bidens taylorii	*Acacia adenocalyx*	*Acacia adenocalyx* was recorded in dense forest in Mtswakara
	Sansevieria kirkii	*Sansevieria kirkii* was recorded in dense forest areas in Mtswakara
Diospyros bussei	*Loseneriella africana*	*Diospyros bussei* was recorded in *Acacia* community in Fungo
Aspilia mossambicensis	*Cissus sylvicola*	*Cissus sylvicola* was recorded in dense forest areas in Mtswakara
Cyanotis sp. nov		*Cyanotis* sp. nov. was recorded only in dense forest areas in Fungo
Pentarhopalopilia umbellulata		*Pentarhopalopilia umbellulata* was recorded mostly in *Acacia* community in Fungo
Lamprothamnus zanguebaricus		*L. zanguebaricus* was recorded in *Acacia* community in Fungo
Gutenbergia sp.	*Stylochiton salaamicus*	
Adenium obesum	*Cussonia zimmermannii*	
Uapaca nitida	*Afzelia quanzensis*	
Huernia archeri	*Tabernaemontana elegans*	
Rytigynia celastroides	*Ormocarpum kirkii*	
Phyllanthus welwitschianus	*Vitex mombassae*	
Dichrostachys cinerea	*Oeceoclades saundersiana*	
Hymenodictyon parvifolia	*Siphonochilus kirkii*	
Garcinia livingstonei	*Pentas bussei*	
Setaria sp.	*Gossypoides kirkii*	
Thecocaris bussei		
Uvaria lucida		
Diospyros consolatae		
Psydrax recurvifolia		
Psydrax polhillii		
Strychnos spinosa		
Artabotrys modestus		

The floristic composition of the *Acacia* communities in *kayas* Mtswakara and Fungo is significantly different, with a higher species richness recorded in *kaya* Fungo. Plant taxa not shared between the *Acacia* communities in the two *kayas* are given in Table 2.16. Although

Grewia plagiophylla is relatively restricted to the *Acacia* community in *kaya* Mtswakara, it is widespread in *kaya* Fungo. The vegetation structures of the two communities shared the absence of the emergent layer. In Mtswakara the abundance cover of the short tree layer in the *Acacia* community was higher than that in *kaya* Fungo, but the shrub layer cover in *kaya* Fungo was about twice that in *kaya* Mtswakara. The relatively low cover of the shrub layer in the *Acacia* community in *kaya* Mtswakara, probably allowed for the higher cover in the herb layer compared to that in *kaya* Fungo.

Table 2.16: Species not shared between the *Acacia* communities in *kayas* Mtswakara and Fungo

Non-shared taxa recorded in *kaya* Mtswakara	Non-shared taxa recorded in *kaya* Fungo	Comments
Acacia etbaica	*Thespesia danis*	*T. danis* was in *Dobera* sub-community in Mtswakara
	Lamprothamnus zanguebaricus	
	Salvadora persica	*S. persica* was in *Dobera* sub-community in Mtswakara
	Pentarhopalopilia umbellulata	*P. umbellulata* was in high canopy forest in Mtswakara
	Acacia nilotica	
	Acacia zanzibarica	
	Acacia reficiens	
	Croton talaeporos	
	Grewia densa	
	Sterculia rhynchocarpa	
	Dalbergia melanoxylon	
	Lantana camara	
	Harrisonia abyssinica	
	Manilkara mochisa	
	Zanthoxylum chalybeum	
	Commiphora africana	
	Lannea schweinfurthii	
	Dichrostachys cinerea	
	Indigofera longimucronata	
	Maerua sp.	
	Chloris roxburghiana	
	Enteropogon sechellensis	
	Eragrostis superba	
	Erythrocephalum minus	
	Sporobolus fimbriatus	
	Vernonia hildebrandtii	
	Flueggea virosa	

CHAPTER THREE

SOILS OF THE KAYA FORESTS

3.1 INTRODUCTION

The East African coastal belt is underlain by marine sediments of various ages from Cretaceous to recent, and in Kenya there are small areas of Jurassic outcrops (White 1983). The Kenya Coastal Plain thus comprises a complex of mainly post-Jurassic (<135 million years old) sediments, which include both marine and fresh water sedimentary rocks (sandstone, limestone, marls, shale, mudstone, and unconsolidated sediments) of progressively younger ages the nearer they are to the present shoreline (Kent 1972; King 1978). Inland from the coastal plain the more undulating topography is underlain principally by Precambrian rocks, but locally by Triassic sediments (White 1983). The surface configuration seems to consist of an association of erosional and depositional landforms, and the soil character is highly influenced by the parent rocks, climate, degree of leaching and topographical features such as position on the slope and degree of waterlogging (Boxem, de Meester & Smaling 1987). The major ecological interest in the Kenya coastal geology centres on the fact that the soils are derived from a wide variety of parent materials (Moomaw 1960).

Both *kayas* Mtswakara and Fungo occur on the soils of the coastal uplands (Coastal Arid and semi-arid land Development Project (CADP) 1991). In the Kenya Coastal soil sequence (CADP, 1991), *kaya* Mtswakara is found on coarse Mazeras sandstone and Shimba grits. According to CADP (1991) these soils are complex and may be: well to imperfectly drained; dark-red to dark-greyish brown; friable to firm; sandy clay to clay, with a topsoil of loamy sand (Ferralo-chromic/Orthic Acrisols, or gleyic luvisols). Some areas are underlain by excessively to imperfectly drained red to light yellowish brown, loose sand to loamy sand (ferralic to luvic arenosols) (CADP, 1991). Waiyaki (1995) identified these soils to have developed from Duruma/Kambe sandstone. The soils derived from Duruma/Kambe sandstone are thought to have formed during the mid-Jurassic epoch in a shallow marine environment (Boxem *et al.* 1987).

Kaya Fungo is found on the coastal upland soils, which developed from fine Mariakani sandstone and Upper Maji-ya-Chumvi siltstone beds (Boxem *et al.*, 1987; CADP 1991) in the driest part of Kilifi. According to CADP (1991) these soils may be well-drained and deep or dark brown to yellow brown, and from very fine sandy loam to clay, with a topsoil of very fine sand to very fine sandy loam. These soils are found in places to have an abrupt transition to sodic deeper subsoil (Orthic Luvisols, with Solodic Planosols) (CADP 1991). According to Boxem *et al.* (1987) the Mariakani formation was formed during the mid-Triassic epoch in a deltaic environment.

3.2 MATERIALS AND METHODS

3.2.1 Soil sampling

A stratified-random sampling design was undertaken for soil sampling. In view of the micro-scale variability of soils, ten sub-samples were randomly and separately collected from different areas within each relevé (sections 2.3 and 2.4), and then the sub-samples were pooled to give a single bulk sample (100-200g fresh weight). The methods of soil sampling are usually determined by the purpose of the investigation. For studies focused on soil nutrient-vegetation interactions, an examination of the soil from the top 10 or 15 cm is usually adequate (Allen 1989). It is this zone which is most biological active, in terms of mineralisation of leaf litter and the activity and death of fine plant roots used for nutrient uptake (Lind & Morrison 1974; Baillie 1989), and this includes roots of large trees (Lind & Morrison 1974; Baillie 1989; Burnham 1989). The deeper parts of the rooting system (> 20cm) of plants, especially trees, is in most cases for anchorage and for maintaining continued contact with soil zones in which the water potential remains adequate even during dry conditions (Russell 1977). In this study soil samples were collected from the top surface (0 - 10 cm) after removal of any loose surface plant litter. Although it was understood that in soil sampling and description, the investigation of the soil profile is important (Allen 1989), in this present study due to socio-cultural constraint which prohibited pit digging in the *kayas*, it was not possible to investigate the details of the soil profiles. The purpose of soil data collected in this study, therefore, was to give a basic understanding of spatial soil variability in the *kaya* forests, to help interpret the soil-vegetation relationships.

3.2.2 Physical characteristics

The physical characteristics of the soils and the soil types from each sample plot were determined in the field and described according to the methods of Fitzpatrick (1980). In each relevé the soil colour, soil texture, presence of rock material, and amount of leaf litter present were recorded. The data on the quantity of ground surface litter in each relevé were quantified using subjective categories: absent, sparse, common or abundant.

Soil samples were air-dried and stored in plastic bags. The samples were then transported by air from Kenya to South Africa for physical and chemical analysis.

3.2.3 Chemical Analysis

Chemical analysis of the soil samples was undertaken at the KwaZulu-Natal Department of Agriculture Soil Fertility and Analytical Services at Cedera, South Africa. The samples were lightly ground and sieved to pass through a 1mm sieve. The <1mm fraction was analysed for: sample soil density; extractable P; K; Ca; Mg; Zn; Mn; total cations; acid saturation; exchange acidity; pH (KCl); organic carbon; and clay contents. The analytical procedures were based on Hunter (1974; 1975) and the details of these methods are given in Appendix IV.

3.2.4 Soil Data Analysis

The similarities between soil samples from different sample plots were investigated through ordination using Principal Component Analysis (PCA) (STATGRAPHICS; Statistical Graphics Corporation, 1991 STSC Inc.). PCA is an ordination multivariate technique that is widely used in research today (Höft, Barik & Lykke 1999), both in pedological and in botanical contexts (Goodman 1990). Compared to other techniques, PCA is relatively objective in that the ordination calculations do not require subjective weights or endpoints (Gauch 1982), and PCA is perhaps the best known multivariate technique for analysing soil data (Williams 1976; Greig-Smith 1980; Clarke & Warwick 1994). The technique serves to summarise data by producing a low-dimension ordination space (of one to three dimensions), while preserving as much of the original structure of the data as possible (Gauch 1982). In the ordination space PCA projections allows insight into the relationships between data components by ordinating similar variables closely together, and dissimilar variables are placed apart (ter Braak 1995).

The soil variables were measured in different units, hence had different ranges and variances. It was necessary, therefore, to standardise (normalise) the data (Clarke & Warwick 1994; ter Braak 1995) so that the arrangement of the data points suffers the least distortion (Gauch 1982). In this study, the Principal Components (PCs) were derived from standardised data where the mean value of a variable was subtracted from each observation and then divided by the standard deviation of that variable (STATGRAPHICS; Statistical Graphics Corporation, 1991 STSC Inc.).

To establish the general pattern of different soil variables in the studied *kaya* forests, the frequencies of percentiles for each soil variable were statistically summarised using SPSS (SPSS version 6.0, SPSS Inc, 1993). And in order to establish the relationships between different soil variables, individual pairs of soil variables were investigated using *Pearson's Product Moment correlation* in STATGRAPHICS software. The details of these relationships between variables were determined further and expressed in scatter plots, together with rates of changes of first order differential equations ($y=b_0 + b_1x$). The R^2 was also determined for making predictions about the relationships between the variables.

3.3 RESULTS: *KAYA* MTSWAKARA SOILS

3.3.1 Physical properties of the soils in *kaya* Mtswakara

The main physical properties of soils from *kaya* Mtswakara were recognised on basis of colour and texture: white sands; pale black sands; pale black sandy-loams; and black sandy-loams (Table 3.1). The sandy soils were particularly associated with a thin topsoil layer over a rocky parent material that was frequently exposed above the soil layer, and weathered rock particles were clearly evident within the soil. The sandy soils were found on gentle slopes that ran into small valleys, and generally associated with open woodland vegetation areas with little ground cover. The sandy soils were characterised by the only sparse amounts of ground surface litter (Table 3.2).

Table 3.1: Physical characteristics of soils in relevés (sample plots) sampled in *kaya* Mtswakara.

Relevé number	Physiognomic Vegetation type	Soil texture	Soil colour	Amount of Litter	Notes
1	*Brachystegia*	Sand	White	Sparse	On outcropping sandstone, notable absence of shrub layer
2	*Brachystegia*	Sand	White	Sparse	Outcropping sandstone and loose sand stone-chips.
3	*Brachystegia*	Sand	White	Sparse	Outcropping sandstone. The site was in the past cultivated
4	*Brachystegia*	Sand	White	Sparse	No rocks, but poor representation of shrub layer
5	*Brachystegia*	Sand	White	Sparse	On outcropping sandstone rocks
6	*Cynometra*	Sand	Pale black	Abundant	Fairly closed forest
7	*Cynometra*	Sandy-loam	Black	Abundant	Fairly dense forest especially the shrub layer
8	Grassland	Sandy-loam	Black	Absent	Freshly burnt site, most shrub species were sprouts
9	*Brachystegia*	Sand	White	Sparse	Loose sandstone, poorly represented tree layer
10	*Julbernadia*	Sand	Pale black	Abundant	Forested site
11	Bush-land	Sand	Pale black	Common	Highly degraded area
12	Grassland	Sand	Pale black	Sparse	Highly degraded area
13	Grassland	Sand	Pale black	Abundant	Highly degraded, most herb species were dead due to drought
14	*Cynometra*	Sandy-loam	Black	Abundant	Fairly closed canopy forest
15	*Cynometra*	Sandy-loam	Black	Abundant	Tree layer was well represented, and with fairly intact canopy.
16	*Julbernadia*	Sandy-loam	Black	Abundant	On outcropping sand stone
17	*Julbernadia*	Sandy-loam	Black	Common	On outcropping sand stone rocks
18	*Julbernadia*	Sand	Pale black	Abundant	Outcropping sandstone, with algae growing on the stones.
19	*Cynometra*	Sand	Pale black	Abundant	Fairly closed canopy. A big tree had fallen
20	*Julbernadia*	Sandy-loam	Pale black	Abundant	Emergent trees absent, with signs of pole cutting
21	*Cynometra*	Sandy-loam	Black	Abundant	Pole cutting was common
22	*Cynometra*	Sandy-loam	Black	Abundant	Pole cutting signs noted.
23	*Cynometra*	Sandy-loam	Black	Abundant	Pole cutting of *Cynometra suaheliensis* was noted
24	*Julbernadia*	Sand	Black	Abundant	

Table 3.1: Continued

Relevé number	Physiognomic Vegetation type	Soil texture	Soil colour	Amount of Litter	Notes
25	*Cynometra*	Sandy-loam	Black	Abundant	Pole cutting was common
26	*Cynometra*	Sandy-loam	Black	Abundant	*Scorodophloeus fischeri* cut (for poles)
27	*Cynometra*	Sand	Pale black	Abundant	*S. fischeri* cut (poles)
28	*Cynometra*	Sandy-loam	Black	Abundant	*Craibia brevicaudata* cut (for poles)
29	*Cynometra*	Sandy-loam	Black	Abundant	
30	*Julbernadia*	Sand	Black	Abundant	*Julbernadia magnistipulata* branch cut and debarked.
31	*Brachystegia*	Sand	White	Sparse	*Brachystegia spiciformis* debarked.
32	Termite mound	Sandy-loam	Pale black	Sparse	*C. suaheliensis* cut (for poles).
33	Termite mound	Sandy-loam	Pale black	Sparse	
34	*Brachystegia*	Sand	White	Sparse	Loose sandstone chips
35	Termite mound	Sandy-loam	Pale black	Sparse	
36	Termite mound	Sand	Pale black	Common	Sandstone pebbles. *C. suaheliensis* cut for building poles.
37	*Julbernadia*	Sand	Pale black	Sparse	*J. magnistipulata* stem had been collected
38	*Julbernadia*	Sandy-loam	Pale black	Abundant	*J. magnistipulata* branches had been cut
39	Termite mound	Sandy-loam	Black	Sparse	Extraction of *C. suaheliensi* timber noted
40	Termite mound	Sandy-loam	Black	Sparse	
41	*Brachystegia*	Sand	White	Sparse	Rock basement with loose sand stone chips
42	*Brachystegia*	Sand	White	Sparse	Outcropping sandstone and pebbles
43	*Brachystegia*	Sand	White	Common	Outcropping sandstone & loose pebbles
44	Termite mound	Sandy-loam	Black	Common	Signs of tree cutting, especially *C. suaheliensis*
45	Grassland	Sand	Pale black	Common	Sand-stone pebbles; degraded area.
46	*Cynometra*	Sandy-loam	Black	Abundant	
47	Wooded-grassland	Sand	Pale black	Absent	Highly disturbed by grazing and fire
48	*Cynometra*	Sandy-loam	Pale black	Common	Rocky substrate exposed by soil erosion following rains
49	*Cynometra*	Sandy-loam	Black	Abundant	*S. fischeri* cut (building poles)
50	Grassland	Sand	Pale black	Absent	Outcropping rocks and sandstone pebbles;
51	Grassland	Sand	Pale black	Absent	Forest edge; highly degraded. and subjected to grazing

Table 3.2: Percentages of sample plots of different soil texture with varied amounts of ground surface litter (soil samples collected from relevés sampled in *kaya* Mtswakara)

Soil type/texture	Litter absent	Litter sparse	Litter common	Litter abundant
Sand soils (n=27)	11.1	44.4	14.8	29.6
Sandy-loam soils (n=24)	4.2	20.8	12.5	62.5

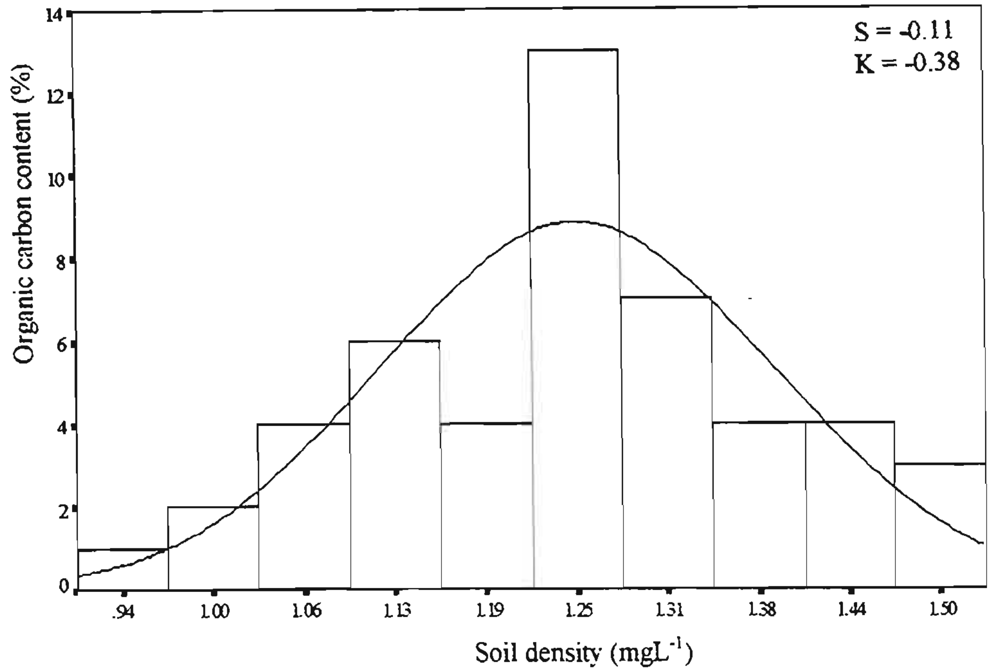
Sandy-loam soils were associated with relatively dense canopy forest areas and with termite mounds. The sandy-loam soils were characterised by a relatively thick topsoil layer, with occasional presence of outcropping rocks especially on the steep slopes running into the river valleys of the rivers Mwache and Mbome. Sandy-loam soils were also associated with abundant ground surface litter (Table 3.2) except for the wooded grassland areas, which were noted to have been affected by fire.

For most samples, the soil density was $<1.3mgL^{-1}$ or less (Table 3.3). Soil samples with relatively high density ($>1.3mgL^{-1}$) were described in the field as sand soils. However, this descriptive attribute of sand soils did not consistently correspond to high soil density conditions, as some sandy soils were characterised by relatively low soil density ($<1.3mgL^{-1}$). The distribution occurrences of measures of soil densities were relatively normally distributed across the soil samples (Fig 3.1), indicating that the soil samples were representative in terms of density, without bias to one extreme measure of density. The mode and the median were about equal to the mean, (about $1.2mgL^{-1}$), which was a true central tendency of the soils in *kaya* Mtswakara.

Table 3.3: Percentages of soil samples of different soil texture containing varied soil densities (soil samples collected from relevés sampled in *kaya* Mtswakara)

Soil type	Soil density of $<1.3mgL^{-1}$	Soil density of $\geq1.3mgL^{-1}$
Sand soils (n=27)	63	37
Sandy-loam soils (n=24)	95.8	4.2

Fig: 3.1: Frequency distribution of density measures for soil samples collected from *kaya* Mtswakara (The mean is the central tendency; 'S' is Skewness; and 'K' is Kurtosis).



3.3.2 Chemical properties of the soils in *kaya* Mtswakara

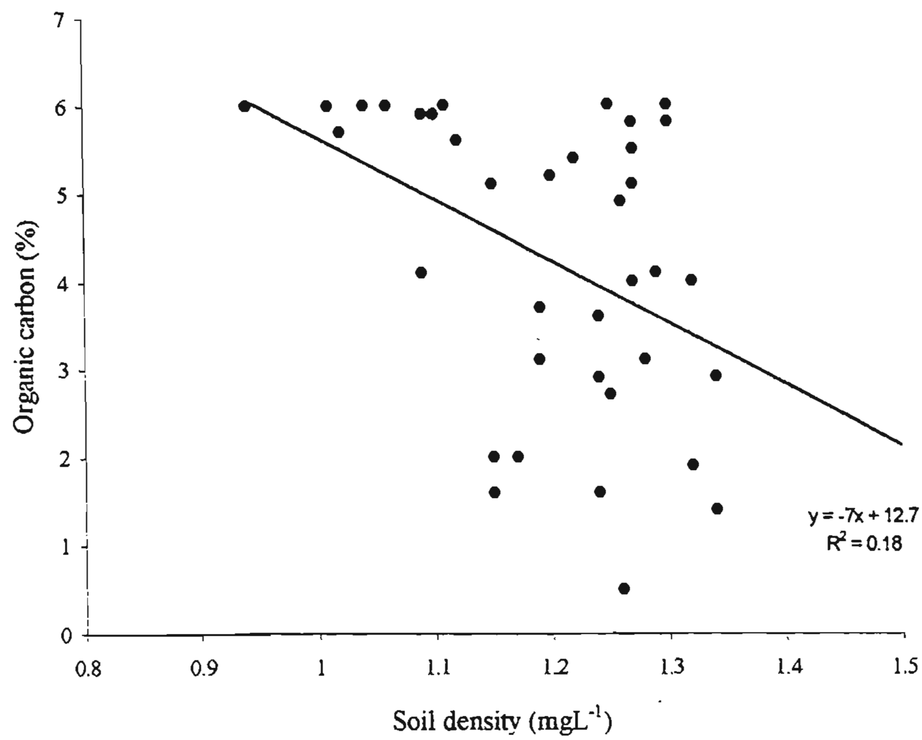
A total of 12 variables for each soil sample were measured, details of which are given in Table 3.4. The infra-red spectrometer used for determining the available organic carbon content in the soil samples could not be used to detect readings for soils that had a density greater than 1.35mgL^{-1}. Therefore, for eleven soil samples (with >1.35mgL^{-1} density) the organic carbon values are missing, most of which were identified in the field as sandy soils. Generally, high soil density values are indicative of low carbon content (Smeda pers. comm.), and this inference was noted to be true for the soils from *kaya* Mtswakara. There was a significant negative correlation ($r = -0.43$, at $p<0.01$) between the organic carbon content and the soil density, and a significant R^2 value (=0.18) (Fig. 3.2).

Table 3.4: Chemical characteristics for soils* collected from sample plots established in *kaya* Mtswakara

Releve	Phosphorus	K	Ca	Mg	Zn	Mn	Exchange acidity	Total cations	Acid saturation	pH	Organic carbon	Clay
1	6.3	95.3	453.1	138.3	1.4	78.1	0.05	4.7	1	5.0	3.1	26
2	1.4	56.6	114.5	99.3	0.3	55.2	0.03	2.3	2	4.8	Nd	20
3	3.0	106.7	412.7	117.9	0.9	37.3	0.01	4.5	0	5.5	2.9	33
4	1.4	117.8	252.1	88.6	0.6	57.1	0.07	3.3	3	5.3	Nd	14
5	5.5	141.7	524.4	229.9	1.4	70.9	0.03	6.2	1	5.3	4.0	19
6	5.9	258.8	857.1	198.3	2.4	100.8	0.04	7.9	1	5.3	3.1	24
7	7.3	267.0	1457.8	196.3	4.3	73.4	0.06	10.5	1	5.9	4.1	24
8	8.7	577.3	781.7	212.2	10.9	156.5	0.06	8.3	1	5.9	1.6	20
9	3.3	75.5	175.5	94.7	0.5	21.8	0.05	2.9	2	5.1	Nd	18
10	3.7	153.7	425.7	112.5	1.2	73.5	0.03	4.7	1	5.0	Nd	32
11	3.0	111.4	478.0	46.2	4.7	45.5	0.02	4.1	1	5.3	1.9	19
12	3.0	253.0	406.7	139.6	1.5	52.2	0.02	5.2	1	5.7	1.4	20
14	10.9	330.7	3258.4	292.1	12.9	18.8	0.03	19.7	0	6.5	6.0	26
15	72.1	325.0	4221.1	266.3	14.4	7.7	0.07	25.1	0	7.3	6.0	26
16	15.0	187.4	639.4	159.1	5.7	78.7	0.06	6.4	1	5.6	5.5	19
17	5.6	179.0	668.5	141.1	47.4	80.6	0.07	6.2	1	5.5	3.6	20
18	7.6	205.9	1492.4	143.7	26.7	31.1	0.08	11.0	1	6.2	3.7	22
19	18.1	239.3	833.1	96.9	18.7	141.7	0.04	7.1	1	5.1	5.1	19
20	8.7	173.0	1080.2	140.5	41.9	63.5	0.05	8.9	1	5.6	4.9	22
21	15.6	578.0	1621.1	377.1	32.8	33.9	0.07	13.9	1	6.2	5.9	24
23	6.5	268.5	892.7	247.6	23.2	24.2	0.02	8.9	0	6.7	1.6	19
24	9.0	218.0	723.8	227.0	3.4	98.4	0.06	7.4	1	5.5	5.4	22
25	10.3	222.8	725.7	117.2	9.3	19.1	0.02	7.2	0	5.8	Nd	15
26	7.9	188.2	1270.1	153.5	37.6	70.9	0.04	10.3	0	5.7	5.8	18
27	23.4	249.5	1487.4	166.7	24.1	153.2	0.12	10.6	1	5.4	6.0	23
28	7.8	239.1	1182.6	167.8	5.4	95.7	0.09	9.2	1	5.2	5.1	25
29	6.6	251.9	2848.1	261.3	2.1	14.2	0.09	18.1	1	6.5	6.0	27
30	4.8	167.4	740.3	162.8	1.9	85.3	0.1	7.2	2	5.4	4.1	20
31	0.7	57.0	167.8	54.4	0.1	40.3	0.05	2.2	3	4.8	Nd	21
32	4.6	206.2	1373.1	203.8	1.8	17.7	0.11	11.9	1	6.6	6.0	23
33	4.5	563.4	1390.2	450.9	2.8	116.1	0.11	13.7	1	6.0	5.6	27
34	2.6	69.3	166.7	83.3	0.5	46.7	0.05	2.6	3	5.1	Nd	15
35	6.1	458.3	1004.5	136.4	2.5	29.5	0.08	9.8	1	7.2	4.0	26
36	1.4	107.0	223.9	119.7	0.6	56.3	0.09	3.5	4	5.2	Nd	22
37	10.8	181.5	539.2	143.1	1.8	100.0	0.06	5.7	1	5.1	5.8	19
38	8.1	133.9	664.5	101.6	1.2	16.1	0.06	5.6	1	5.6	2.9	20
39	5.9	417.6	982.4	593.1	1.0	78.4	0.13	11.2	1	5.1	5.7	45
40	6.4	330.9	777.3	151.8	1.8	545.5	0.10	6.7	2	5.3	5.9	36
41	2.9	157.4	246.3	129.4	0.7	44.1	0.06	3.8	2	5.0	Nd	27
42	1.4	78.9	88.0	77.5	0.2	26.1	0.16	2.1	11	4.3	Nd	16
43	2.1	70.6	117.5	93.0	0.2	15.4	0.78	3.3	34	4.2	Nd	30
44	15.9	526.6	1633.0	403.2	4.6	117.0	0.12	12.2	1	5.2	6.0	44
45	6.4	311.2	684.0	216.8	1.0	64.0	0.07	7.6	1	6.8	2.7	26
46	19.7	341.0	930.8	195.7	5.4	36.8	0.11	8.5	2	6.3	2.0	18
47	8.0	132.0	1137.6	176	6.0	104.0	0.12	9.5	2	5.6	6.0	21
48	7.0	222.6	1679.1	182.6	1.4	13.0	0.07	12.1	1	6.1	2.0	26
49	8.3	208.3	1720.8	85.8	3.8	16.7	0.08	11.9	1	6.7	5.2	27
50	1.6	499.2	1121.4	238.9	1.1	19.0	0.08	11.2	1	6.2	0.5	21

* For units of measurement see text; Nd = not determined

Fig. 3.2: Variation of organic carbon content with soil density, for soils collected from *kaya* Mtswakara



Relatively high levels of Ca in soil samples (14, 15 and 29) corresponded with relatively high levels of total cations, while relatively low levels of Ca in soil samples (2, 9, 31, 34, 42 and 43) corresponded with relatively low levels of total cations (Table 3.4).

Although the low levels of Ca consistently coincided with relatively low levels of K, Mg, Zn and P, very high levels of Ca did not correspond with very high levels of these cations, except for P in sample 15. In some samples (21, 33, 39 and 44) high levels of K corresponded with high levels of Mg, but overall the high levels of Mg and K did not correspond with high levels of total cations. The high levels of total cations corresponded with relatively low exchange acidity and acid saturation, while low levels of total cations in some samples (42 and 43) corresponded with exceptionally high levels of exchange acidity and acid saturation (Table 3.4). Low pH levels in most samples (2, 9, 31, 34, 42 and 43) coincided with the combined low levels of Ca, K, Mg, Zn and P, although the high pH levels did not necessarily coincide with high levels of these constituents.

In summary the soil base richness was inversely related to soil acidity; and relatively high levels of total cations were associated with the sandy-loam soils, while low levels of total cations was associated with sandy soils. There was no immediate observable simple pattern elucidating relationships between organic carbon and clay contents to the other soil variables.

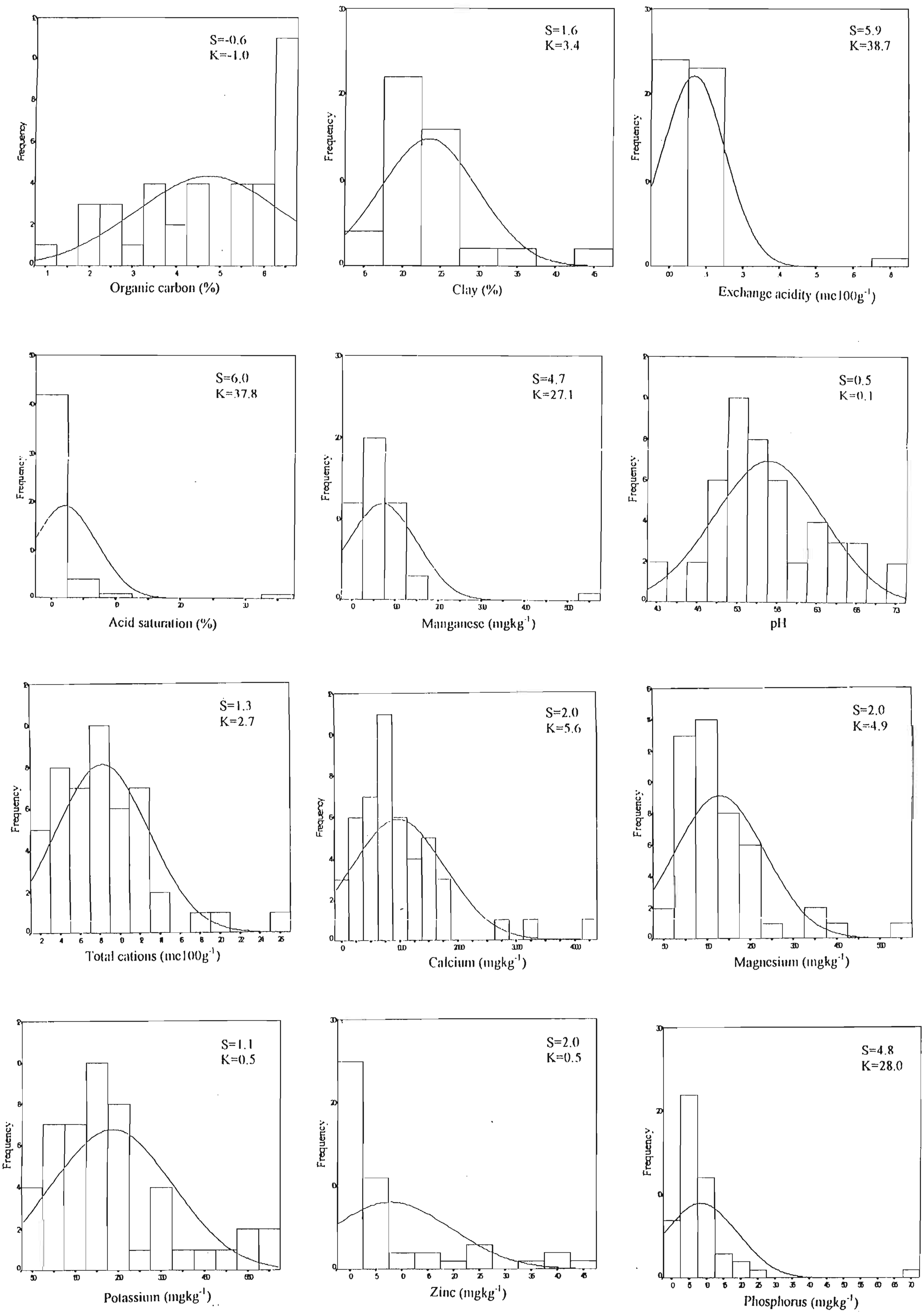
Soils from the sample plots across the *kaya* forest showed considerable variations in the concentrations of different variables (Table 3.5), which was an affirmation of differences in soil quality. Among the soil cations measured (weight to weight ratio) Ca was found in highest concentrations and Zn was found in least concentrations (Table 3.5).

Table 3.5: Mean values (standard deviation in brackets), and range of soil variables for soil samples collected from *kaya* Mtswakara (n=48, except for organic carbon n=37)

Soil variable	*Mean*	*Standard deviation*	*Standard error*	*Range*
Phosphorus ($mgkg^{-1}$)	8.5	10.6	1.5	0.7 - 72.1
K ($mgkg^{-1}$)	235.7	141.5	20.4	56.6 - 578
Ca ($mgkg^{-1}$)	972.3	809.7	116.9	88 - 4221.1
Mg ($mgkg^{-1}$)	179.8	104.5	15.1	46.2 - 593.1
Zn ($mgkg^{-1}$)	7.8	11.8	1.7	0.1 - 47.4
Mn ($mgkg^{-1}$)	69.6	80.1	11.6	7.7 - 545.5
Exchange acidity ($me/100g^{-1}$)	0.09	0.12	0.02	0.01 - 0.78
Total cations ($me/100g^{-1}$)	8.3	4.7	0.7	2.1 - 25.1
Acid saturation (%)	2.1	5.0	0.7	0 - 34
pH (KCl)	5.6	0.7	0.1	4.2 – 7.3
Organic Carbon (%)	4.3	1.7	0.3	0.5 - 6
Clay (%)	23.5	6.4	0.9	14 - 45

The distribution frequencies of the soil variables are illustrated in (Fig. 3.3). Major departures from normality in the histograms are seen in most variables, which show positive skew influenced by a small percentage frequency of high values. This positive skewness is particularly high for: Mn, P, acid saturation, and exchange acidity, because of high 'outlier' values in these data sets. Total cations, Ca, Mg, and clay are similar but less pronounced. Only organic carbon showed a tendency to negative skewness, and the frequency of pH values was relatively normally distributed. Eleven samples which were likely to have relatively very low levels of organ carbon were not included, therefore, the current observations on organic carbon is subject to needing further support from additional data.

Fig. 3.3: Frequency distribution of measures of soil variables for soil samples collected from sample plots established in *kaya* Mtswakara (The mean is the central tendency; 'S' is Skewness and 'K' is Kurtosis)



3.3.3 Ordination of *kaya* Mtswakara soil samples

The chemical soil variables, except organic carbon for which values for some samples were missing (Table 3.4), were investigated by Principal Components Analysis (PCA). The interpretation of the inter-sample relationships was facilitated by a bi-plot ordination in which the soil variables were plotted. On the bi-plot ordinations (Figs. 3.4 and 3.5) the points represent the soil variables. The coefficients defining the principal components (PCs) may be used to infer real meaning to the PCs, as the size and sign of each coefficient is an indication of the proportion of the variance each variable accounts for along the PC.

The first three PCs accounted for 71.5% of the variance (Table 3.6). The first PC, which accounted for 38.5% of the variance, had high positive values for P, K, Ca, Mg, total cations and pH, and low positive values for clay and Zn; and negative values for Mn, exchange acidity and acid saturation (Table 3.6). The first PC was essentially a contrast between base rich (high levels of K, Ca, Mg) soils at the positive pole of the axis and base poor acidic soils at the negative pole (Fig. 3.4). The first PC, therefore, can be interpreted as a soil fertility axis, with relatively fertile soils to the positive end and infertile soils to the negative end. The second PC, which accounted for 18.9% of the variance, had high positive values for exchange acidity, acid saturation and clay; low positive values for Ca and total cations; and negative values for P, Zn and pH (Table 3.6). The second PC was a contrast between relatively high acidity soils on the positive end and relatively low acidity soils on the negative end (Fig. 3.4). The second PC therefore can be defined as a soil acidity axis. The third PC, which accounted for 14.2% of the variance, had high positive values for P, exchange acidity and acid saturation; low positive values for total cations and pH, and very high negative values for Mn and clay (Table 3.6). The plot of PC 1 against PC 3 (Fig. 3.5) appears to give very little additional information for the interpretation of the data set. The dominant role of exchangeable Mn, as a factor separate from its role as an indicator of acidic conditions, was difficult to establish.

Fig. 3.4: Soil variables plotted in the PCA space defined by the first and second Principal Components (for soils collected from *kaya* Mtswakara)

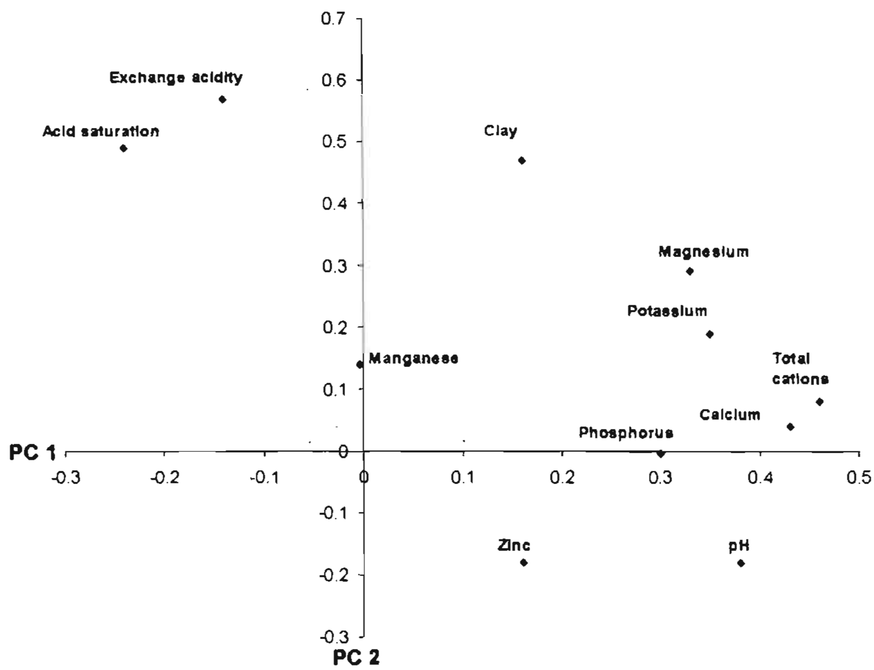


Fig. 3.5: Soil variables plotted in the PCA space defined by the first and third Principal Components (for soils collected from *kaya* Mtswakara)

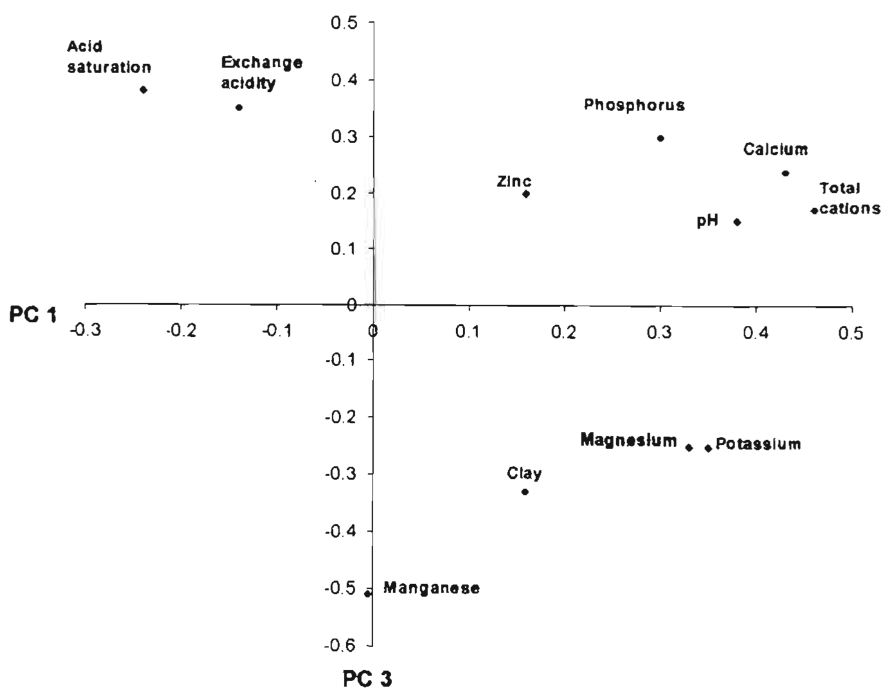


Table 3.6: Latent vectors from a PCA of chemical soil variables for soil samples collected from *kaya* Mtswakara.

Soil variable	PC 1	PC 2	PC 3
Phosphorus	0.30	-0.003	0.30
Potassium	0.35	0.19	-0.25
Calcium	0.43	0.04	0.24
Magnesium	0.33	0.29	-0.25
Zinc	0.16	-0.18	0.20
Manganese	-0.004	0.14	-0.51
Exchange acidity	-0.14	0.57	0.35
Total cations	0.46	0.08	0.17
Acid saturation	-0.24	0.49	0.38
pH	0.38	-0.18	0.15
Clay	0.16	0.47	-0.33
Variance	38.5	18.9	14.2
Cumulative variance	38.5	57.4	71.5

The texture of the soils on the PCA hyperspace defined by the first and second axes indicate that most sandy-loam soils were relatively base-rich and sandy soils were generally base-poor (Fig. 3.6). Along the soil acidity axis (PC 2), most soil samples (>95%) were ordinated within –2 and +2 of the axis, reflecting a lower range of variation associated with this gradient compared to that in soil fertility axis (-6 to +8). The observations made concerning clay content were less clear than the soil texture ordination (Fig 3.6). Soil samples with relatively high (>25%) clay content were associated with relatively high base-status (PC 1) and high acid saturation (PC 2) (Fig. 3.7). None of soil samples from *kaya* Mtswakara had less than 10% clay content. Abundant ground surface litter was associated with relatively high and moderate base-status, while low amounts of litter were associated mostly with low base-status (Fig. 3.8). For the soil samples where organic carbon was measured, relatively high organic carbon content was common in the relatively high base-status soils, and low organic carbon content was common in the relatively low base-status soils (Fig. 3.9).

Fig. 3.6: Soil texture ordinated on PCA space defined by the first and second PCs, for soil samples collected from sample plots established in Mtswakara

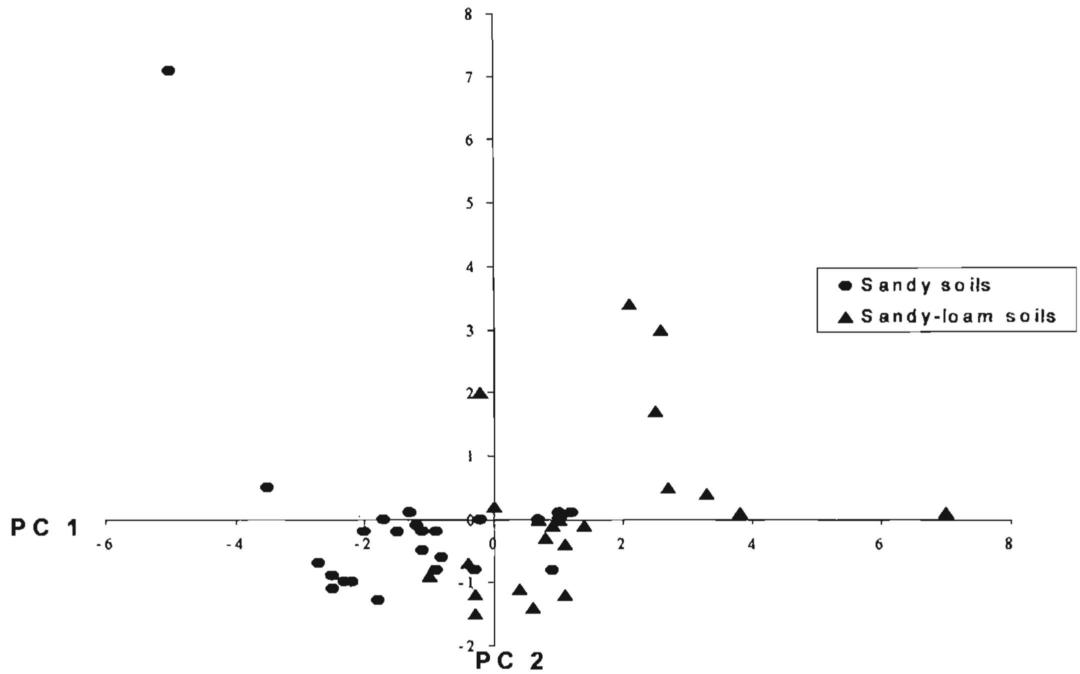


Fig. 3.7: Clay content ordinated on PCA space defined by the first and second PCs, for soil samples collected from sample plots established in Mtswakara

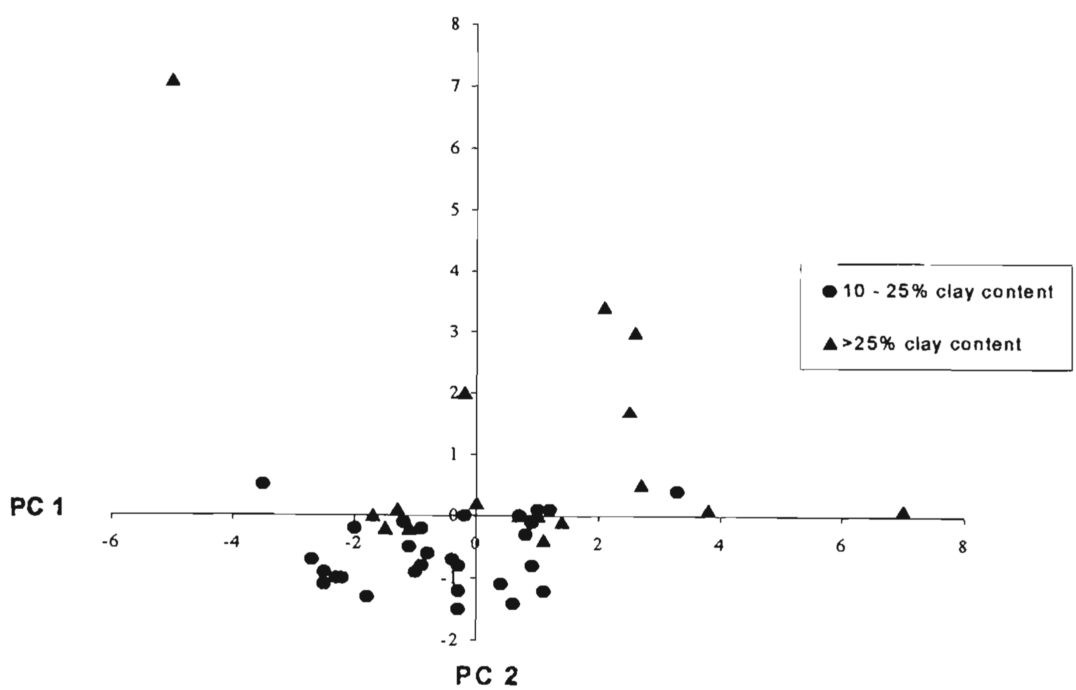


Fig. 3.8: Ordination of ground surface litter in the PCA space defined by the first and second Principal Components, for soils collected *kaya* Mtswakara

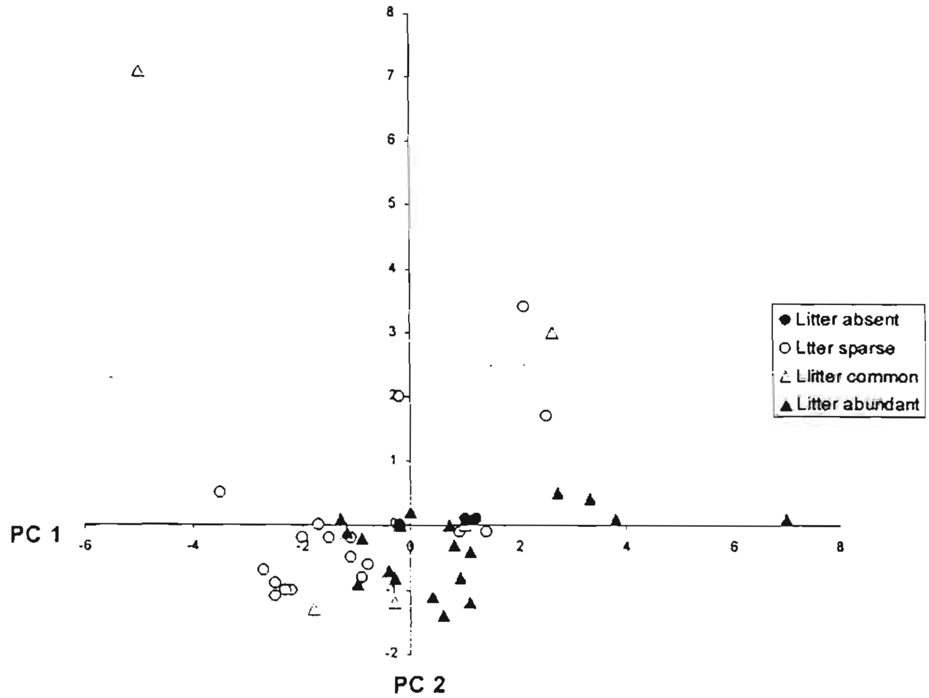
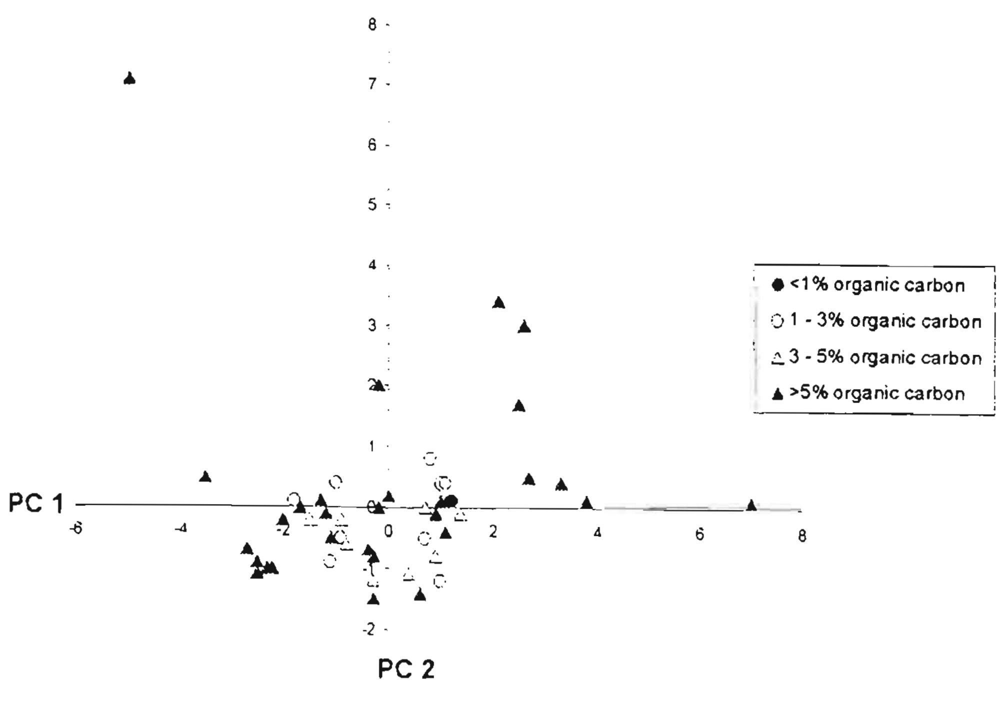


Fig. 3.9: Ordination of organic carbon content in the PCA space defined by the first and second Principal Components, for soils collected from *kaya* Mtswakara



The termite mounds were mostly identified as soils of relatively higher base-status (Fig. 3.10). The soils on the termite mounds are mostly sandy-loams, characterised by relatively moderate to high clay contents, moderate to high ground surface litter, and high organic carbon contents.

Comparatively, relative high base-status in soils was associated with the absence or relatively low vegetation disturbance levels, while moderate disturbance was mostly associated with the relatively low base-status in soil (Fig. 3.11). Disturbance here is defined as vegetation destruction, particularly tree species removal. The land slope on which the sample plots were established was compared to PC 1 (the fertility gradient) and showed a curve-linear relationship (Fig. 3.12), that had a significant R^2 (=0.15). This suggests that flatter areas were the extremes of base-status i.e. high or low. Whereas the soils of the steeper slopes have a base-status more within the middle range.

Fig. 3.10: Ordination of termite mounds in the PCA space defined by the first and second Principal Components, for soils collected from *kaya* Mtswakara

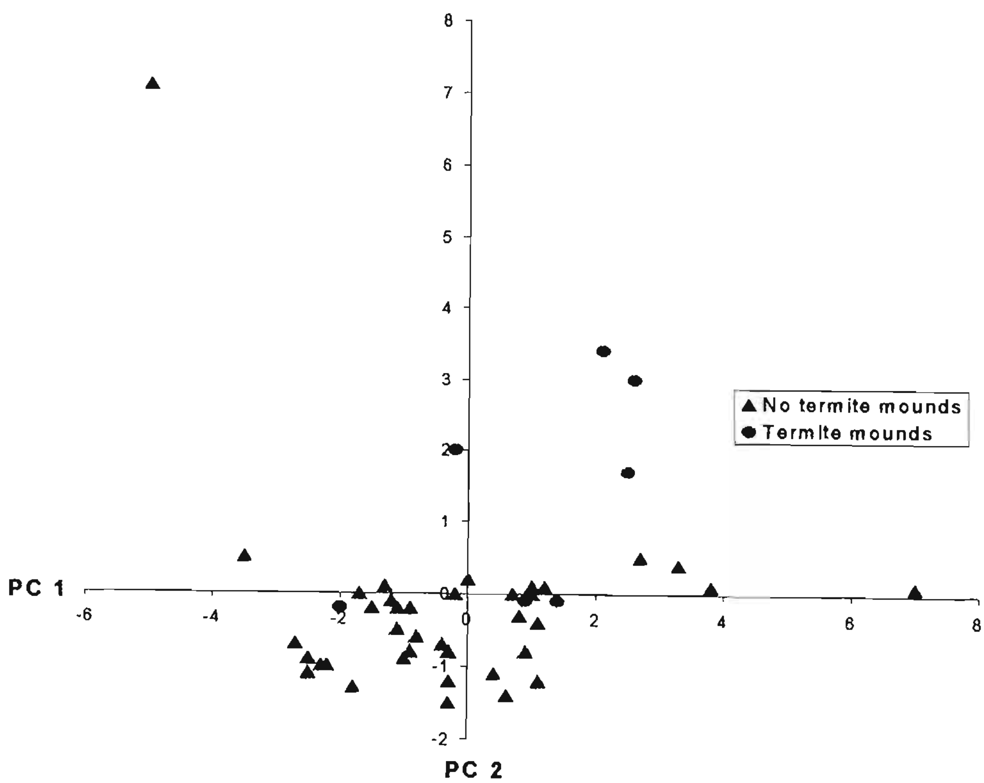


Fig. 3.11: Ordination of vegetation disturbance levels in the PCA space defined by the first and second Principal Components (soil and vegetation data collected from *kaya* Mtswakara)

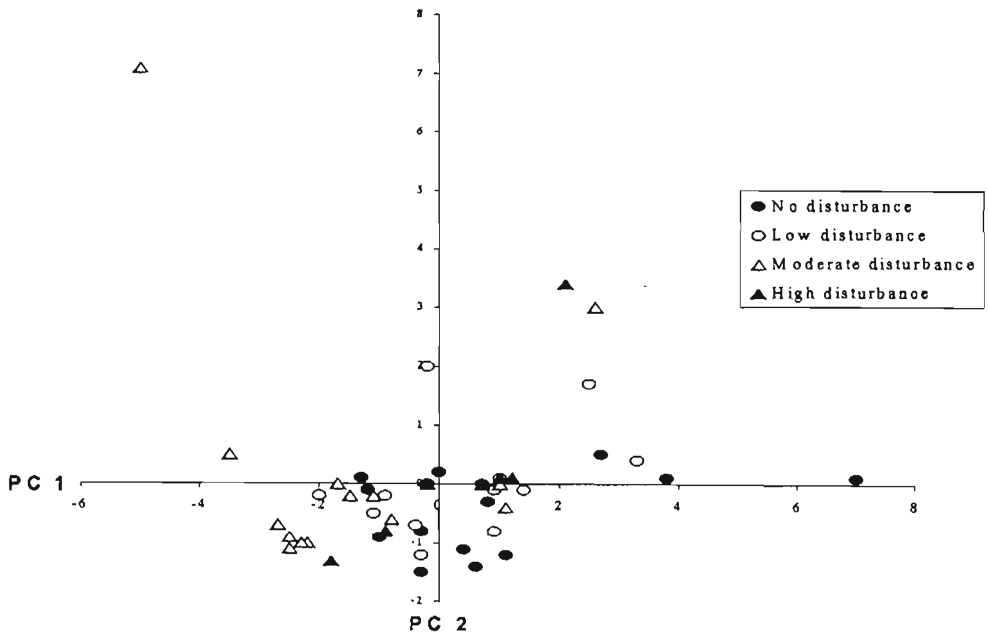
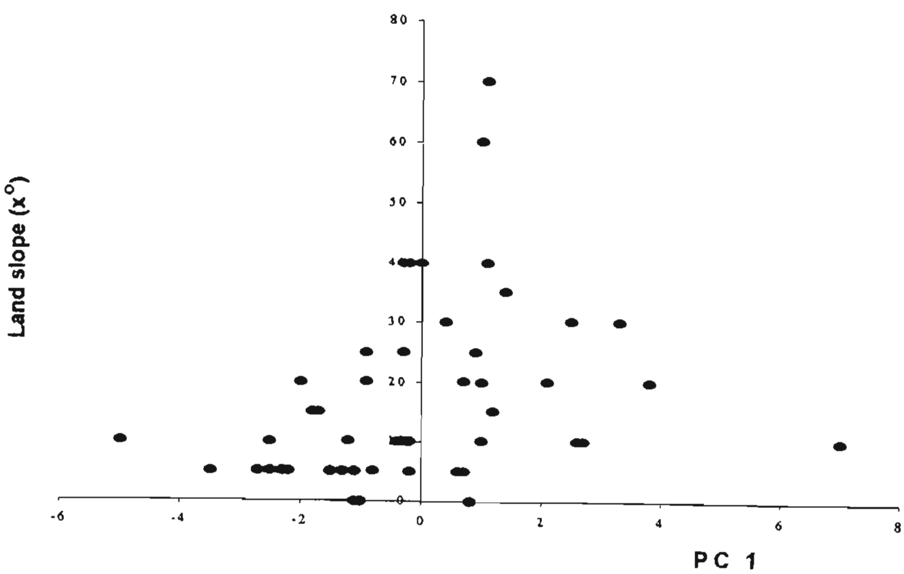


Fig. 3.12: Land slope (x°) in the relevés in relation to the first Principal Component (for relevés sampled in *kaya* Mtswakara)



3.3.4 Correlation between soil variables (soils from *kaya* Mtswakara)

The results of a correlation analysis on the soil data set are given in Table 3.7. A total of 24 correlations were statistically significant at $p \leq 0.05$; 21 correlations were positive and three were negative. Total cations had the most correlations (eight), while slope and Zn did not correlate with any other soil variables. Organic carbon content was included in this analysis.

The total cations correlated positively with the major cations (Ca, Mg and K) with a very high correlation coefficient ($r=0.97$) for total cations v. Ca (Table 3.7). The concentration values of Ca, Mg and K were converted from $mgkg^{-1}$ to $me100g^{-1}$ (the units for total cations), and the correlation details between the total cations and the major cations were investigated further using scatter plots (Fig. 3.13a, b and c). The high R^2 value and the high gradient value in the regression line equation of total cations v. Ca (Fig. 3.13a), indicated that Ca was the dominant constituent of the total cations, relative to K and Mg. However, in the scatterplot (Fig. 3.13a) samples 14, 15 and 29, were noted to have exceptionally high levels of Ca ($>10me100g^{-1}$) compared to the rest of the data set. When the samples 14, 15 and 29 were excluded (Fig. 3.13d, e and f), a significant correlation between total cations and Ca was maintained ($r=0.96$, at $p<0.001$), but the correlation coefficient values in total cations v. Mg, and total cations v. K increased (from $r= 0.53$ and 0.43 to $r= 0.66$ and 0.73 at $p<0.001$ respectively). Fig. 3.14 shows the proportion each of the cations Ca, Mg and K contributed to the total cations; the samples plotted in order of increasing values of total cations. It is clear how Ca increasingly dominated the total cation exchange capacity especially as the total cation exchange capacity increased over $10me100g^{-1}$. The influence of the very high Ca samples (14, 15 and 29) on the total cations is clearly seen.

In addition to correlation with Ca, Mg and K, the total cations was also correlated positively with phosphorus, pH, organic carbon and clay; and correlated negatively with acid saturation (Table 3.7). In total cations v. phosphorus, and in Ca v. phosphorus, sample 15 showed considerably higher levels of phosphorus than the values predicted by the linear regression model (Fig. 3.15a and b). When sample 15 was excluded the R^2 values reduced considerably in total cations v. phosphorus (0.4 to 0.2), and in Ca v. phosphorus (0.5 to 0.19) (Fig. 3.15c and d), but the correlations were still statistically significant ($r= 0.64$, and $r=0.68$ respectively) at $p<0.001$. This may suggest that variation of soil phosphorus level was influenced by the Ca levels in the soils, but not by the other cations (Mg, K or Zn).

Table 3.7: Correlation matrix between variables (soil variables and slope) for the samples collected from sample plots established in Mtswakara

		1	2	3	4	5	6	7	8	9	10	11	12	13
1	Slope													
2	Phosphorus													
3	Potassium													
4	Calcium		0.65***											
5	Magnesium			0.66***										
6	Zinc													
7	Manganese													
8	Exchange acidity			0.36*		0.44**								
9	Total cations		0.61***	0.43**	0.97***	0.53***								
10	Acid saturation				-0.37*			0.43**	0.57***	-0.34*				
11	pH		0.33*		0.58***			-0.42**		0.55***				
12	Organic carbon				0.43**				0.43**	0.45**				
13	Clay			0.36*		0.59***			0.41*	0.32*			0.33*	

Only statistically significant coefficients given: *** correlation at $p \leq 0.001$, ** at $p \leq 0.01$, * at $p \leq 0.05$.
The correlation frequencies were: Total possible correlations (n) = 78; recorded significant correlations = 24;
Individual variable significant correlations were Slope= 0; P= 3, K= 4; Ca= 4; Mg= 4; Zn= 0; Mn= 2; Exchange acidity = 5; Total cations = 8; Acid saturation = 4; pH = 4; Organic carbon = 4; and Clay = 5.

Fig. 3.13: Correlation between total cations and (a) calcium, (b) magnesium, and (c) potassium, inclusive of samples 14, 15 and 29. Correlation between (d) calcium, (e) magnesium, and (f) potassium, exclusive of samples 14, 15 and 29 (soils collected from *kaya* Mtswakara)

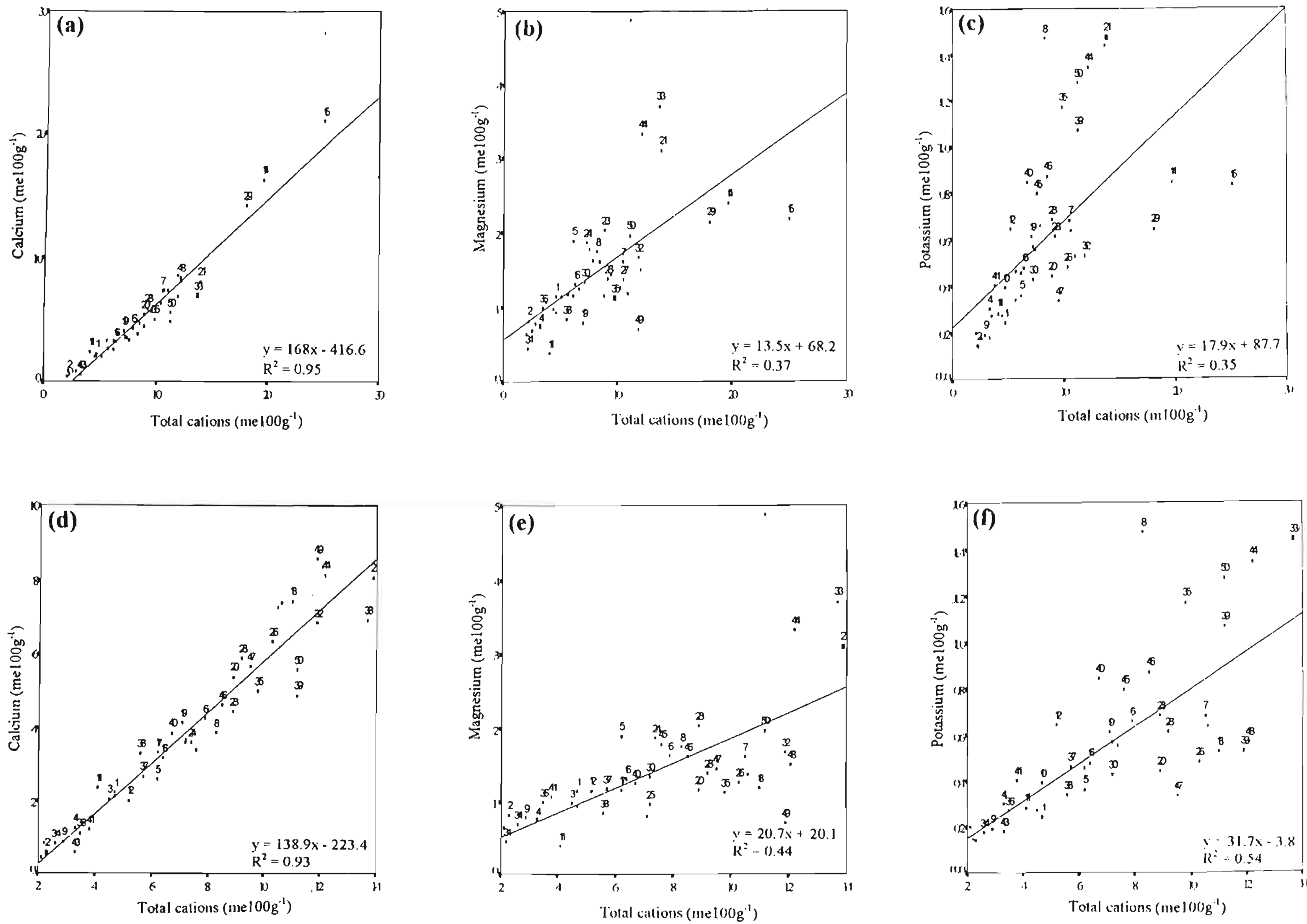


Fig. 3.14: Proportion of the cations Ca, Mg and K in relation to total cations concentrations (soils collected from *kaya* Mtswakara)

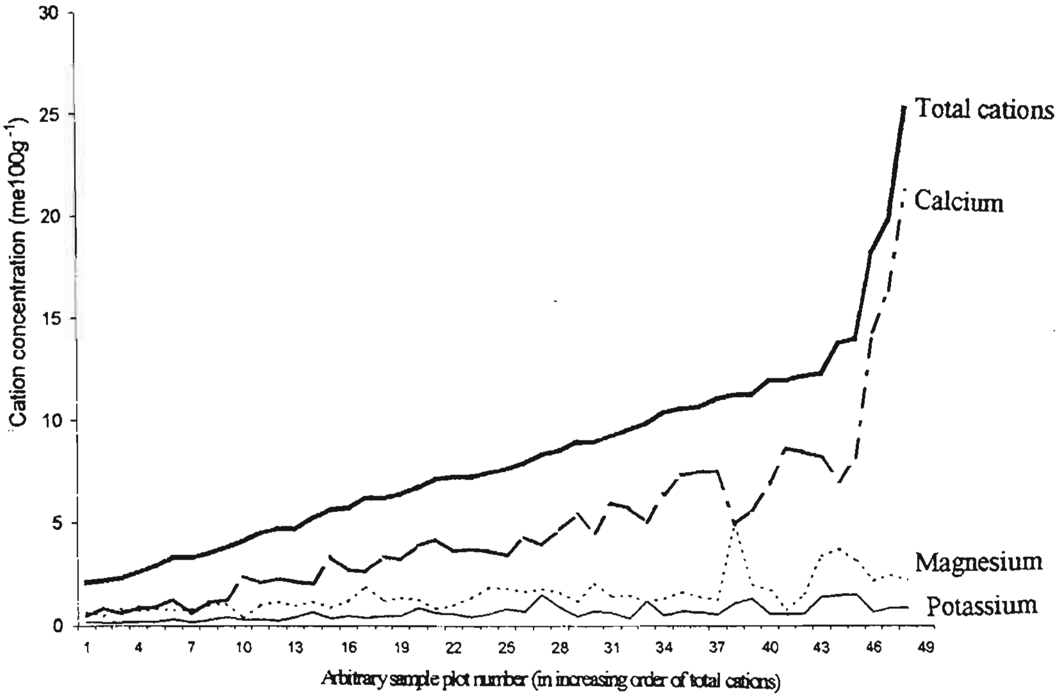
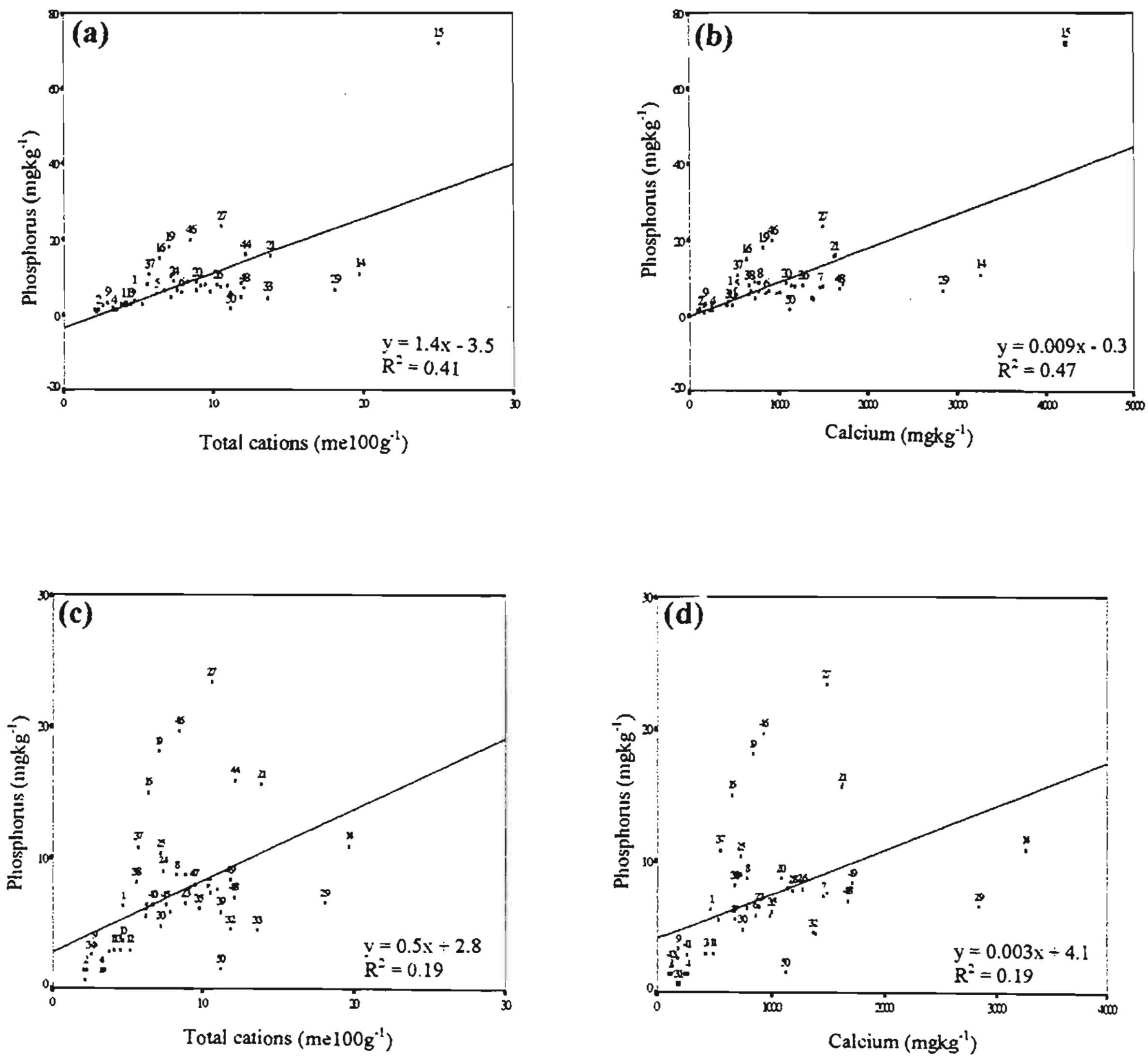


Fig. 3.15: Correlation between phosphorus and (a) total cations, and (b) calcium, inclusive of sample 15; correlation between phosphorus and (c) total cations and (d) calcium, exclusive of sample 15 (soils collected from *kaya* Mtswakara)



The acid saturation had a significant negative correlation with total cations and Ca ($r = -0.34$, and -0.37 at $p<0.05$ respectively). In acid saturation against total cations and Ca, the R^2 values were not significant, and sample 43 showed high levels of acid saturation, while samples 14, 15 and 29 showed higher levels of the cations, than the rest of the data set (Fig. 3.16a and b). When these outlier samples were excluded, significant negative correlations were maintained ($r = -0.34$, and -0.37 at $p<0.05$ with total cations and with Ca respectively), and the R^2 values increased to significant values (from 0.08 to 0.2 for total cations; and from 0.07 to 0.18 for Ca). As would be expected, Mn had significant positive correlation with acid saturation ($r = 0.43$, at $p<0.01$), but contrary to expectation, Mn also had significant positive correlation with pH ($r = 0.42$, at $p<0.01$, respectively) (Table 3.7). In Mn v. acid saturation, the R^2 value was not significant ($R^2 = 0.009$), and sample 40 had a much high level of Mn than the rest of the data set, while samples 42 and 43 had high levels of acid saturation than predicted by the regression model (Fig. 3.16c). When samples 40, 42 and 43 were excluded, the R^2 value reduced further to 0.002, which meant that the positive correlation of Mn and acid saturation was not significant. In Mn v. pH the R^2 value was also not significant ($R^2 = 0.04$), and sample 40 had high levels of Mn than the rest of the data set (Fig. 3.16d). When sample 40 was excluded, the R^2 value increased (from 0.04 to 0.09), but was still not significant.

There was a significant positive correlation between pH v. total cations, pH v. Ca and pH v. phosphorus. In pH v. total cations, and in pH v. Ca (Fig. 3.17a and b), the outlier samples 14, 15 and 29 were noted again. When these samples were excluded significant correlations were maintained ($r = 0.66$, 0.61 at $p<0.001$ in pH v. total cations and pH v. Ca respectively), but the R^2 values reduced (from 0.5 to 0.4, and from 0.5 to 0.37 respectively) though remained significant. In pH v. phosphorus the R^2 value was significant ($R^2 = 0.19$), but sample 15 showed high levels of both pH and phosphorus (Fig. 3.17c). When sample 15 was excluded the correlation was not significant at $p<0.05$, and the R^2 value reduced to a non-significant value ($R^2 = 0.06$), which suggests that soil pH variation did not affect the concentration of exchangeable phosphorus in the soil.

Fig 3.16: Correlation between acid saturation and (a) total cations, (b) calcium and (c) Mn; and (d) pH (soils collected from *kaya* Mtswakara)

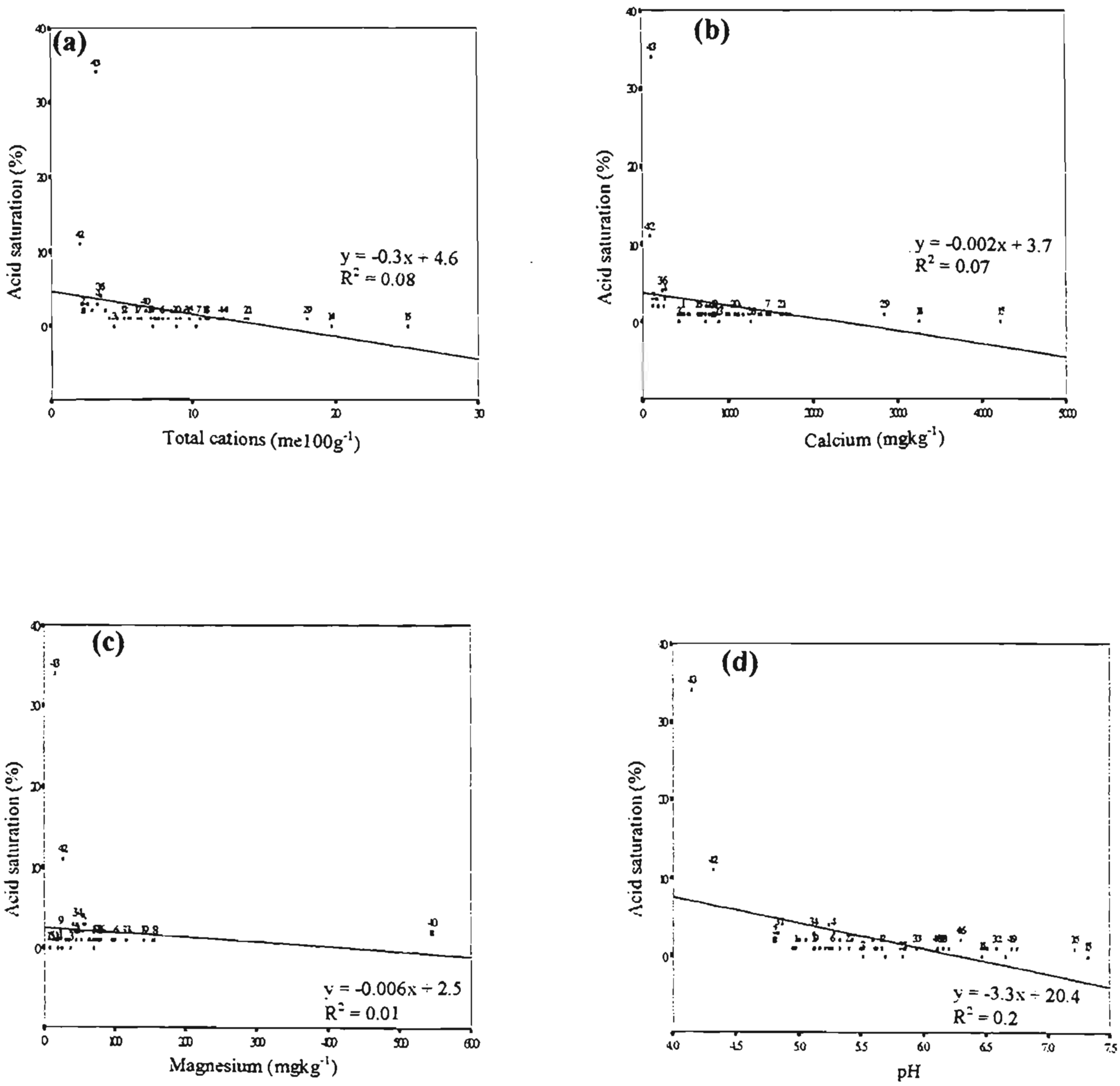
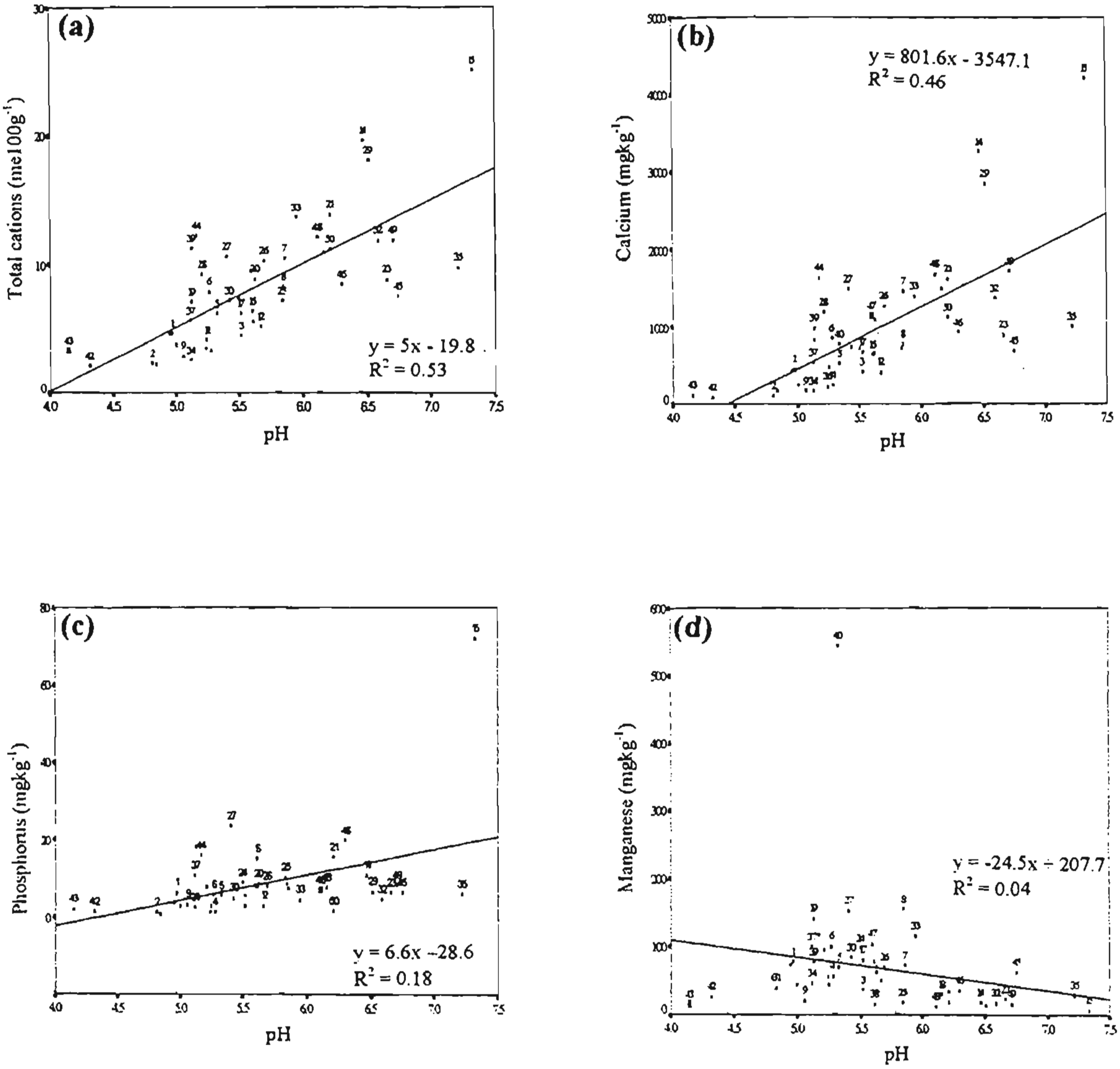


Fig. 3.17: Correlation between pH and (a) total cations, (b) calcium, (c) phosphorus and (d) manganese (soils collected from *kaya* Mtswakara)

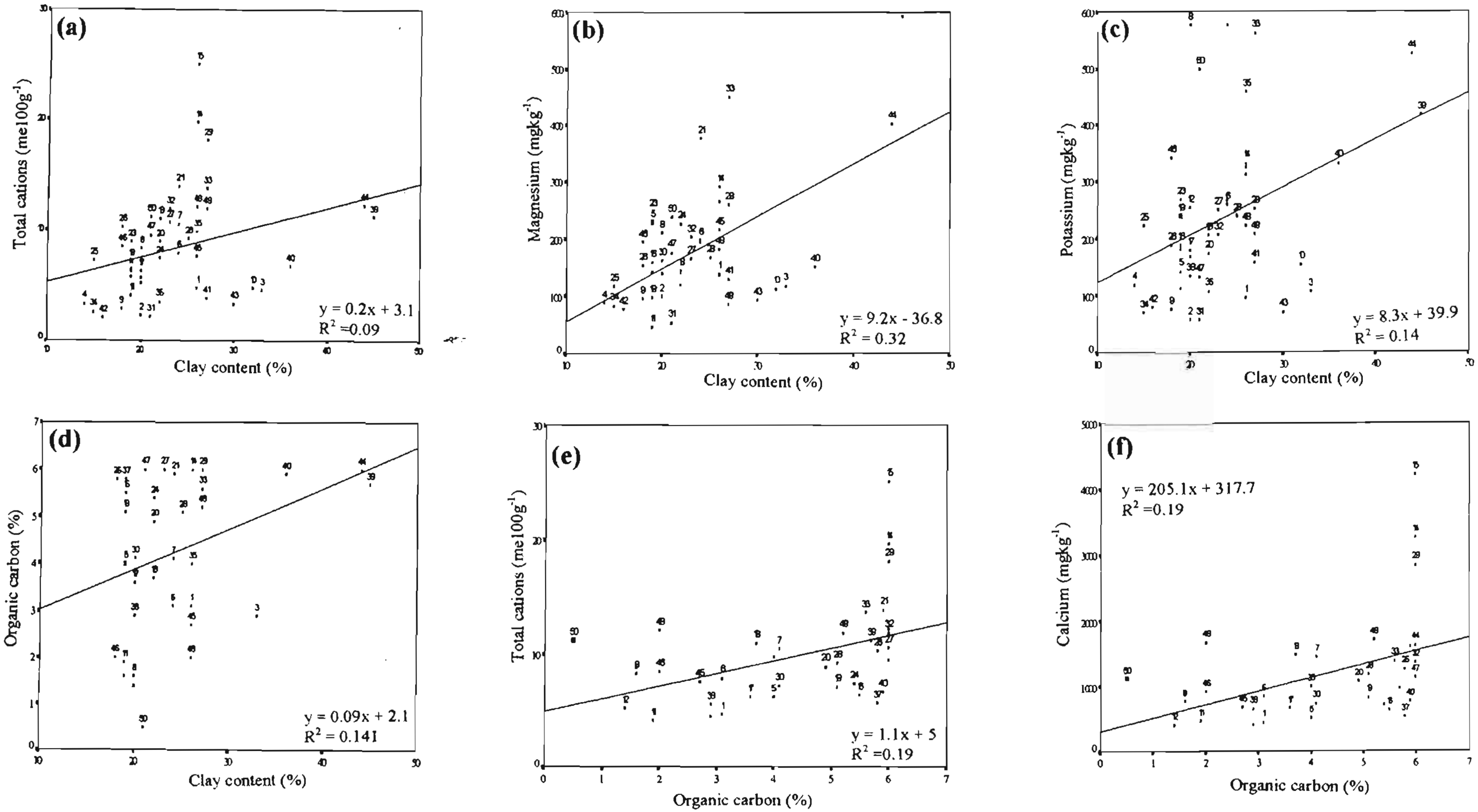


Although Mn showed significant negative correlation against pH ($r = -0.42$, at $p<0.01$), (Fig. 3.17d), but the R^2 value was not significant ($R^2 = 0.04$), and sample 40 had a very high level of Mn compared to the rest of the data set. When sample 40 was excluded the correlation improved ($r = -0.65$, at $p<0.001$), and the R^2 value increased but was still not significant, which means, exchangeable Mn concentrations in these soils were not affected directly by pH variation.

There was a significant correlation in total cations v. clay ($r = 0.32$, at $p<0.05$), but in the scatterplot (Fig. 3.18a) the R^2 value is not significant. The significant correlation in Mg v. clay ($r = 0.59$, at $p<0.001$) coincided with a significant R^2 value ($R^2 = 0.32$) (Fig. 3.18b). Clay also had significant correlation with K ($r = 0.36$, at $p<0.05$). In the scatterplot, the R^2 value was significant (=0.14), but samples 8, 21, 23, 35 and 50 had higher values of K than predicted by the regression model (Fig. 3.18c). When the outlier samples were excluded from the analysis, the significant correlation was maintained ($r = 0.58$, at $p<0.001$) and the R^2 value increased from 0.14 to 0.30. There was no significant correlation between clay and the other cations (Ca and Zn). In the correlation analysis (Table 3.7) clay had a significant correlation with organic carbon ($r = 0.33$, $p<0.05$). In the scatterplot (Fig. 3.18d), the R^2 value was not significant (=0.11) and samples 39 and 44 had higher clay levels than about twice the value of the rest of the data set. When samples 39 and 44 were excluded the correlation was not significant at $p<0.05$, and the R^2 value decreased (from 0.11 to 0.06). Therefore, for the soils in *kaya* Mtswakara, variation in levels of clay content affected the exchangeable concentrations of Mg and K in the soils, but not the other cations.

Unlike the results for clay, the organic carbon correlated significantly with total cations and with Ca ($r = 0.43$ for both, at $p<0.01$). The R^2 value in both was significant ($R^2 = 0.19$). However, in the scatter plots of organic carbon v. total cations (Fig. 3.18e) and organic carbon v. Ca (Fig. 3.18f), samples 14, 15 and 29 (as noted earlier) showed much higher levels of total cations and Ca. When these samples were excluded, the significant correlations were maintained ($r = 0.34$, and 0.37, at $p\leq0.5$, for total cations and for Ca respectively), but the R^2 values reduced to non-significant values (0.11 and 0.13 respectively). This indicated that for an organic carbon range of 0 – 6% in the soils, no relationship with total cations could be observed, although it must be noted that the organic carbon data set was incomplete.

Fig. 3.18: Correlation between clay and (a) total cations (b) magnesium (c) potassium, (d) organic carbon; and correlation between organic carbon and (e) total cations, and (f) calcium (soils collected from *kaya* Mtswakara)



The outlier samples from the data set illustrated in the distribution frequency, were emphasised and identified in the scatterplots. The outliers included samples 14, 15 and 29 which showed exceptional high levels of total cations, specifically, Ca. Sample 15 also had exceptional high levels of phosphorus. These samples (14, 15 and 29) were collected from relevés sampled in relatively undisturbed dense canopy forest areas of gentle slope (10-20°), and were characterised by sandy-loam soils. Samples 42 and 43 had higher levels of soil acidity than the rest of the data set. These samples were from relevés sampled on woodland areas characterised by sandy soils, with outcropping sandstones and loose sandstone pebbles (Table 2.1). Samples 39 and 40 had exceptional high levels of clay; in addition sample 40 had an exceptional high level of Mn. The two samples were from relevés sampled on termite mounds (Table 2.1), in a surrounding of *Brachystegia* woodland on a sandy soil. These outlier samples from localities of different environmental conditions probably reflect the true and extreme edaphic qualities of the sites. If not, then the observations might be a result of sampling and/or analytical errors.

3.4 RESULTS: KAYA FUNGO SOILS

3.4.1 Physical properties of the soils in *kaya* Fungo

Kaya Fungo is situated on a relatively flat area. In *kaya* Fungo the main soil types recognised based on field observation of colour and texture were white sands, pale grey sandy-loams, grey sandy-loams, pale black sandy-loams and black sandy-loams (Table 3.8). The sandy-loams, which were the most common soil type in *kaya* Fungo, occasionally formed a thin top layer of very fine texture. White sands were exclusively found in the Mirihi-ya-Kirao forest patch. The amounts of leaf litter on the ground surface in the relevés were considerable different, with a general observation of abundant litter on sandy-loam soils and sparse/absent litter on sandy soils (Table 3.9). Abundant litter was noted mostly in relatively dense canopy forest areas, while sparse to common levels of litter were recorded in the *Acacia* thicket areas, and absence of litter was consistent in open grassland areas that were characterised by frequent fires.

Table 3.8: Physical characteristics of soils in the individual relevés (sample plots) established in *kaya* Fungo.

Relevé number	Physiognomic Vegetation type	Soil texture	Soil colour	Amount of Litter	Notes
1	Wooded grassland	Sandy-loam	Pale gray	Sparse	The area borders a freshly burnt site and signs of grazing were noted.
2	Acacia thicket	Sandy-loam	Pale gray	Common	*Acacia* spp. dominated a large stretch of the area.
3	Acacia thicket	Sandy-loam	Pale gray	Abundant	Signs of grazing were noted. Most herbaceous species had died due to drought
4	Acacia thicket	Sandy-loam	Pale gray	Absent	The area had been burnt, shrub species were sprouting. Signs of grazing were noted.
5	Acacia thicket	Sandy-loam	Pale gray	Sparse	*Grewia plagiphylla* stem had been collected.
6	Wooded grassland	Sandy-loam	Pale gray	Sparse	Area was highly disturbed and subjected to grazing.
7	Acacia thicket	Sandy-loam	Pale gray	Common	Signs of burning and grazing were noted.
8	Acacia thicket	Sandy-loam	Pale gray	Common	Area crossed by footpaths., with signs of grazing
9	Wooded grassland	Sandy-loam	Pale gray	Absent	Dominated by herb species, was Mungwari's farm, left fallow but had been cultivated previous year.
10	Wooded grassland	Sandy-loam	Pale gray	Common	*Acacia spp.* and *Grewia forbesii* dry sticks had been collected.
11	Wooded grassland	Sandy-loam	Pale gray	Abundant	A raised site (possible a termite mound), next to a freshly burnt area.
12	Mixed Forest	Sandy-loam	Black	Abundant	*Manilkara sulcata* had been collected
13	Mixed Forest	Sandy-loam	Black	Abundant	*Manilkara sulcata* and *Combretum schumannii* had been collected.
14	Mixed Forest	Sandy-loam	Black	Abundant	*Craibia brevicaudata* saplings dominated herb layer.
15	Wooded grassland	Sandy-loam	Pale gray	Sparse	Cattle truck had crossed the area.
16	Wooded grassland	Sandy-loam	Pale gray	Sparse	Some youth were grazing their livestock at neighbourhood (within the *kaya* area).
17	Wooded grassland	Sandy-loam	Pale gray	Abundant	Most herbaceous plants were dead due to drought.
18	Wooded grassland	Sandy-loam	Pale gray	Sparse	Sample plot was next to (Kabani's) abandoned farm. Signs of grazing were noted.
19	Wooded grassland	Sandy-loam	Pale gray	Abundant	Most herbaceous species had died due to drought
20	Wooded grassland	Sandy-loam	Pale gray	Abundant	Most herbaceous species had died due to drought
21	Wooded grassland	Sandy-loam	Pale gray	Abundant	Most herbaceous species had died due to drought.
22	Wooded grassland	Sandy-loam	Black	Abundant	Most herbaceous species were dead due to drought.
23	Mixed Forest	Sandy-loam	Black	Common	Fresh signs of collection of *Combretum schumannii*
24	Mixed forest	Sandy-loam	Black	Abundant	*Commiphora eminii* was noted to have fall possible due to wind effect.
25	Mixed Forest	Sandy-loam	Black	Common	Undergrowth density was low, probably due to shade effect, by dense shrub layer.
26	Wooded grassland	Sandy-loam	Pale gray	Sparse	Signs of burning were noted, and all the shrubs were sprouts from burnt mother plant
27	Wooded grassland	Sandy-loam	Pale gray	Sparse	Shrub layer was dominant.
28	Mixed Forest	Sandy-loam	Pale black	Abundant	Collected *Combretum schumannii* was sprouting.
29	Mixed Forest	Sandy-loam	Black	Common	*Coffea sessiliflora* and *Combretum schumannii* had been collected. The latter was sprouting

Table 3.8: Continued

Relevé number	Physiognomic Vegetation type	Soil texture	Soil colour	Amount of Litter	Notes
30	Mixed Forest	Sandy-loam	Pale black	Abundant	Climber species over-grew others species
31	Wooded grassland	Sandy-loam	Pale gray	Sparse	Emergents and canopy trees were absent, but shrub layer was dense. There were signs indicating big trees had been cut in the past.
32	Mixed Forest	Sand loam	Black	Abundant	There were signs of building poles collection
33	Mixed Forest	Sandy-loam	Black	Abundant	
34	Grassland	Sandy-loam	Pale gray	Sparse	The site had been burnt, and the 'new' grass attracted grazing livestock. Most shrub species were sprouts of burnt mother plant
35	Wooded grassland	Sandy-loam	Pale black	Absent	The area had been burnt, and was being grazed.
36	Mixed Forest	Sandy-loam	Black	Abundant	Crossed by footpaths, *Afzelia quanzensis* stem and mature roots had been collected.
37	Wooded grassland	Sandy-loam	Pale gray	Sparse	Tree specie had been cut and/or debarked.
38	Mixed Forest	Sandy-loam	Black	Abundant	*Hugonia castaneifolia* roots had been collected
39	Julbernadia	Sandy-loam	Pale black	Common	*Julbernadia magnistipulata* was debarked and died. Stumps of *Afzelia quanzensis* noted.
40	Mixed Forest	Sandy-loam	Black	Abundant	*Hugonia castaneifolia* roots had been collected
41	Mixed Forest	Sandy-loam	Black	Abundant	Collected *Combretum schumannii* was sprouting.
42	Mixed Forest	Sandy-loam	Black	Abundant	
43	Mixed Forest	Sandy-loam	Black	Abundant	Collected *Combretum schumannii* was sprouting.
44	Julbernadia	Sandy-loam	Black	Abundant	Collected *Combretum schumannii* was sprouting.
45	Mixed Forest	Sandy-loam	Pale black	Common	*Hugonia castaneifolia* roots collected.
46	Wooded grassland	Sandy-loam	Pale gray	Absent	Burning and grazing sings noted, shrub species were sprouts of burnt plants.
47	Wooded grassland	Sandy-loam	Pale gray	Absent	Freshly burnt, and shrub species were sprouting.
48	Julbernadia	Sandy-loam	Pale black	Common	Signs of firewood collections were noted
49	Mixed Forest	Sandy-loam	Pale black	Common	Climber species were noted to grow over other species.
50	Brachystegia	Sand	White	Sparse	Cattle path was crossing through the area.
51	Brachystegia	Sand	White	Sparse	Tree species had been collected, and signs of charcoal making noted.
52	Brachystegia	Sand	White	Sparse	*Brachystegia spiciformis* branches had been collected and signs of charcoal making noted.
53	Brachystegia	Sand	White	Sparse	*Brachystegia spiciformis* had been fell down, and signs of charcoal making noted.
54	Brachystegia	Sand	White	Sparse	Stems of tree species had been collected, and signs of charcoal making activities noted.

The scarcity of litter in the sandy soil in *Brachystegia* woodland areas was partly ascribed to the patchy vegetation which seemed to result partly from logging and charcoal burning activities which were prevalent. Outcropping rocks were absent in both sandy-loam and sandy soils in *kaya* Fungo.

Table 3.9: Percentages of sample plots of different soil texture with varied amounts of ground surface litter (soil samples collected from relevés sampled in *kaya* Fungo)

Soil type	Litter absent	Litter sparse	Litter common	Litter abundant
Sand soils (n=5)	0	100	0	0
Sandy-loam soils (n=50)	10.2	22.4	22.4	44.9

The soils from *kaya* Fungo were characterised by low soil density. All soil samples had a density of 1.3mgL^{-1} or less. The only exception, sample six, had a density of 1.5mgL^{-1}. In the field sample six was described as sandy-loam. Due to the relatively high soil density, the organic carbon value for this soil sample was not determined. For the soils from *kaya* Fungo, like the soils from *kaya* Mtswakara, soil density was inversely related to organic carbon content, as indicated by the significant negative correlation coefficient ($r= -0.8$, at $p<0.001$) and a significant R^2 value (=0.7) (Fig. 3.19). The frequency distribution of soil density was nearly normal (Fig. 3.20).

3.4.2 Chemical properties of the soils in *kaya* Fungo

Twelve soil variables were measured, and the details of each variables are given in Table 3.10. Relatively high levels of Ca consistently corresponded with relatively high levels of total cations; and for most samples high levels of Ca also corresponded with relatively high levels of Mg. In only few samples did high levels of Ca correspond (independently) with high levels of K, Zn and P (Table 3.10).

Fig. 3.19: Variation of organic carbon content with soil density for soils collected from *kaya* Fungo

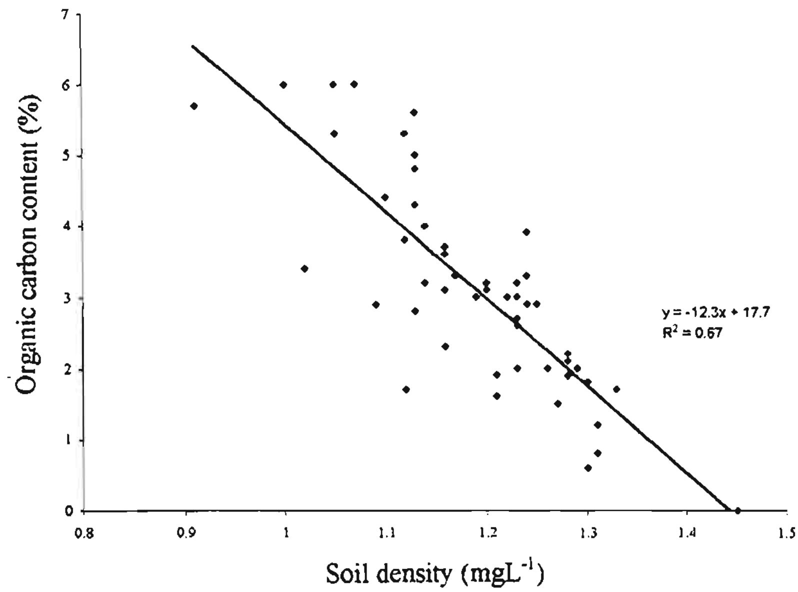


Fig. 3.20: Frequency distribution of density measures for soil samples collected from *kaya* Fungo (The mean is the central tendancy; 'S' is Skewness; and 'K' is Kurtosis)

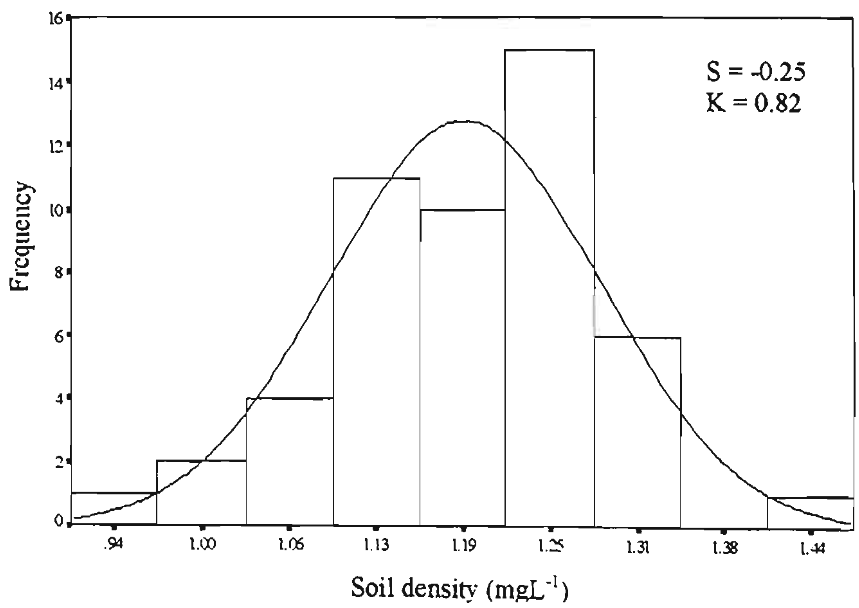


Table 3.10: Chemical characteristics for soils* collected from sample plots established in kaya Fungo

Releve	Phosphorus	K	Ca	Mg	Zn	Mn	Exchange acidity	Total cations	Acid saturation	pH.	Organic carbon	Clay
1	1.8	90.2	1380.4	670.5	0.4	11.6	0.05	14.2	0	7.0	1.7	31
2	2.0	183.3	1705.9	819.6	2.1	98.0	0.08	16.1	0	5.7	3.4	27
3	2.3	204.6	554.6	148.5	0.6	5.4	0.03	5.9	1	5.6	1.8	11
4	4.7	172.7	423.4	114.8	0.4	12.5	0.03	4.5	1	5.1	2.1	10
5	6.3	230.7	424.4	184.3	0.9	12.6	0.03	5.4	1	5.4	1.5	12
6	4.1	89.0	243.4	64.1	0.5	10.3	0.03	2.9	1	4.9	nd	05
7	3.8	92.5	421.8	121.1	0.8	33.1	0.04	4.5	1	5.3	1.7	09
8	2.3	164.1	384.0	163.4	1.4	26.7	0.04	4.9	1	5.4	1.2	09
11	6.3	233.9	1145.5	540.2	1.7	53.6	0.04	12.1	0	5.2	3.8	28
12	8.8	212.3	1112.3	241.2	3.0	29.8	0.04	9.3	0	5.1	4.0	19
13	10.6	228.3	1038.9	349.6	1.2	15.9	0.03	9.8	0	5.4	5.0	18
14	13.3	337.2	1095.6	243.4	2.5	18.6	0.06	9.5	1	5.1	5.6	19
16	3.9	204.7	469.5	186.7	1.1	14.1	0.02	5.7	1	5.7	2.2	13
17	4.1	174.0	357.7	149.6	1.4	9.8	0.06	4.3	2	4.7	2.0	16
18	4.9	110.6	639.8	180.5	0.7	7.3	0.01	6.1	0	5.2	2.6	12
19	5.7	70.7	455.3	122.0	0.5	17.9	0.15	4.4	4	4.4	3.2	16
20	4.9	65.0	438.2	126.0	0.7	16.3	0.15	4.4	4	4.3	2.7	15
21	3.1	104.7	448.1	165.1	0.5	5.4	0.03	5.0	1	5.3	2.0	10
22	5.7	67.2	521.3	141.8	0.5	17.2	0.14	5.0	3	4.3	3.0	16
23	5.8	73.3	465.8	131.7	0.6	20.0	0.14	4.5	4	4.3	3.2	17
24	5.8	74.2	466.7	127.5	0.8	20.0	0.13	4.4	4	4.3	3.1	17
25	5.7	65.9	450.4	123.6	0.6	19.5	0.13	4.4	4	4.3	3.0	16
26	6.5	75.8	583.9	147.6	0.6	21.8	0.12	5.5	3	4.3	2.9	15
27	7.2	76.8	390.4	108.8	1.1	24.8	0.07	3.9	2	4.3	2.9	15
28	7.7	72.6	509.4	141.9	0.6	20.5	0.13	4.7	3	4.3	3.3	19
29	6.4	74.3	542.2	153.2	0.7	22.9	0.14	4.7	3	4.3	2.9	20
30	6.1	72.8	500.9	143.9	0.6	22.8	0.14	4.6	4	4.3	3.2	19
31	7.1	214.2	1031.0	432.7	1.5	10.6	0.08	10.6	1	5.1	4.3	19
32	14.3	261.0	2086.7	617.1	4.0	35.2	0.07	17.0	0	5.1	6.0	24
33	5.4	131.3	1651.8	276.8	1.2	27.7	0.04	12.2	0	5.8	5.3	20
34	32.8	268.1	962.2	173.9	2.4	17.6	0.03	8.3	0	5.7	3.0	15
35	6.7	308.6	1641.9	575.2	2.3	4.8	0.06	14.5	0	5.3	5.3	23
36	12.1	197.2	1695.3	512.1	2.0	5.6	0.06	14.2	0	5.0	6.0	20
38	9.7	192.7	537.9	124.2	1.2	5.6	0.03	5.3	1	5.2	3.3	14
39	15.5	220.7	537.1	128.4	1.2	6.0	0.04	5.0	1	4.7	3.7	16
40	10.0	303.6	1798.2	420.9	2.5	5.6	0.05	14.6	0	5.6	4.4	20
41	19.0	474.0	1726.0	406.0	3.1	4.0	0.04	13.2	0	5.5	6.0	23
42	23.1	509.9	1803.3	437.4	4.3	6.6	0.08	12.7	1	5.7	5.7	28
43	19.5	223.9	1246.9	203.5	3.0	18.6	0.06	9.6	1	4.9	4.8	19
44	8.1	208.9	762.9	180.6	1.8	10.5	0.05	7.3	1	5.3	3.9	13
45	7.8	133.6	787.1	268.1	1.3	6.9	0.04	7.6	1	5.3	3.1	17
46	7.8	200.0	677.58	209.5	1.1	8.6	0.05	6.6	1	5.0	2.3	18
47	7.1	208.0	906.2	264.6	1.0	7.1	0.04	8.2	0	5.5	2.8	19
48	5.5	152.3	439.8	98.4	0.9	10.9	0.04	4.4	1	4.7	1.9	13
49	7.8	188.8	1003.4	222.4	1.4	12.1	0.06	8.6	1	5.0	3.6	18
50	5.0	147.9	231.4	117.4	0.5	19	0.53	3.7	17	4.1	1.6	16
51	9.2	81.7	113.7	52.7	0.5	17.6	0.60	2.4	33	4.0	0.8	12
52	9.5	111.9	254.8	81.0	0.9	17.5	0.11	2.9	5	4.3	2.0	13
53	4.1	95.0	479.3	162.8	1.1	41.3	0.07	4.9	2	5.1	1.9	15
54	2.3	214.6	177.7	71.5	0.1	9.2	0.17	2.9	8	4.5	0.6	11

* For units of measurement see text; nd = not determined.

The summary statistics for the soil variables from *kaya* Fungo are given in Table 3.11. The frequency distribution of measurements for the soil variables is given in Fig. 3.21. Distribution frequency for most soil variables was positively skewed, influenced by a small percentage frequency of high values, except for organic carbon, clay content, and pH. The positive skew was more pronounced in phosphorus, exchange acidity, acid saturation and Mn. Organic carbon and clay content were relatively normally distributed, and pH had a possible bi-module distribution and less pronounced positive skew. K also showed a bi-module distribution, but with pronounced positive skew.

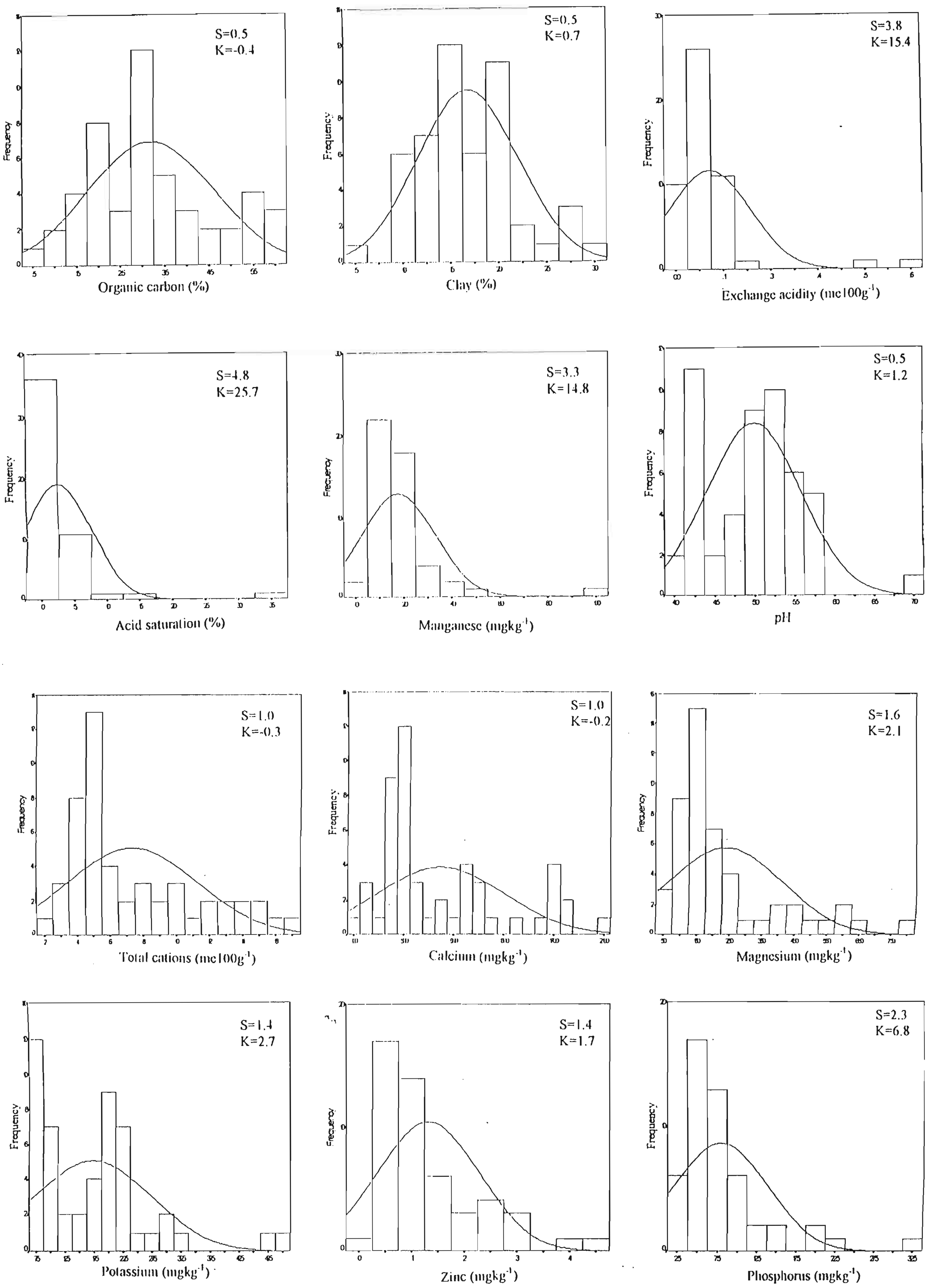
Table 3.11: Mean values (standard deviation in brackets) and range of soil variables for soils collected from *kaya* Fungo (for all n=50, except carbon n=49)

Soil variable	Mean	Standard deviation	Standard error	Range
Phosphorus ($mgkg^{-1}$)	8.0	5.8	0.8	1.8 - 32.8
K ($mgkg^{-1}$)	173.4	98.4	13.9	65 - 509.9
Ca ($mgkg^{-1}$)	794.4	515.4	72.9	113.7 – 2086.7
Mg ($mgkg^{-1}$)	237.0	173.9	24.6	52.7 - 819.6
Zn ($mgkg^{-1}$)	1.3	1.0	0.1	0.1 - 4.3
Mn ($mgkg^{-1}$)	17.9	15.4	2.2	4 – 98
Exchange acidity ($me/100g^{-1}$)	0.09	0.11	0.02	0.01 - 0.6
Total cations ($me/100g^{-1}$)	7.4	4.0	0.6	2.4 – 17
Acid saturation ($me/100^{-1}$)	2.5	5.2	0.7	0 - 33.0
pH (KCl)	5.0	0.6	0.1	4.0 - 7.0
Carbon (%)	3.2	1.4	0.2	0.6 - 6.0
Clay (%)	16.8	5.2	0.7	5.0 - 31.0

3.4.3 Ordination of *kaya* Fungo soil samples

The relationship between soil variables (P, K, Ca, Mg, Zn, Mn, exchange acidity, total cations, acid saturation, pH, organic carbon and clay) were investigated using PCA. The first three PCs accounted for 81% of the variance.

Fig. 3.21: Frequency distribution of measures of soil variables for soil samples collected from sample plots established in *kaya* Fungo (The mean is the central tendency; 'S' is Skewness and 'K' is Kurtosis)



The first PC (PC 1) accounted for 51.8% of the variance, and was essentially a contrast between nutrient (P, K, Ca, Mg, Zn,) rich soils at the positive pole, and nutrient poor soils at the negative pole (Fig. 3.22). There was strong positive loadings for Ca, Mg, Zn, total cations, organic carbon and clay (Table 3.12). PC 1 represented mainly a gradient of fertility, with fertile (base-rich) soils at the positive end and infertile (base-poor) soils at the negative end. PC 2, which accounted for 15% of the variance, was characterised by high positive loadings for exchange acidity and acid saturation, and a large negative value for pH (Table 3.12). PC 2 was largely a gradient of soil acidity, with relatively more acidic soils ordinated at the positive pole; and less acidic soils (high pH) at the negative pole (Fig. 3.22). PC 3 accounted for 14.2% of the variance, and had a high positive loading for Mn, and negative loadings for P and K (Table 3.12 and Fig. 3.23). It is interesting that the PC 3 derived from *kaya* Fungo soils data set is similar to that derived from the *kaya* Mtswakara soils data set. The contrast between high Mn soils compared to high phosphorus soils is an interesting one, but which needs further investigation to understand any edaphic and ecological meaning.

Table 3.12: Latent vectors from a PCA of chemical soil variables for soil samples collected from *kaya* Fungo

Soil variable	**PC 1**	**PC 2**	**PC 3**
Phosphorus	0.2	0.25	-0.49
Potassium	0.29	0.09	-0.34
Calcium	0.38	0.09	0.07
Magnesium	0.34	0.06	0.35
Zinc	0.34	0.18	-0.21
Manganese	0.06	0.11	0.56
Exchange acidity	-0.2	0.61	0.1
Total cations	0.38	0.06	0.17
Acid saturation	-0.22	0.56	0.03
pH	0.25	-0.34	0.08
Organic carbon	0.32	0.15	-0.15
Clay	0.3	0.22	0.27
Variance	51.8	15	14.2
Cumulative variance	51.8	66.8	81

Fig. 3.22: Ordination of soil variables in the PCA space defined by the first and second Principal Components (for soils collected from *kaya* Fungo)

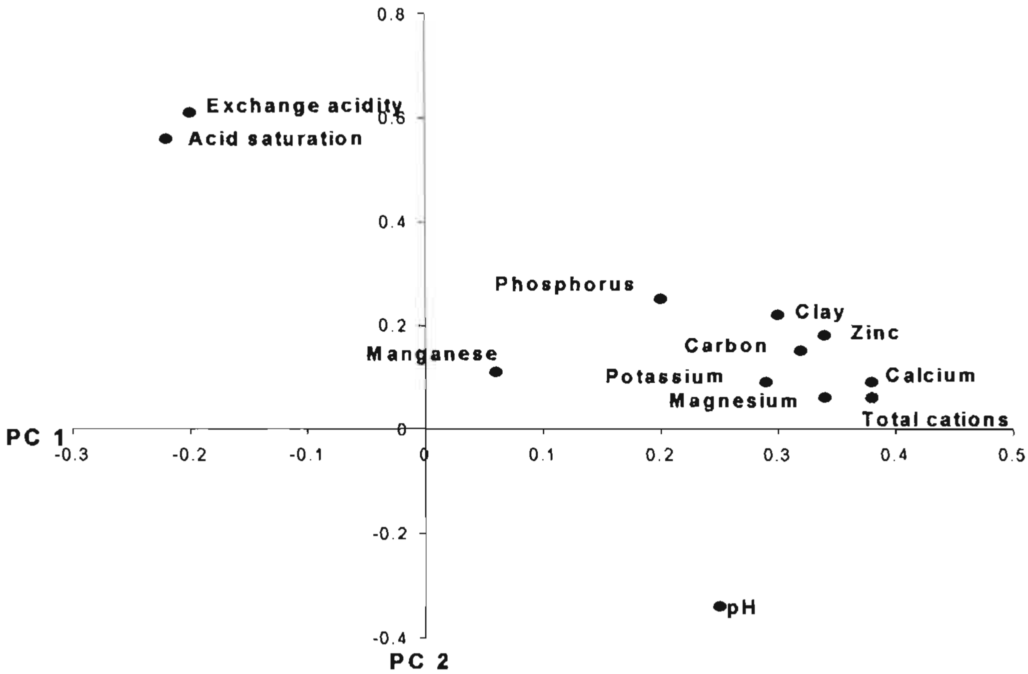
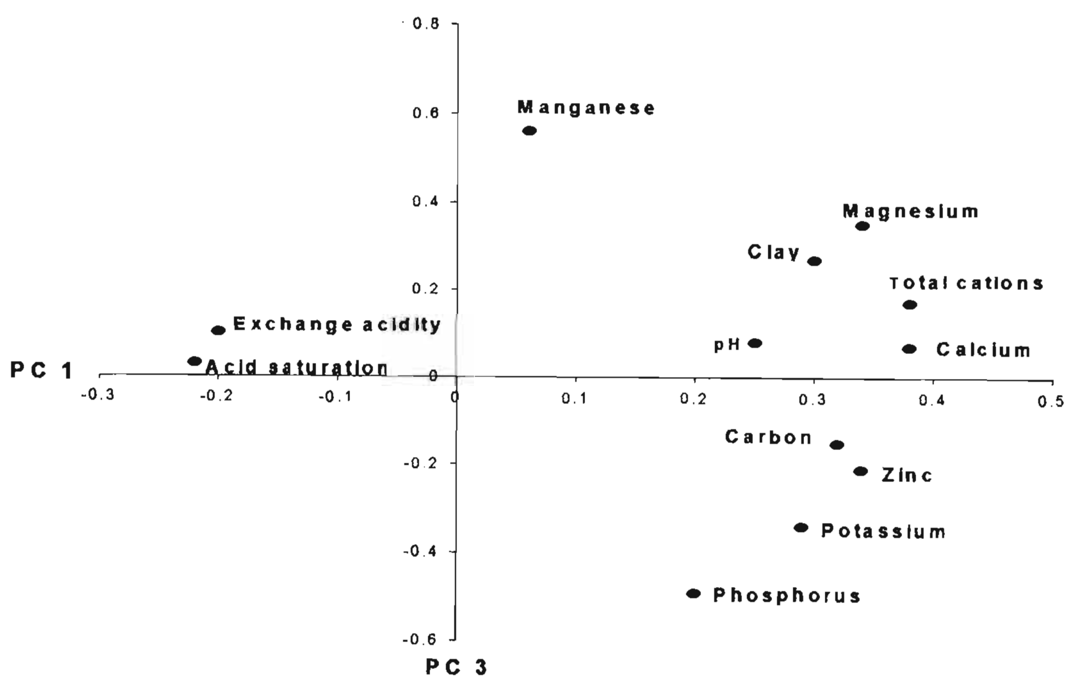


Fig. 3.23: Ordination of soil variables in the PCA space defined by the first and third Principal Components (for soils collected from *kaya* Fungo)



The physical texture of the soil on the PCA hyperspace defined by the soil fertility (PC 1) and soil acidity (PC 2) axes shows that the sandy-loam soils ranged from relatively moderate to high soil fertility conditions, while the few sandy soils were of lower fertility (Fig. 3.24). Relatively, soils with high clay content (>25%) were exclusively associated with high soil fertility, and soils with low clay content (<10%) were exclusively associated with low soil infertility (Fig. 3.25). Soils with moderate clay content (10-25%) ranged between low and high soil fertility status. Organic carbon was also positively associated with the soil fertility, as soils with relatively high (>5%) organic carbon content were of relatively high fertility status, and vice versa (Fig. 3.26).

Abundant ground surface litter was common on high fertile soil areas, while low amounts of litter (sparse) was more common in soils with lower fertility (Fig. 3.27). However, relevés in which litter was absent it was also noted that soils were of moderate soil fertility. This probably was effected by the burning activity (noted in these relevés) which released nutrient cations into the soil, resulting in a higher and perhaps temporary increase in soil fertility. Relatively, high soil fertility was also associated with relative absence of vegetation disturbance, and moderate vegetation disturbance was mostly associated with lower soil fertility (Fig. 3.28). Contrary to anticipation though, low disturbance was common in soils with low fertility status. This observation was difficult to explain, and the relationship between vegetation disturbance and soil fertility is probably complex and affected by historical factors.

3.4.4 Correlation between soil variables (soils from *kaya* Fungo)

In the PCA ordination although some soil variables were noted to be strongly associated, the details of these correlations are worth discussing by pair-wise correlation analysis. Table 3.13 shows the results of the correlation analysis. A total of 44 correlations were statistically significant at $p \leq 0.05$, of which 34 were positive and 10 were negative (Table 3.13). Ca had the most correlations (10), while Mn had the least (2). All negative correlations were between exchange acidity or acid saturation and the other soil variables (Table 3.13).

Fig. 3.24: Ordination of soil texture in the PCA space defined by the first and second Principal Components (for soils collected from *kaya* Fungo)

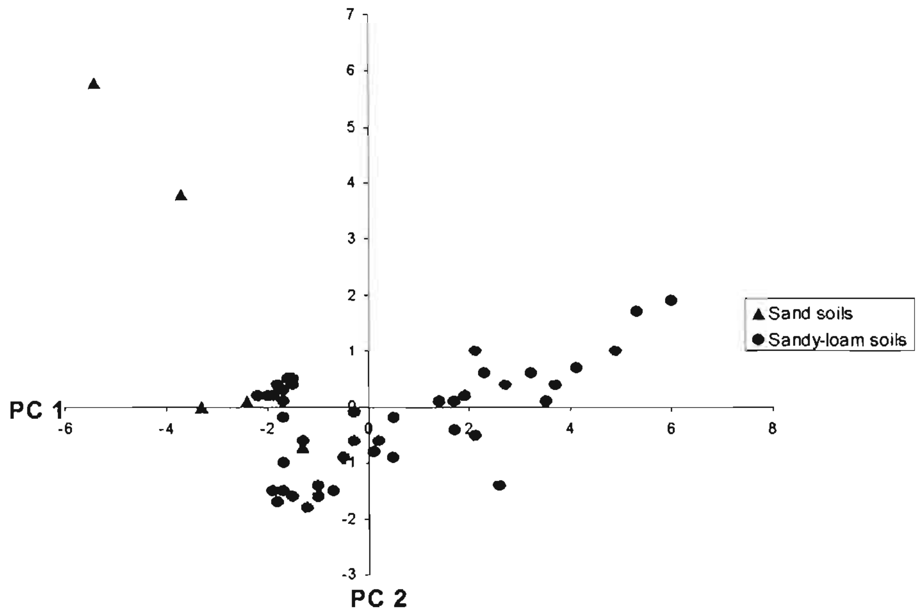


Fig. 3.25: Ordination of clay content in the PCA space defined by the first and second Principal Components (for soils collected from *kaya* Fungo)

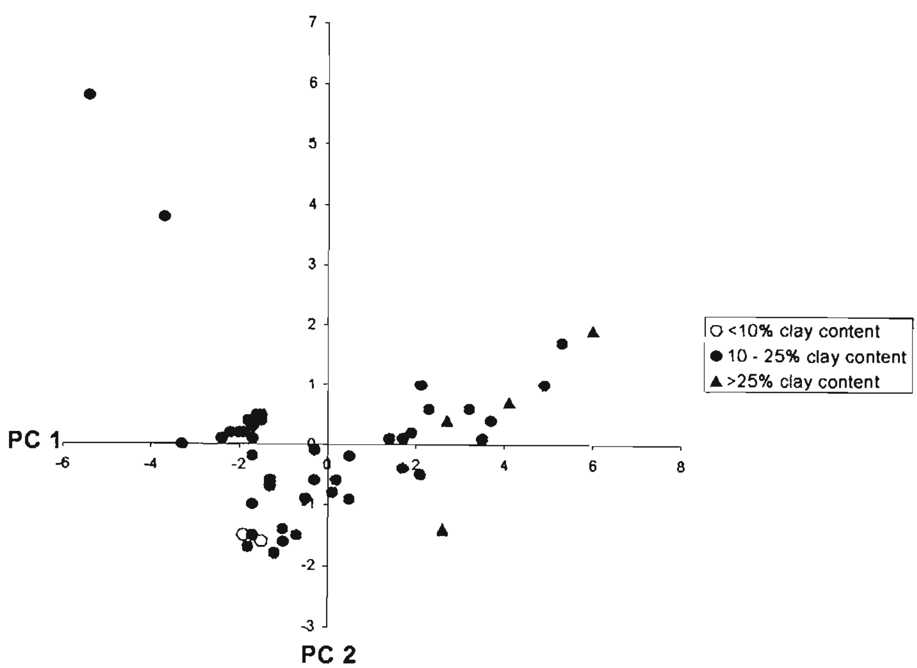


Fig. 3.26: Ordination of organic carbon content in the PCA space defined by the first and second Principal Components (for soils collected from *kaya* Fungo)

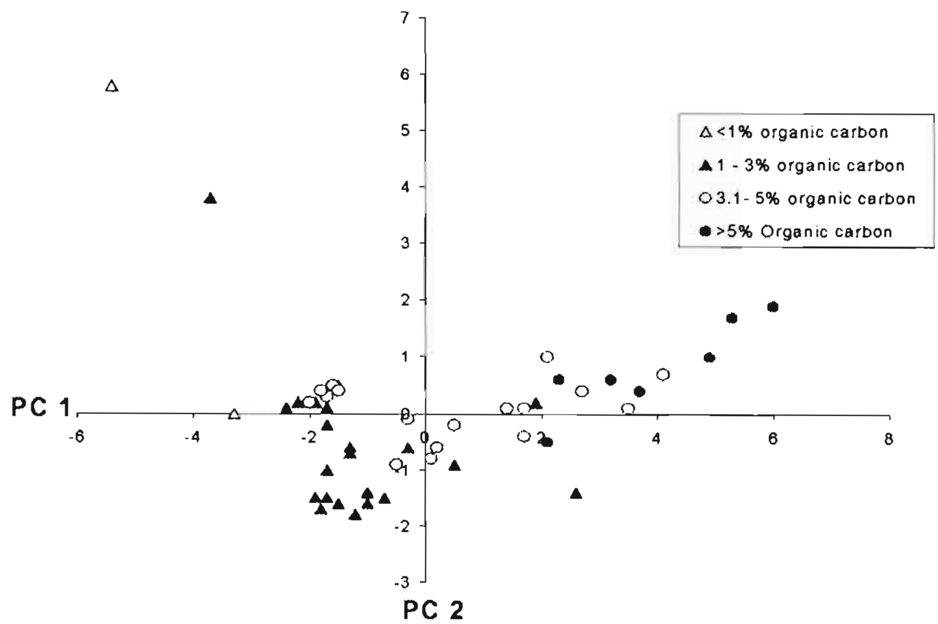


Fig. 3.27: Ordination of ground surface litter in the space defined by the first and second Principal Components (for soils collected from *kaya* Fungo)

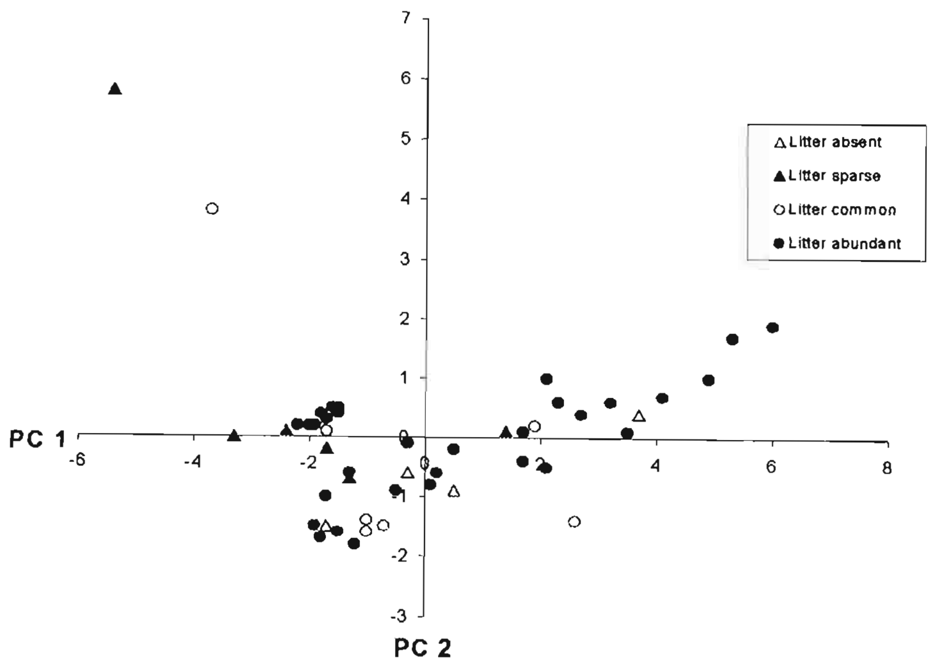


Fig. 3.28: Ordination of vegetation disturbance levels in the PCA space defined by first and second Principal Components (soil and vegetation data collected from *kaya* Fungo)

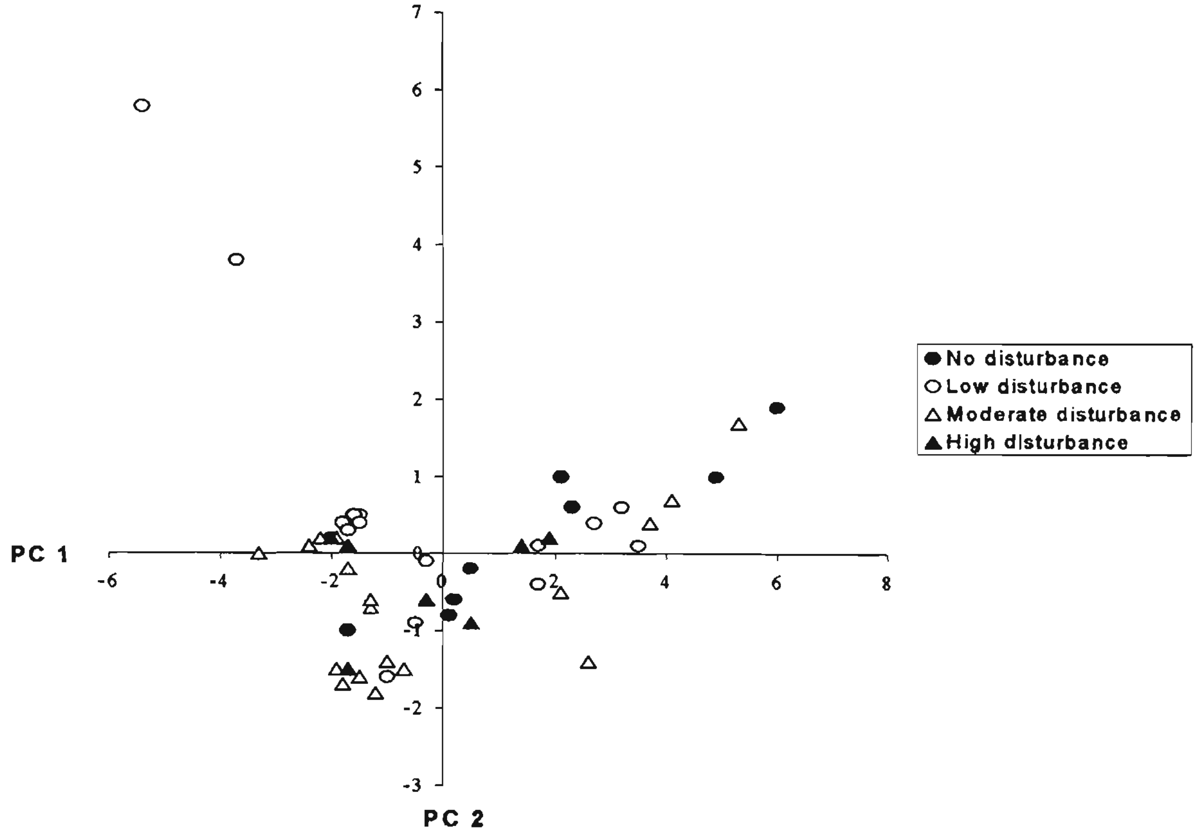


Table 3.13: Correlation matrix between soil variables of the samples collected from *Kaya* Fungo

		1	2	3	4	5	6	7	8	9	10	11	12
1	Phosphorus												
2	Potassium	0.54***											
3	Calcium	0.32*	0.61***										
4	Magnesium		0.42**	0.82***									
5	Zinc	0.64***	0.79***	0.73***	0.46**								
6	Manganese				0.42**								
7	Exchange acidity			-0.36*									
8	Total cations		0.6***	0.98***	0.92***	0.68***		-0.31*					
9	Acid saturation			-0.43**	-0.34*	-0.31*		0.95***	-0.39**				
10	pH		0.48***	0.63***	0.64***	0.38**		-0.57***	0.66***	-0.52***			
11	Organic carbon	0.46**	0.51***	0.75***	0.44**	0.68***		-0.31**	0.67***	-0.41**			
12	Clay		0.32*	0.76***	0.8***	0.46**	0.32*		0.8***		0.33*	0.57***	

Only statistically significant coefficients given: *** correlation at $p \leq 0.001$, ** at $p \leq 0.01$,* at $p \leq 0.05$. 44 significant correlations were recorded of the possible 66 correlations. Individual significant correlations were Phosphorus= 4; Potassium= 8; Calcium= 10; Magnesium= 9; Zinc= 9; Manganese= 2; Exchange acidity = 5; Total cations = 9; Acid saturation = 7; pH = 8; Carbon = 9; Clay = 8.

Total cations correlated positively with the major cations Ca, Mg, K and Zn at $p \leq 0.001$. In total cations v. Ca, and total cations v. Mg there were very high correlation coefficients ($r = 0.98$ and $r = 0.92$, at $p<0.001$ respectively) (Table 3.13). To establish the pair-wise relationships between the total cations and Ca, Mg and K, the $mgkg^{-1}$ units for the major cations were converted to $me100g^{-1}$ (same units as that for total cations). Scatterplots for Ca and Mg against total cations (Fig. 3.29a and b) showed strong linear trends with very high R^2 values (0.96 and 0.87 respectively), and no outliers. The scatterplots for K and Zn against total cations (Fig. 3.29c and d) also had significant R^2 values (0.36 and 0.52 respectively). However, in the total cations v. K, samples 41 and 42 had considerably higher levels of K than that predicted by the linear regression model; and in total cations v. Zn, sample 42 had high levels of Zn. In both scatterplots (Fig. 3.29c and d) sample 1 had much lower values of K and Zn than predicted by the linear regression model. When the outlier samples (1 and 42) were excluded from the analysis, in the total cations v. Zn the significant correlation was maintained, with an increase in both the correlation coefficient value (from $r = 0.68$ to 0.79, at $p<0.001$) and the R^2 value (from $R^2 = 0.52$ to 0.64). When the outlier samples (1, 41 and 42) were excluded in the analysis, in the total cations v. K significant correlation was maintained with a slight increase in both the correlation coefficient value ($r = 0.6$ to 0.63, at $p<0.001$) and the R^2 value ($R^2 = 0.36$ to 0.41).

The proportions of Ca, Mg, and K to increasing values of total cations were compared (Fig. 3.30). Ca and Mg increased considerably as the total cations increased above $25me100g^{-1}$, thus both making significant contributions to the total cation exchange capacities of the soils. The proportion of K remained consistently low even at very high levels of total cations.

Fig.3.29: Correlation between total cations and **(a)** calcium, **(b)** magnesium, **(c)** potassium, and **(d)** zinc (soils collected from *kaya* Fungo)

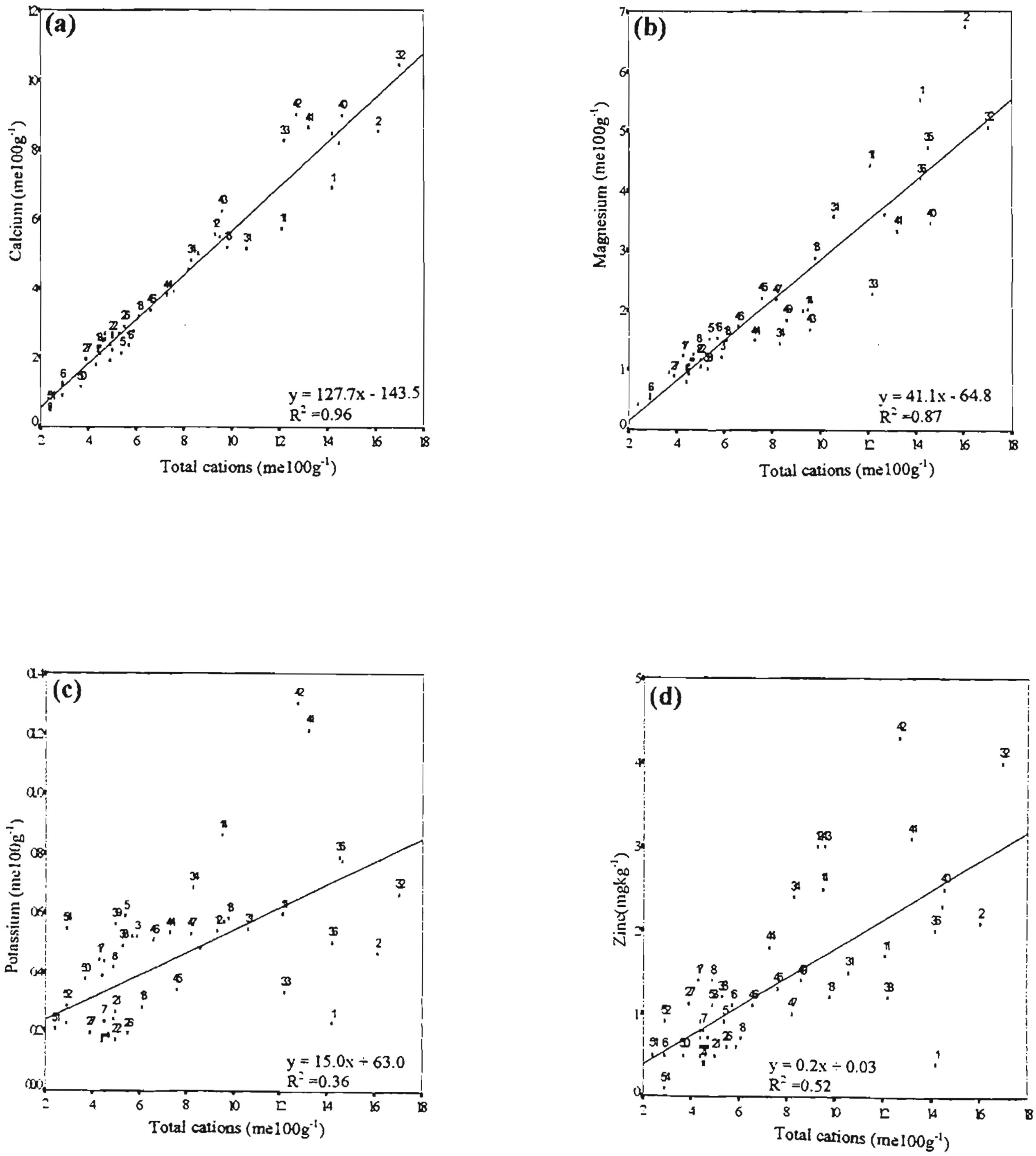
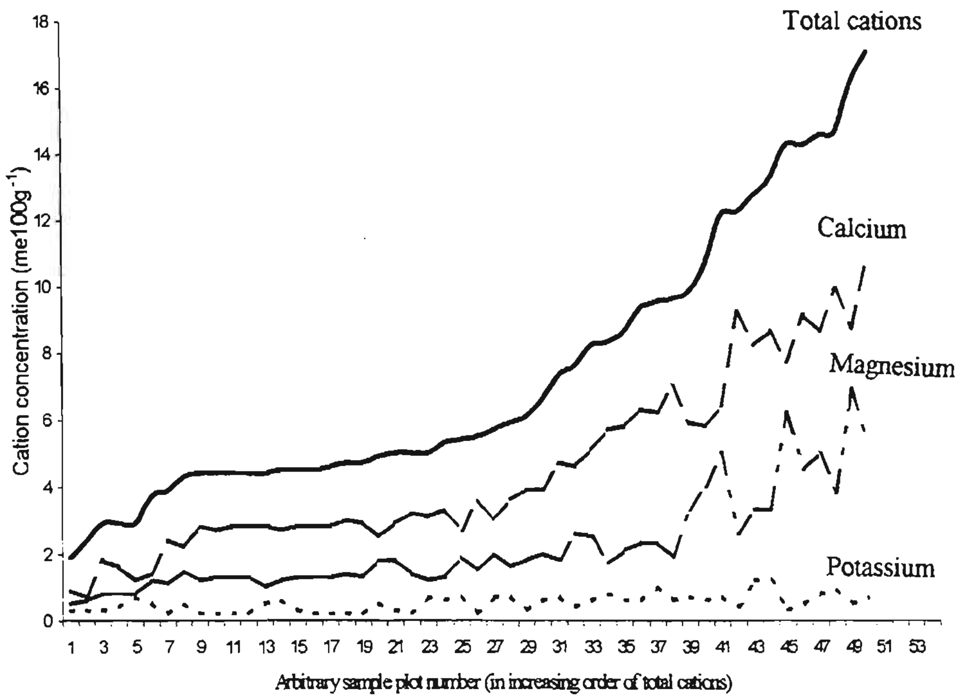


Fig. 3.30: Proportion of cations Ca, Mg and K in relation to total cations (soils collected from *kaya* Fungo



Phosphorus also correlated significantly with the cations Ca, ($r = 0.32$, $p<0.5$), K and Zn ($r = 0.54$ and 0.64 respectively, $p<0.001$), but not with Mg or total cations (Table 3.11). Scatterplots showed linear regression models which were reasonably good for K v. phosphorus and Zn v. phosphorus, and both had significant R^2 of 0.37 and 0.46 respectively (Fig. 3.31b and c). In Ca v. phosphorus the R^2 value was of lower significance ($R^2 = 0.18$) (Fig. 3.31a). In all the scatterplots (Fig. 3.31a, b and c) sample 34 had exceptionally high levels of phosphorus relative to the values predicted by the regression model for the levels of the other cations. When sample 34 was excluded from the analysis, the significance of the correlations improved as the correlation coefficients and the R^2 values increased (i.e. $r = 0.5$, 0.67, and 0.74, at $p<0.001$, and $R^2 = 0.26$, 0.45, and 0.55 for Ca, K and Zn respectively) (Fig. 3.31d, e, and f). Based on these observations it can be concluded that extractable P in the soils was influenced by the levels of Ca, K and Zn, but not by total cations nor Mg.

Organic carbon, usually associated with cation exchange sites, correlated positively with total cations, Ca, K, Zn ($r = 0.67$, 0.75, 0.51, 0.68 respectively, at $p<0.001$), and with Mg ($r = 0.44$, at $p<0.01$) (Table 3.11). The scatterplots showed good linear relations in organic carbon against total cations, Ca, and Zn (Fig. 3.32 a, b, and e), with significant R^2 values ($R^2 = 0.53$, 0.65 and 0.53 respectively). In scatterplots for organic carbon against total cations, Ca and Mg (Fig. 3.32 a, b, and e) samples 1 and 2 had relatively low organic carbon values than predicted by the regression models. When samples 1 and 2 were excluded, the significance of the correlations of organic carbon against total cations, Ca and Mg improved ($r = 0.85$, 0.89, and 0.76, at $p<0.001$ respectively), and the R^2 values increased to 0.72, 0.78, and 0.58 respectively. This may indicate that the dominant cations Ca and Mg in relevés 1 and 2 were derived additionally from weathering of parental rock material, as well as these cations being derived through decomposition of organic matter. In organic carbon v. phosphorus ($r = 0.46$, at $p<0.01$), the scatterplot (Fig. 3.32f) had a significant R^2 value (= 0.29), but sample 34 had higher levels of phosphorus than predicted by the regression model. When sample 34 was excluded, the organic carbon v. phosphorus correlation improved ($r = 0.7$, at $p<0.001$), and the R^2 value increased (from 0.29 to 0.49). This suggests a strong association between soil organic carbon content and extractable phosphorus concentration in the soil.

Fig. 3.31:Correlation between phosphorus and (a) calcium (b) potassium (c) zinc (inclusive of sample 34); and correlation between phosphorus and (d) calcium, (e) potassium, and (f) zinc (exclusive of sample 34) (soils collected from *kava* Fungo)

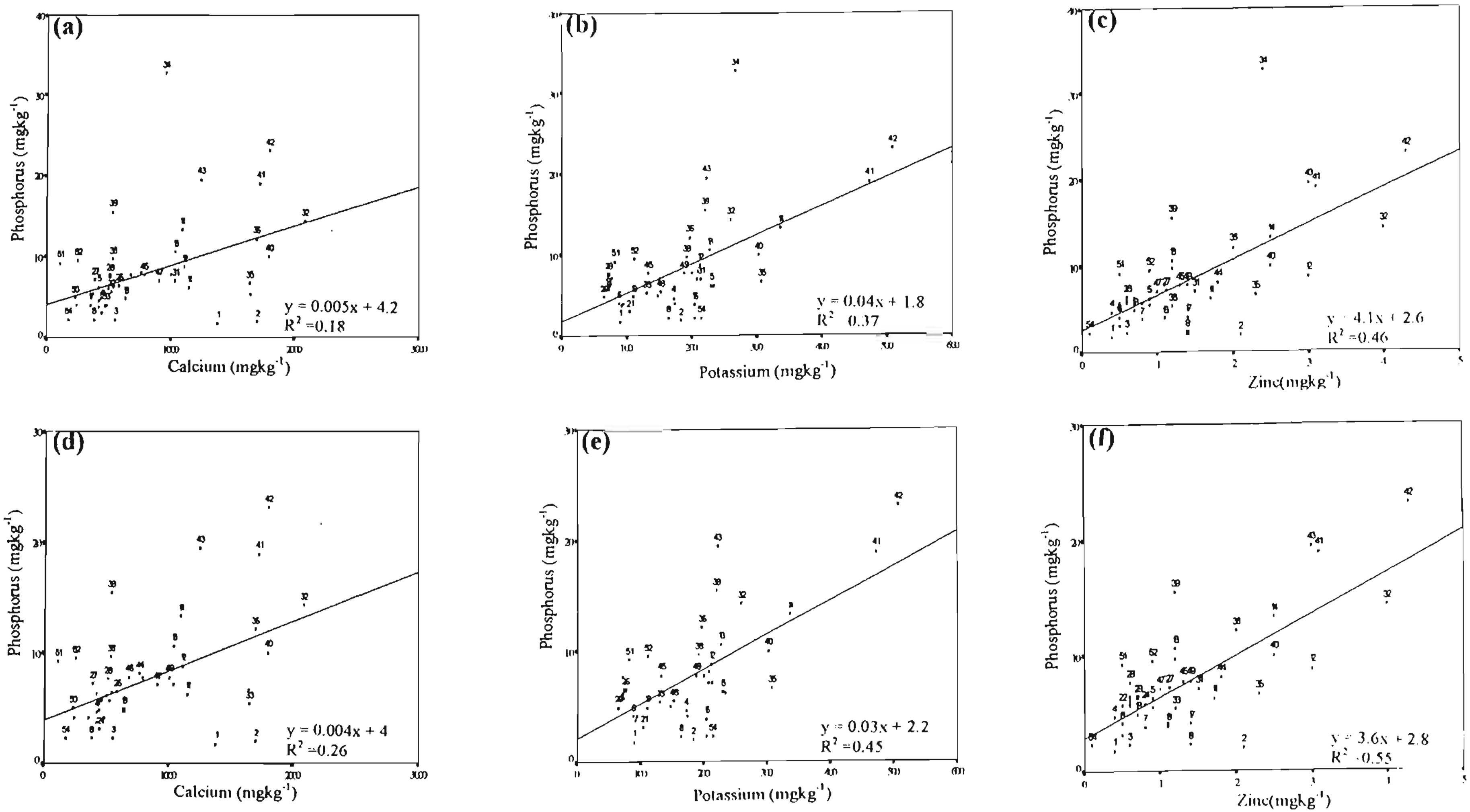
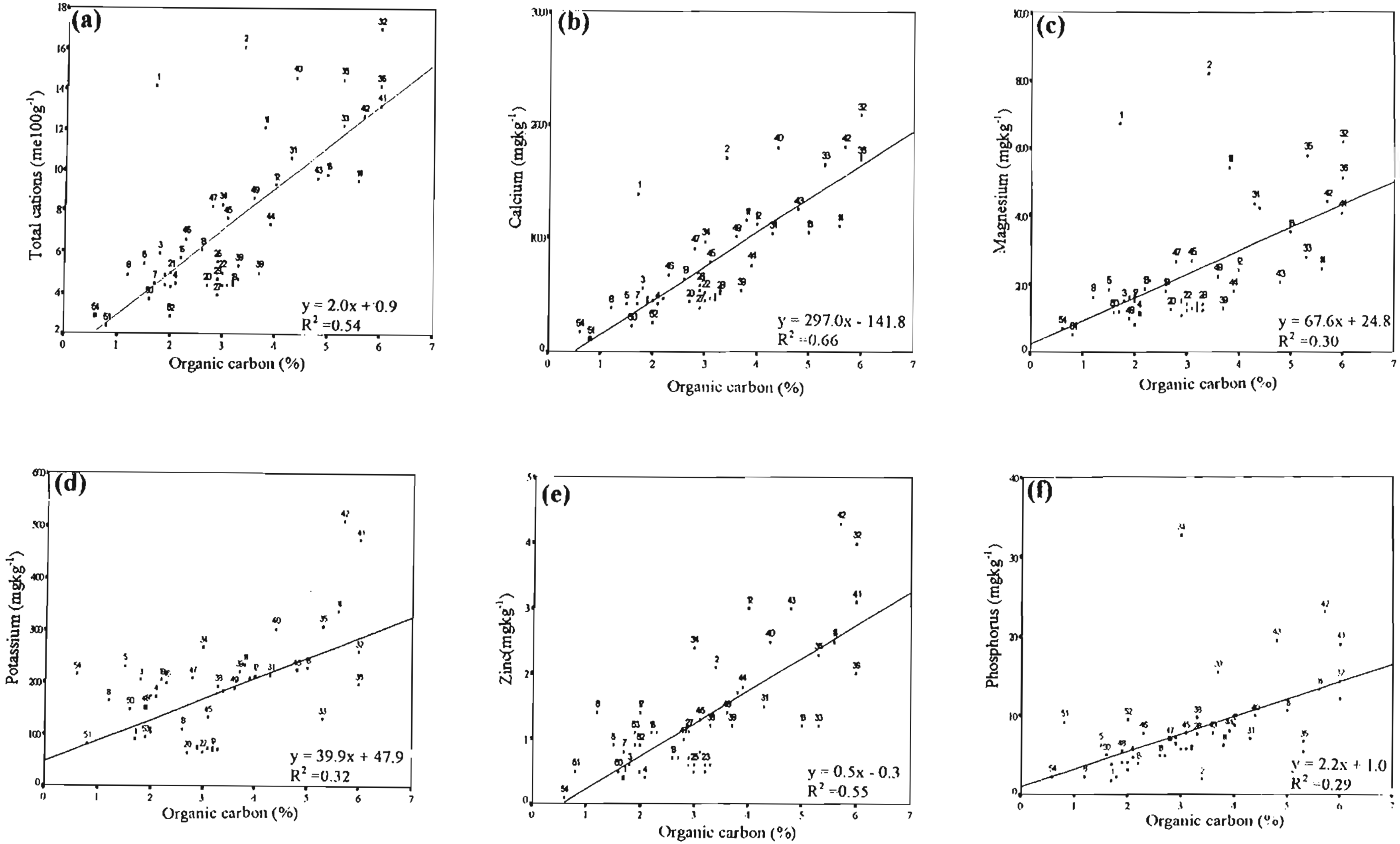


Fig. 3.32: Correlation between organic carbon and (a) total cations (b) calcium (c) magnesium (d) potassium (e) zinc and (f) phosphorus (soils collected from *kaya* Fungo)



Clay, also important for cation exchange sites, had significant positive correlations with total cations, Ca, Mg (r = 0.8, 0.76, 0.8 respectively, at $p<0.001$), with Zn (r = 0.46, at $p<0.01$), and with K (r = 0.32, at $p<0.05$) (Table 3.11). Scatterplots showed particular strong positive linear trends between clay and the two dominant cations Ca and Mg, with significant R^2 values (Fig. 3.33b and c). In clay v. K the R^2 value was also significant (R^2 = 0.16), but samples 41 and 42 showed high values of K, while sample 1 showed low levels of K, than that predicted by the regression model (Fig. 3.33d). When the outlier samples were excluded from the analysis, significant correlation in clay v. K was maintained (r = 0.3, at $p<0.05$), but the R^2 value reduced to non-significant value (i.e. 0.11). In the clay v. Zn the R^2 value was significant (R^2 = 0.29), but samples 32 and 42 showed high levels of Zn, while sample 1 showed low levels of Zn (Fig. 3.33e). When the outlier samples were excluded from the analysis the significant correlation in clay v. Zn improved (r=0.54 at $p<0.001$), and R^2 value increased slightly (from 0.29 to 0.3). Clay also positively correlated with organic carbon (r = 0.33, at $p<0.05$), with a significant R^2 value (0.37) (Fig. 3.33f). This suggests a strong relationship between the clay and organic matter in *kaya* Fungo soils, which were mainly sandy loams. It is likely that the binding sites for cations in these soils are typical of loams where the clay-organic matter micelles form the major sites for cation exchange, and the levels of extractable Ca, Mg and Zn are strongly influenced by the clay content in the soils.

Acid saturation had significant negative correlations with pH (r= -0.52, at $p<0.001$), total cations, Ca, organic carbon (r= -0.39, –0.43 and –0.41 at $p<0.01$ respectively), Mg, and Zn (r= -0.34 and –0.31, at $p<0.05$ respectively) (Table 3.11). As would have been expected acid saturation had significant positive correlation with exchange acidity (r=0.95, at $p<0.001$). Mn might be expected to show a positive correlation with acid saturation, however, this was not observed for *kaya* Fungo soils. The scatterplots showed that in acid saturation against total cations, Ca, Mg, Zn, and organic carbon content, samples 50 and 51 had much higher levels of acid saturation (Fig. 3.34a, b, c, d, and f), and the R^2 values were significant except for Zn and exchange acidity. When samples 50 and 51 were excluded from the analysis, the correlations (acid saturation against total cations, Ca, Mg, and Zn) improved significantly (r = -0.65, -0.62, -0.56, and -0.51 at $p<0.001$ respectively), and improved slightly in acid saturation v. organic carbon (r = –0.42, at $p<0.05$). The R^2 values increased considerably, even that in acid saturation v. Zn became significant (R^2 = 0.25).

Fig. 3.33: Correlation between clay content and (a) total cations (b) calcium (c) magnesium (d) potassium, (e) zinc, and (f) organic carbon (soils collected from *kaya* Fungo)

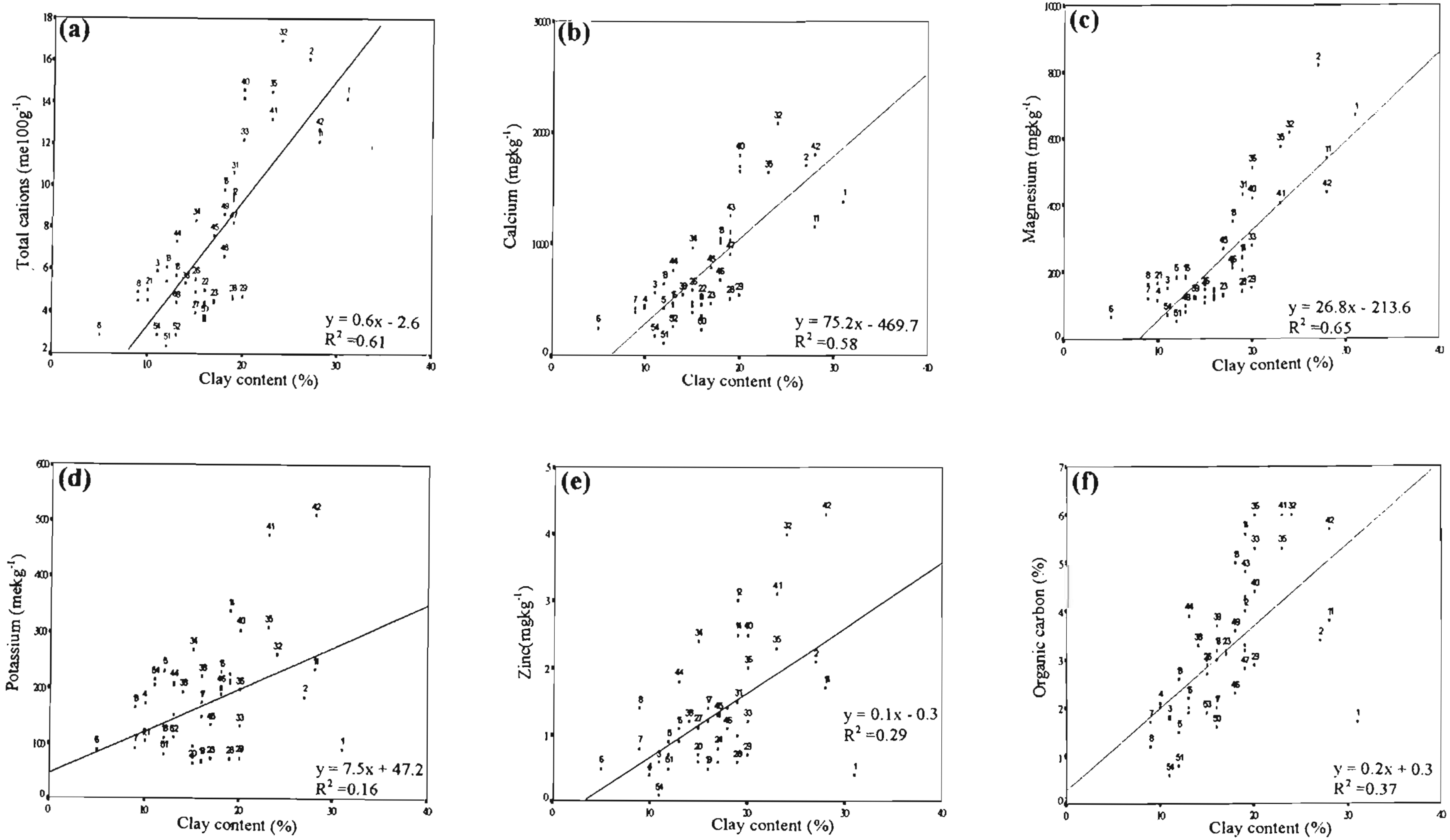
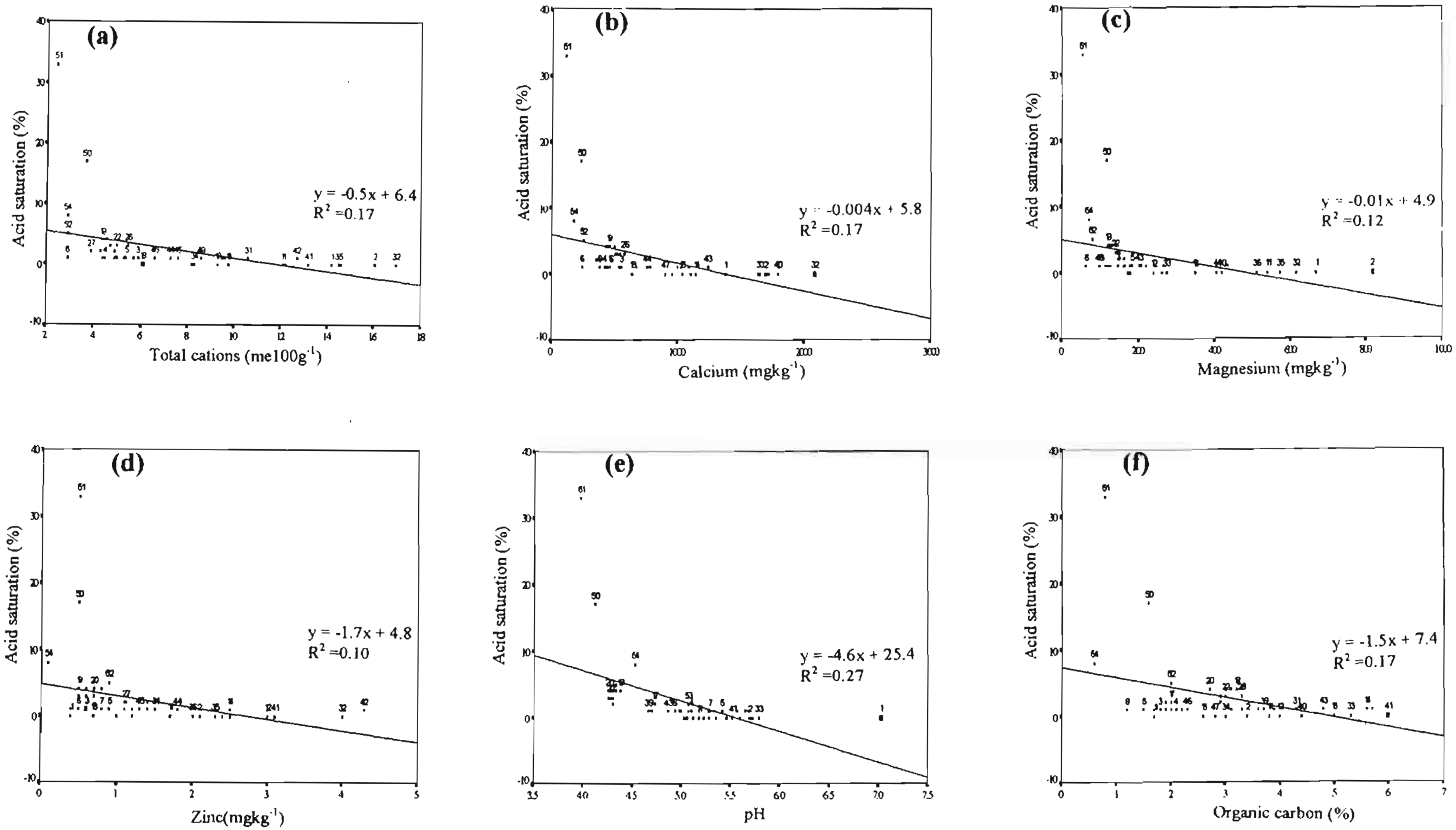


Fig. 3.34: Correlation between acid saturation against (a) total cations (b) calcium (c) magnesium (d) zinc (e) pH and (f) organic carbon (soils collected from *kaya* Fungo)

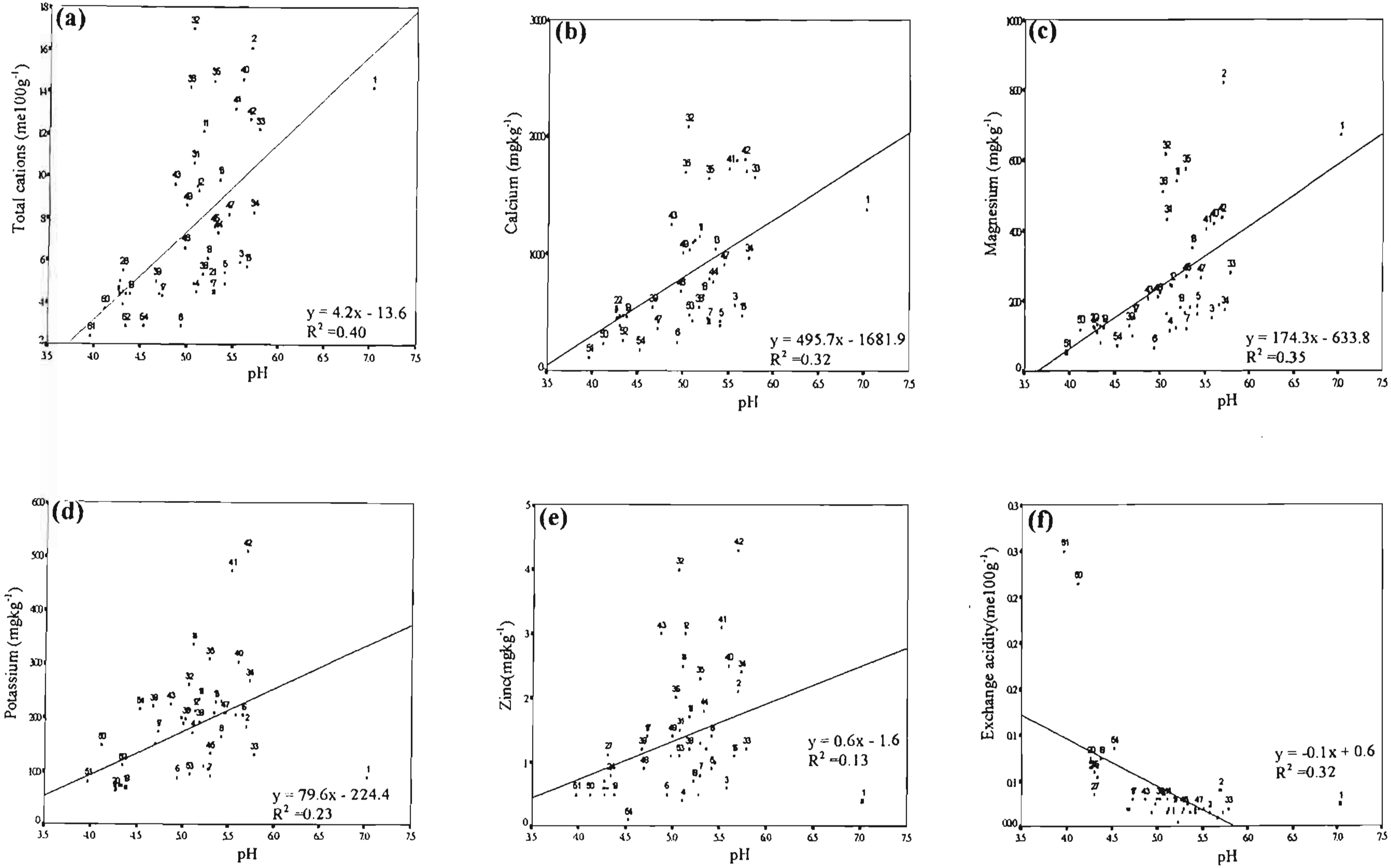


In the plot of acid saturation v. pH, sample 1 had high pH value, while samples 50 and 51 had higher acid saturation, compared to the rest of the data (Fig. 3.34e). When the outlier samples were excluded from the analysis, a significant negative correlation was maintained (r = -0.77, at $p<0.001$), and the R^2 value increased significantly (0.27 to 0.59).

In the correlation matrix (Table 3.13) pH had significant positive correlations with total cations, Ca, Mg, K and Zn (r = 0.66, 0.63, 0.64, 0.48 and 0.38, at $p<0.001$ respectively), and significant negative correlation with exchange acidity (r = -0.57, at $p<0.001$) (Table 3.13). In all the scatterplots (Fig. 3.35) sample 1 showed higher pH value than the rest of the data set. When sample 1 was excluded in pH against total cations and Ca (Fig. 3.35a and b), significant correlations were maintained (r = 0.61 and 0.58, at $p<0.001$ respectively) and the R^2 value was reduced (from 0.40 to 0.36) but was still significant in pH v. total cations, and increased slightly (from 0.32 to 0.33) in pH v. Ca.

In pH v. Mg, soil sample 2 had higher levels of Mg than predicted by the regression model (Fig. 3.35c). When the samples 1 and 2 were excluded, significant correlation was maintained (r = 0.49, at $p<0.001$), and the R^2 value decreased from 0.35 to 0.23, but was still significant. In pH v. K, samples 41 and 42 had higher K levels than predicted by the regression model (Fig. 3.35d). When samples 1, 41 and 42 were excluded from the analysis, significant correlation was maintained (r = 0.64, at $p<0.001$), and the R^2 value increased from 0.23 to 0.40. In pH v. Zn the samples 32 and 42 had considerable higher Zn values than predicted by the regression model (Fig. 3.35e). When samples 1, 32 and 42 were excluded, significant correlation was maintained (r = 0.52, at $p<0.001$), and the R^2 value increased from a non-significant to a significant value (i.e. from 0.13 to 0.26). The pH had significant negative correlation with exchange acidity (r = -0.57, at $p<0.001$), but in the scatterplot sample 1 had a higher pH than, and samples 50 and 51 had higher exchange acidity compared to the rest of the data (Fig. 3.35f). When samples 1, 50 and 51 were excluded from the analysis significant negative correlation was maintained (r= -0.79, at $p<0.001$), and the R^2 value increased from 0.32 to 0.61, suggesting a stronger negative association between pH and exchange acidity. These associations reflect the expected association between the soil base cations to pH (i.e. high cations concentrations in soils increased the pH value), in loamy soils where the base/H^+ status is dominated by clay-humus complexes.

Fig. 3.35: Correlation between pH and (a) total cations (b) calcium (c) magnesium (d) potassium (e) zinc, and (f) exchange acidity (soils collected from *kaya* Fungo)



Outlier soil samples noted above include sample 1, which was characterised by a relatively very low levels of K, Zn and organic carbon, and high pH. Sample 1 was collected from a relevé sampled on a *Acacia reficiens* dominated, relatively flat area, and very close to a seasonal swamp site that fills up with water during the rains, but remains dry for most part of the year. The high pH could have reflected a higher salinity caused by evapo-transpiration, and probably the cations K and Zn leached to the lower soil layers. Soil samples 41 and 42 had higher levels of K than the rest of the data set, a contrast to sample 1. In addition sample 42 also had relatively very high levels of Zn. The two samples (41 and 42) were collected from relevés sampled in dense canopy forest areas, with abundant ground surface litter. Sample 32, showed a relatively higher level of Zn to the clay content. Soil sample 32 was collected from a relevé sampled in more of a shrub than forest area. The high levels of acid saturation in samples 50 and 51, reflected a contrast to the rest soil samples. Soil samples 50 and 51 were sands collected from *Brachystegia* woodland areas, while most of the other soil samples were sandy-loam soils, collected from forest, scrubland or grassland areas. Therefore, the outlier soil samples in *kaya* Fungo soil data are more likely to be reflecting the extreme qualities of the soils in their specific local sites, rather than being a product of sampling and/or analytical errors.

3.5 DISCUSSION

The results presented in this chapter relate to the surface soils collected in the two kayas. It must be emphasised that these soils were collected and investigated as part of a survey of the vegetation in these kayas and not for a study of the soils *per se*. Thus, it was the vegetation-soil relationships which were the primary focus of the study. However, it was considered worthwhile to provide a clear picture of the variation in soils before an analysis and discussion of the vegetation-soil relationships (presented in Chapter Four). The discussion here, therefore, primarily focuses on comparing and summarising some interesting aspects of the soil data. It must be further noted that there were limitations to a wider interpretation of these soil data. In particular, these limitations included: the sampling of surface soils only i.e. no profile analysis; the use of extractable values for the major nutrients i.e. no total values or measurements of nutrient inputs; the missing data for organic carbon and the limitations of the analysis method used; and the absence of any measurements for nitrogen.

In both *kayas*, Mtswakara and Fungo, the soils were of two main physical types, namely sandy and sandy-loam soils with a number of different (field) colour categories. The soil texture-colour descriptions seemed to summarise reasonably well the general characteristics of the soils and the variation within the complete soil data set (Table 3.14 and Table 3.15). Comparisons between soil nutrient data and other published data is often problematical. This is because of both the variety of extractants and methods of determination currently in use, together with the more theoretical consideration of the ecological meaning of such values. Of particular difficulty is that most of the published values are based upon agronomic methods of soil analysis and interpretation of critical or threshold values for plant growth are based upon crop species (Baillie 1989). However, Table 3.16 gives typical values for such concentrations (Landon 1991) and indicates the ranges of the *kaya* soils in relation to these critical values. The following discussion and summary of the soil variation is based on these tables.

Table 3.14: A Summary of the major soil variables based on the texture-colour description of the soils from *kaya* Mtswakara (mean values and standard deviations in brackets; and modal category for leaf litter)

Soil type	**pH**	**Tcations me100g^{-1}**	**P me100g^{-1}**	**Ca me100g^{-1}**	**Amount of ground surface litter**	**Clay (%)**
White sands (n=11)	4.9 (0.4)	3.4 (1.3)	0.03 (0.02)	1.2 (0.7)	Sparse	21.7 (6.4)
Pale black sands (n=13)	5.6 (0.5)	7.1 (2.5)	0.06 (0.04)	3.7 (1.8)	Abundant	22.1 (3.6)
Pale black sandy-loam (n=7)	6.1 (0.6)	10.3 (2.6)	0.09 (0.06)	6.2 (1.7)	Abundant	23.9 (2.5)
Black sandy-loam (n=17)	5.9 (0.6)	11.4 (5.2)	0.13 (0.15)	7.5 (5.1)	Abundant	25.5 (8.7)

Table 3.15: A Summary of the major soil variables based on the texture-colour description of the soils from *kaya* Fungo (mean values and standard deviations in brackets; and modal category for leaf litter)

Soil Type	pH	Tcations me100g^{-1}	P me100g^{-1}	Ca me100g^{-1}	Amount of ground surface litter	Clay %
White sands (n=5)	4.4 (0.4)	3.4 (1.0)	0.06 (0.03)	1.3 (0.7)	Sparse	13.4 (2.1)
Pale grey sandy loams (n=21)	5.2 (0.6)	6.8 (3.6)	0.06 (0.06)	3.3 (1.9)	Sparse	15.5 (6.6)
Pale black sandy loams (n=7)	4.8 (0.4)	7.1 (3.7)	0.08 (0.03)	3.9 (2.2)	Common	17.9 (3.1)
Black sandy loams (n=17)	5.0 (0.5)	9.3 (4.2)	0.1 (0.05)	5.6 (2.9)	Abundant	19.0 (3.7)

In *kayas* Mtswakara and Fungo (specifically the *Mirihi-ya-Kirao* forest patch) very acid (pH 4-5), very low base status (3-4 meq 100g^{-1}), white sands were found. These were similar in the two kayas and clearly distinguished by being areas with *Brachystegia* woodland. It is difficult to know how these soils were formed and if they have similar histories at the two sites. In the Mtswakara soils (Table 3.14), there was a general trend of increasing pH (from 4.9 to 6.1), and from very low to medium base status (total cations, phosphate and calcium) and percentage clay through the sequence: white sands; pale-black sands; pale-black sandy loams; to black sandy loams. This sequence would seem to be generally in line with the description of these soils being acrisols (illuvial soils with low activity clays), with varying degrees of leaching producing soils with varying levels of low base status which is dominated by exchangeable calcium, and a range of acid to weakly acid soils (Fitzpatrick 1980; Binkley & Vitousek 1989; Landon 1991; CADP 1991).

Table 3.16: Comparison of soil data from *kayas* Mtswakara and Fungo to critical values (based on Landon 1991)

Soil Variable	Critical values	Most recorded texture-coloursoil type in Mtswakara	Most recorded texture-colour soil type in Fungo
Total cation ($me100g^{-1}$)	>40 very high		
	10-25 medium	Pale black sandy-loams, Black sandy-loams	
	5-10 low	Pale black sand	Pale grey sandy-loams, Pale black sandy-loams, Black sandy-loams
	<5 very low	White sands	White sands
Ca ($me100g^{-1}$)	>10 high		
	4-10 medium	Pale black sandy-loams, Black sandy-loams	Black sandy-loams
	<4 low	White sands, Pale black sands	White sands, Pale grey sandy-oams, Pale black sandy-loams
Mg ($me100g^{-1}$)	>4 high		
	0.5-4 medium	White sands, Pale black sands, Pale black sandy-loams, Black sandy-loams	White sands, Pale grey sandy-loams, Pale black sandy-loams, Black sandy-loams
	<0.5 low		
Phosphorus ($\mu g\ g^{-1}$)	>15 high		
	5-15 medium	Pale black sands, Pale black sandy-loams, Black snady-loams	White sands, Pale black sandy-loams, Black sandy-loams
	< 5 low	White sands	Pale grey sandy-loams,
K ($me100g^{-1}$)	≥0.6 high	Pale black sandy-loams, Black sandy-loams	
	<0.6 low	White sands, Pale black sands	White sands, Pale grey sandy-loams, Pale black sandy-loams, Black sandy-loams
Zn ($\mu g\ g^{-1}$)	≥1.0 high	Pale black sands, Pale black sandy-loams, Black sandy-loams	Pale black sandy-loams, Black sandy loams
	<1.0 low	White sands	White sands, Pale grey sandy-loams

The soils in *kaya* Fungo also showed trends between the soils defined by their texture and colour and the variables (Table 3.15). The white sands, as mentioned above were similar to those in *kaya* Mtswakara, although the pH and the clay content were lower. Similarly the sandy loam soils in *kaya* Fungo, in contrast to those in *kaya* Mtswakara, were relatively more acidic, being nearer pH 5 than pH 6 and with lower clay content and lower base status than soils in *kaya* Mtswakara. Most of the soils in *kaya* Fungo were pale grey in colour, which was absent in soils from *kaya* Mtswakara, an indicative of luvisols and/or planosols (CADP 1991). In these soils albic E horizons have developed by the movement of clay and iron down the soil profile (Fitzpatrick 1980; Landon 1991). These pale grey sandy loams did not differ significantly in pH, clay content or base status from the pale black sandy loams. Although the data are not conclusive there was a trend to higher base status and clay content from these pale grey and black-grey soils to the black sandy loams.

The positive correlation between plant litter and sandy-loam soils (Table 3.2, 3.9), is attributed to higher vegetation covers which had potentially higher litter-fall rates. Ground surface litter increases nutrient input rates to the soil through direct leaching from leaves and mineralisation. The soil colour descriptions of the topsoil layers sampled give an indication of the organic matter content of the soils and the darker soils are associated with moderate to abundant leaf litter (Tables 3.14 and 3.15).

The first three principal components accounted for much of the variance in the soil data (71.5% and 81% for *kayas* Mtswakara and Fungo respectively), and indicates the usefulness of PCA in soil chemical data analysis where many inter-correlations between the variables exist. In both *kayas* Mtswakara and Fungo the soils were primarily described by a fertility or base status gradient (Figs 3.4; 3.22). The high fertility status was associated with relative high clay content (Figs. 3.7; 3.25), high organic carbon (Figs. 3.9; 3.26), low vegetation disturbance (Figs. 3.11; 3.28), and in *kaya* Mtswakara also with termite activity (Fig. 3.10) and gentle undulating terrain (Fig. 3.12).

The second PC axis was associated with soil acidity and pH. Soil pH and base status are strongly inter-related especially when the nutrient supply is dominated by the cation exchange sites associated with active clays and organic matter. The availability of the nutrient cations is decreased by high soil acidity, because non-nutrient cations (H^+ and Al^{3+}) occupy a substantial portion of the exchange sites (Binkley & Vitousek 1989). But as the pH increases the tightly adsorbed non-nutrient cations (H, Al and Fe ions) on the negatively charged sites of clay are removed and the sites become available for nutrient cations hence an increased soil fertility (FitzPatrick 1980). It is interesting therefore, that the PCA has separated these two main soil characteristics and suggests that there are influences of soil acidity on base status which are independent of cation exchange capacity e.g. pH effects on litter decomposition rates or hydrogen ion release through nitrification.

It is possible to speculate that the predominance of sandy-loam soils which have developed over a long period of time on relatively flat terrain at Fungo have given rise to well-developed leached soils where the levels of nutrients in the surface soil are closely associated with the presence and size of the exchange capacity of the soil clay and organic matter and the inputs of nutrients from leaf litter to the soil surface. Evidence for this includes both the PCA model where most of the variation was accounted for by the first and second PCs (Table 3.12) and the correlation matrix (Table 3.13) between individual variables. This correlation matrix clearly shows very significant inter-correlation between clay content, total cations and organic matter and thus indicating the strong relationships between exchange sites and levels of bases. Thus the ion exchange capacity and acidity both summarise the major variation in Fungo soils and are probably good indicators of the availability of nutrients to the vegetation biomass. While in *kaya* Mtswakara soils, which had a higher proportion of sandy soils in the analysis, the relationships between the base status, clay and organic matter were weaker than in *kaya* Fungo.

The most noticeable differences in the physical characteristics of the sites and soils between *kayas* Mtswakara and Fungo included the presence of rock material at the surface, termite mounds, and terrain which showed considerable variation in slope in *kaya* Mtswakara, whereas these factors were absent in *kaya* Fungo. These factors are likely to have influenced local soil development processes in *kaya* Mtswakara. These factors would include the presence of unweathered minerals and significant weathering processes and dissolution of hydroxyl-oxides and oxides of the clay fraction in the soil profile, the action of soil invertebrates particularly termites, and the processes of lateral water movement and erosion on steep slopes (Singer & Munns 1987; Binkley & Vitousek 1989).

The observed relative high fertility of soils on degraded termite mounds can be attributed to the material transportation to the surface by the termites in the process of building their termitaria (Samoiloff, Balakanich and Petrovich 1974; Burnham 1989). Termites are selective, moving only soil materials less than 1mm in diameter (FitzPatrick 1980), with incidental collection of nutrient cations (particularly Ca) in their food material (Samoiloff *et al.* 1974), and in the process alter the CEC and nutrient cation availability of soil in which they occur.

The observed decrease in soil fertility on steep slopes compared to similar soils on flat terrain may be as a result of colluvial movement from the steep slopes with deposition in lower lying areas. In soils found on uniform topography and on gentle undulating terrain most of the cations released from chemical weathering and organic matter decomposition enter the cation exchange process, while soils on steep slopes the nutrients can be exported in water flow at the surface or lower in the soil profile. However, supplies of nutrients can continually occur through constant rejuvenation where erosion may remove the top soil but weathering of parent material releases nutrients into the plant rooting zone (Whitmore 1989). Weathering processes can be important, also, for inputs of nutrients where the conditions are favourable such as in the shallow soils with rock outcrops in *kaya* Mtswakara. Thus in tropical soils where there are high temperatures and, wet and dry seasons, weathering rates can often be significant in the supply of bases (Burnham 1989).

CHAPTER FOUR
VEGETATION-ENVIRONMENT RELATIONSHIPS WITH PARTICULAR REFERENCE TO SOILS

4.1 INTRODUCTION

Although there are over 300,000 species of terrestrial vascular plants worldwide, these species occur together in communities that are often similarly structured (Tilman 1986). The convergence of unrelated plant species that have different morphological, physiological, and life history traits to form a plant community (Orians & Paine 1983) leads to floristic variation in the plant communities both in time and space (Chesson 1986). The occurrence of floristic variation in plant communities raises a number of important questions in plant ecology. For example, is the floristic variation generally predictable? Can the structure and composition of the plant communities be described by measurable environmental gradients? Or are there unique explanations to be invoked for each situation?

There are two potential explanations for vegetation patterns (Tilman 1986). First, that the plant species may occur in a locality because of some traits that determine their responses to major biotic or abiotic environmental constraints. Second, that species are not differentiated with respect to such traits, but are functionally identical, i.e. the 'neutral species' hypothesis (Tilman 1986), and the composition of a community is determined purely by random processes of invasion and extinction (MacArthur & Wilson 1967). The second explanation seems to explain patterns observed on small spatial scales, but it is unlikely to explain the long-term persistence of species within a region (Tilman 1986). Since the plant species are not identical, they must be differentiated in their traits, which determine their responses to changes in major environmental factors, hence the vegetation patterns observed.

At the Kenya coast two studies have examined vegetation changes along environmental gradients (Hawthorne *et al.* 1981; Schmidt 1991). Hawthorne *et al.* (1981) investigated the floristic patterns of *kayas* Kambe and Ribe, and identified four factors namely, watercourses, limestone, slope and disturbance, as the principal factors responsible for the formation of different plant groups. However, some vegetation patterns in *kayas* Kambe and Ribe, did not have obvious correlation with the identified causal factors (Hawthorne *et al.* 1981) and further investigation was recommended. The plant communities identified in the Shimba Hills were differentiated partly on the basis of soil types, disturbance level and aspect (Schmidt 1991).

Plant species occurring in stable plant communities are generally expected to be adapted to the prevailing environmental conditions. Although broad vegetation types are known to share common basic environmental conditions, smaller vegetation units vary in their floral components and are, therefore, also likely to differ in their physical and biological determinant factors. The distribution of vegetation types can be influenced by factors such as: quantities of various environmental resources (climate, light, soils etc) (Tilman 1980, 1982; Hawthorne 1993); species specialization to certain periods of a seasonally fluctuating climate i.e. the phenological niche (Grubb 1986); differences in competitive abilities of plants; and their stress tolerance, e.g. susceptibility to herbivory or predation (Lubecho 1978). Vegetation succession and cyclic change can result from intrinsic change brought about by the plants themselves (Goldsmith & Harrison 1976, Bannister 1976). According to Cumming (1982) vegetation formations can result from complex and chaotic interactions of climate, fire, grazing, the plants and soil nutrient stocks in the ecosystem. In simple or general ecological understanding, climate is the major factor controlling the patterns of tropical vegetation (Longman & Jenik 1987), while soil conditions and gradients are important as determinant factors at the plant community level (Bannister 1976; Eyre 1968). Therefore, in a given biogeographical region much of the variation in the local composition of plant communities is associated with soil gradients (Lindsey 1961; Hole 1976; Rabinovitch-Vin 1979, 1983; Jenny 1980).

After establishing a classification framework for the vegetation in Chapter Two, explanations on the cause of the observed vegetation patterns are sought. This chapter presents an analysis of results of the vegetation classification (Chapter Two) in relation to the variation in the soils (Chapter Three). It particularly uses the PCA soil models and the PCA axes within an indirect gradient analysis context. The vegetation patterns in the two *kayas* are further discussed in terms of historical factors such as plant use, disturbance and fire.

4.2 MATERIALS AND METHODS

Vegetation types identified in the TWINSPAN classification in Chapter Two were related to the soil environmental gradients (PC axes) discussed in Chapter Three. The vegetation types were described in relation to the physico-chemical characteristics of the soils derived from each relevé. The descriptive characteristics of the general vegetation (species richness and vegetation structure) and of specific vegetation types were displayed in an analogous way to the soil variables on the PCA space defined by the PCs 1 and 2 derived from the PCA of soil chemical characteristics. The premise adopted here was that, if the soil factors are responsible of the distribution and variation of vegetation units, then soil samples (numbered according to their respective relevés) would be displayed on the PCA hyperspace in groups similar to those displayed in the TWINSPAN classification.

Statistical comparisons of the quantitative data of the soil variables between different vegetation types were also made. Mean values of each variable in the vegetation types were compared using ANOVA and the Scheffé test (Sokal & Rohlf 1981) for normally distributed data, and the Kruskal-Wallis test (Sokal & Rohlf 1981) for data that is not normally distributed. The normal distribution of the data was determined using Kolmogorov-Smirnov goodness of fit test (Sokal & Rohlf 1981), and Pair-wise comparisons were determined using the Mann-Whitney test (Sokal & Rohlf 1981). All the statistical analyses were done using SPSS (SPSS version 6.0, SPSS Inc. 1993).

4.3 RESULTS

4.3.1 Vegetation-environment relationships in Mtswakara

General vegetation-soil relationships

Considering that the first axis (PC 1) in the PCA described most of the variance in the soil data (Table 3.5), descriptive characteristics of the vegetation were investigated along that axis. The descriptive vegetation characteristics included: species richness, cumulative vegetation cover (leaf canopy cover), number of vegetation layers, vegetation cover in the individual layers and vegetation structure. 'Species richness' referred to the number of species in each relevé (10 x 20m). 'Cumulative vegetation cover', an index of vegetation biomass or productivity, referred to the summative foliage cover of the relevé area, derived by summing the cover index in the four vegetation layers in the relevé (Table 2.4). 'Vegetation structure' was described on the basis of the vegetation layer with the highest cover, designated as 1, 2, 3 and 4 for emergent, short tree, shrub and herb layers respectively. The 'number of vegetation layers' referred to the layers (out of four) found in the relevé, and 'vegetation cover' in the individual layers as the cover index of each layer (Table 2.4).

The species richness along PC 1 (the gradient of soil fertility) showed a positive significant relationship (Fig. 4.1) where the relatively low soil fertility status were associated with lower numbers of higher plant species. This suggests that the soil fertility at relatively low levels is limiting to species richness. Cumulative vegetation cover increased along the soil fertility gradient (Fig. 4.2), but relevés 14 and 15 had exceptionally high levels of vegetation cover and high positive PC1 values than the rest of the data set. When relevés 14 and 15 were excluded the regression had a low R^2 value (=0.01) meaning that the cumulative vegetation cover was not significantly affected by variation in soil fertility. The negative correlation between vegetation structure and PC 1 suggests that vegetation with highest cover in the herbaceous layer is found on relatively low fertile soils, while vegetation with highest cover in the emergent layer is on relatively high fertile soils (Fig 4.3). However, this analysis was doubtful as there were only four possible values for 'structure'.

For the vegetation cover in the four layers, only cover in the emergent and in the shrub layers had significant positive correlation with PC 1 ($r = 0.44$ and $r= 0.4$, at $p<0.05$ respectively) (Figs. 4.4 and 4.5). This suggests that increase in soil fertility corresponded to increase in vegetation cover in the emergent and shrub layers only. However, the emergent layer data was difficult to interpret with a high number of zeros i.e. emergent layer absent, and the bias caused by the two data points (relevés 14 and 15) which had very high cover and high positive values for PC1. Thus increased soil fertility as represented by PC1 is probably associated with a gradient in increasing vegetation productivity. This increased productivity is achieved through contributions from increased canopy development (and leaf area index), increased structural complexity and increased number of species. The role of the shrub layer seems to be important in contributing to this conclusion and this interpretation of these results.

Fig. 4.1: Variation in species richness along the first Principal Component for vegetation and soil data collected from *kaya* Mtswakara

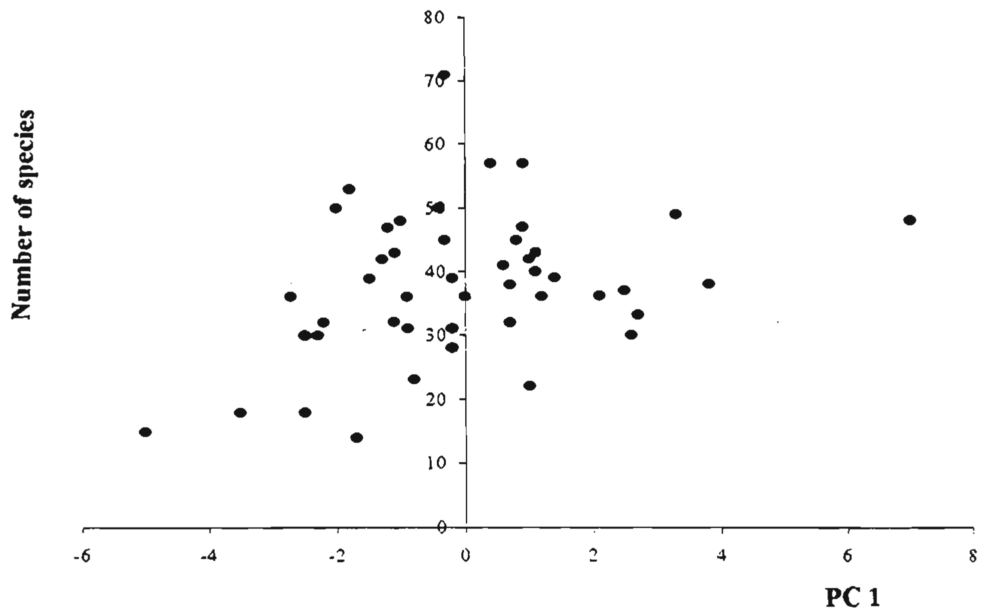


Fig. 4.2: Variation of cumulative vegetation cover along the first Principal Component, for vegetation and soil data collected from *kaya* Mtswakara

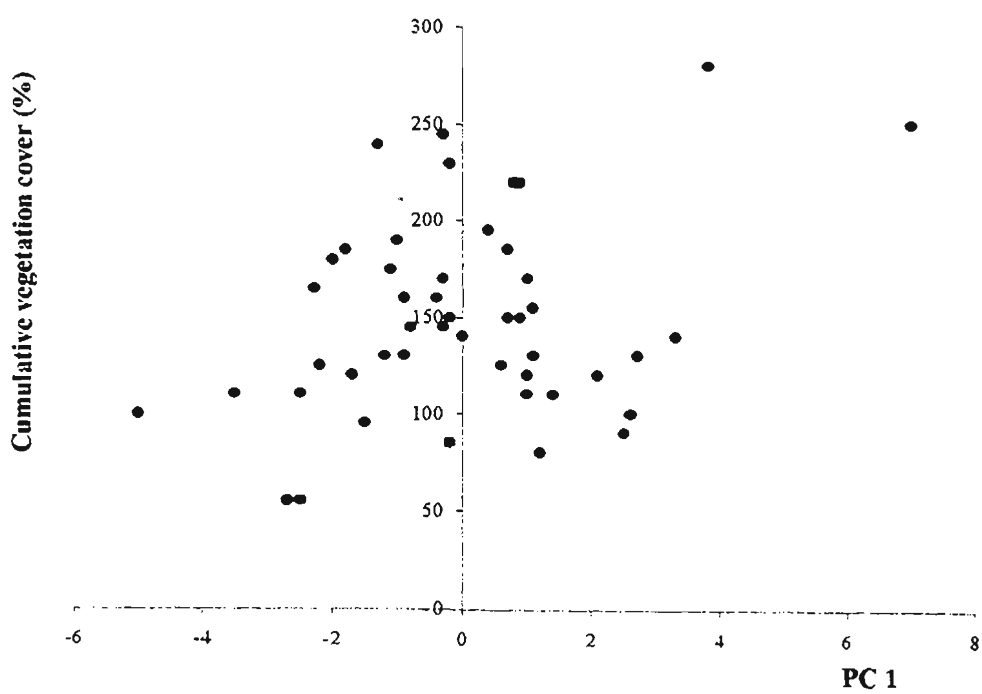


Fig. 4.3: Vegetation structure in relation to the first Principal Component, for vegetation and soil data collected from *kaya* Mtswakara

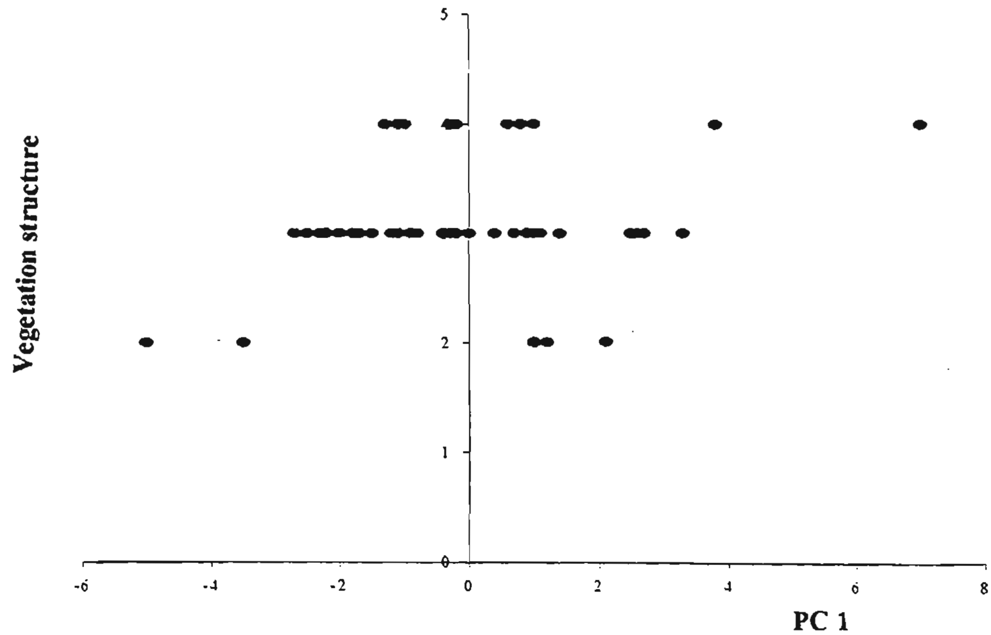


Fig. 4.4: Variation in vegetation cover in the emergent layer along the first Principal Component, for vegetation and soil data collected from *kaya* Mtswakara

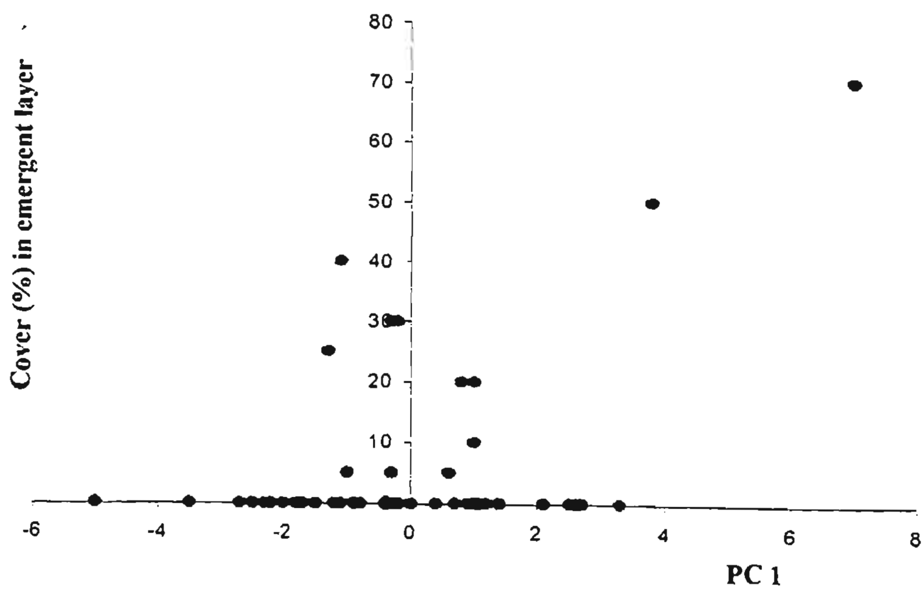
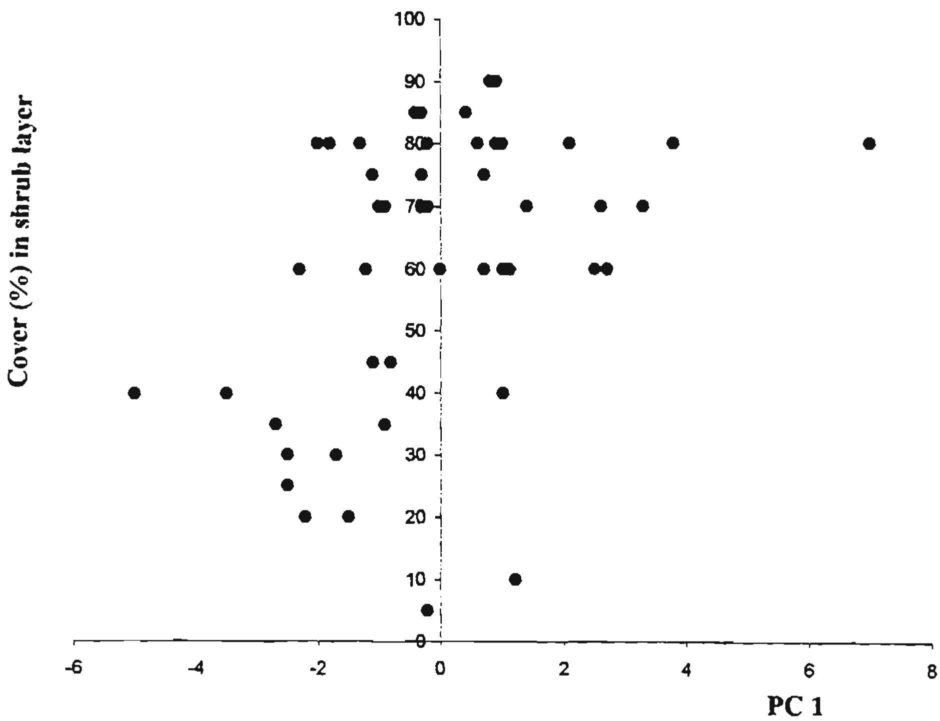


Fig. 4.5: Variation in vegetation cover in the shrub layer along the first Principal Component, for vegetation and soil data collected from *kaya* Mtswakara



Vegetation-soil relationships in specific vegetation types

In the main soil types identified in *kaya* Mtswakara, the relatively dense forest community (*Scorodophloeus* community) was associated with the black sandy-loam soils, and *Hugonia* community was more broadly across the black-sandy and sandy-loam soils (Table 4.1). The wooded *Acacia* community was associated exclusively with pale-black sandy soils, and the woodland *Brachystegia* community was strongly associated with white sandy soils and rocky outcrops (Table 4.1). The amounts of ground surface litter differed substantially between the vegetation types. In the *Scorodophloeus* community and in the *Ochna-Pancovia* sub-community there was abundant ground surface litter (Table 4.2). *Dobera* sub-community, occurring on the termite mounds, was the exceptional case where a high canopy forest had low amounts of litter; this could be attributed to the observed degradation which reduced the emergent and short tree canopy layers, hence reduced the amount and rate of litter fall. In the *Brachystegia* community the amount of ground surface litter ranged between sparse to common, which was, perhaps, due to both lower leaf-fall rates and lower decomposition rates in the relatively acidic soils. In the *Acacia* community ground surface litter was commonly absent. This may have been because of: relatively lower litter input as the emergent and canopy layers in vegetation unit were not common; frequent fires which was likely to burn existing litter and hence affect its accumulation; and relative high decomposition rates of litter with relatively higher nitrogen content.

The relationships between vegetation type and the soil chemical variables can be analysed in relation to PCA hyperspace defined by the first and second PCs (Fig. 4.6). The open squares represent individual relevés and the lines represent the soil variables. The length of each vector is proportional to the magnitude of influence of that particular variable in the given direction. Variables with longer vectors are more important in influencing variation, and the relevés to the tip of each vector are most strongly correlated with and influenced by that variable. In addition, the position of each line with respect to the PCs (1 and 2) indicates how closely correlated the PC is to that soil variable.

Table 4.1: Soil colour and texture in the vegetation types identified in *kaya* Mtswakara

Community	**Sub-community**	**Relevés (%) on white sandy soil**	**Relevés (%) on pale-black sandy soil**	**Relevés (%) on pale black sandy-loam soil**	**Relevés (%) on black sandy-loam soil**
***Scorodophloeus* dense forest community (n=16)**	*Commiphora-Asplenium* sub-community (n=5)	0	0	20	80
	Ricinodendron sub-community (n=11)	0	18.2	9.1	72.7
***Hugonia* dense forest community (n=13)**	*Ochna-Pancovia* sub-community (n=8)	0	50	25	25
	Dobera loranthifolia sub-community (n=5)	0	20	60	20
***Brachystegia* woodland community (n=16)**	*Rytigynia celastroides* sub-community (n=7)	85.7	14.3	0	0
	Psydrax faulknerae sub-community (n=7)	71.4	28.6	0	0
***Acacia* wooded community (n=6)**		0	100	0	0

Table 4.2: Relative amounts of ground surface litter in vegetation types identified in *kaya* Mtswakara

Vegetation type	Litter absent (Relevés %)	Litter sparse (Relevés %)	Litter common (Relevés %)	Litter abundant (Relevés %)
Scorodophloeus community (n=16)				
Commiphora-Asplenium sub-community (n=5)	0	0	20	80
Ricinodendron sub-community (n=11)	0	0	0	100
Hugonia community (n=13)				
Ochna-Pancovia sub-community (n=8)	0	12.5	12.5	75
Dobera loranthifolia sub-community (n=5)	0	100	0	0
Brachystegia community (n=16)				
Rytigynia celastroides sub-community (n=7)	0	85.7	0	14.3
Psydrax faulknerae sub-community (n=7)	0	71.4	28.6	0
Acacia community (n=6)	50	16.7	16.7	16.7

The vegetation types in the PCA hyperspace indicated the *Scorodophloeus* community (*Ricinodendron* and *Commiphora-Asplenium* sub-communities) to be on relatively fertile soils and *Brachystegia* community (*Psydrax* and *Rytigynia* sub-communities) on relatively infertile soils (Fig. 4.7). While *Hugonia* community occurred on soils ranging from moderate fertility (*Dobera* sub-community), to low fertility (*Ochna-Pancovia* sub-community), and *Acacia* community also occurred on soils of low to moderate fertility. In the PCA hyperspace, therefore, the vegetation types were separated along soil fertility gradients, where the dense forest *Scorodophloeus* community was on the most fertile soils, the woodland *Brachystegia* community on the least fertile soils. The dense forest *Hugonia* community and wooded *Acacia* community occurred on low to moderate fertile soils.

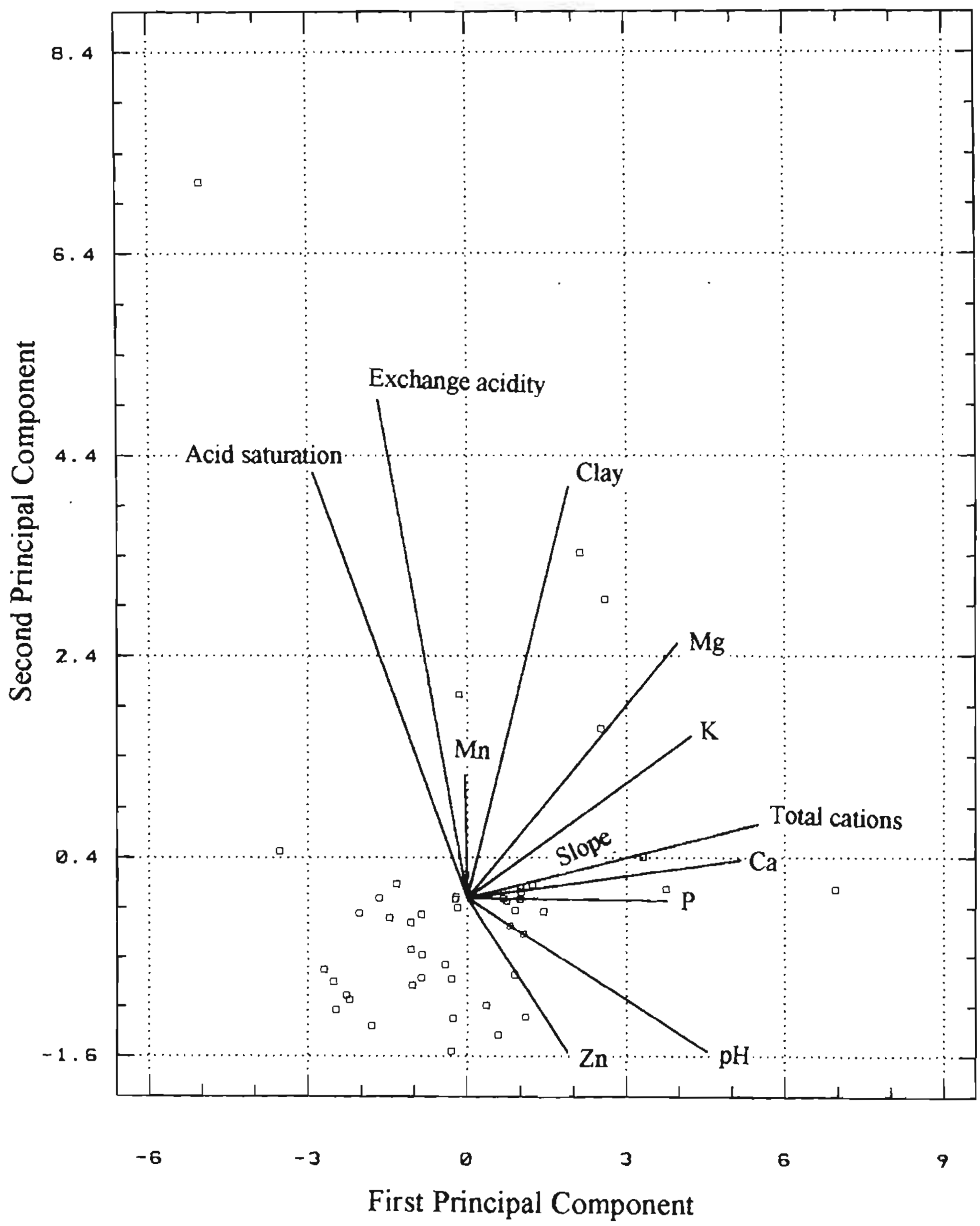
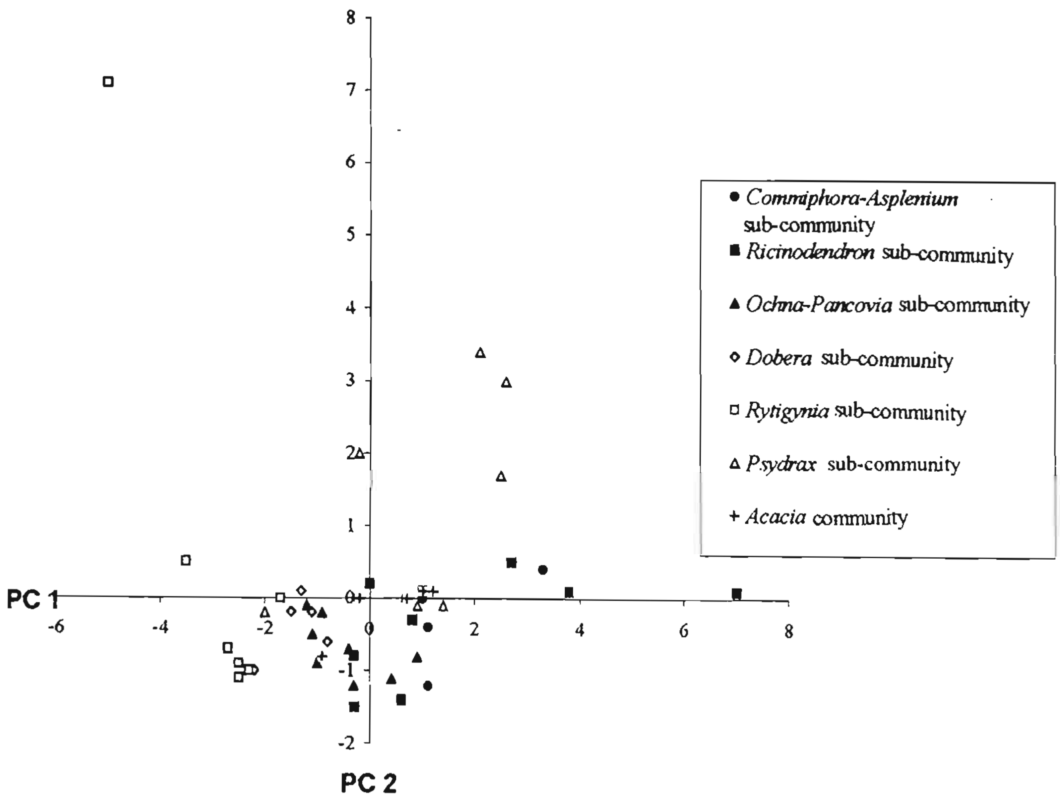


Fig. 4.6: Ordination of sampled relevés in relation to the soil variables (for soils collected from *kaya* Mtswakara)

Fig. 4.7: *Kaya* Mtswakara vegetation types plotted in space defined by the first and second Principal Components



The mean values of the soil variables for each vegetation type are given in Table 4.3. The *Commiphora-Asplenium* and *Ricinodendrum* sub-communities, had high mean values of total cations, Ca, Mg, and phosphorus, coinciding with low mean values of exchange acidity and acid saturation. In the *Ricinodendron* sub-community, however, phosphorus levels were very high in sample 15, and Ca levels were very high in samples 14, 15 and 29, which resulted in the high standard deviation values for these variables (Table 4.3). Even after sample 15 was excluded, *Ricinodendron* sub-community still had the highest mean value of phosphorus (11.8mg kg^{-1}), and after excluding samples 14, 15 and 29, the mean value of Ca (1093.1mgkg^{-1}) in *Ricinodendron* sub-community was still higher than all the other vegetation types except for *Commiphora-Asplenium* sub-community. Based on the mean values of the soil variables, the *Scorodophloeus* community (*Ricinodendron* and *Commiphora-Asplenium* sub-communities) can be considered as a vegetation type that occurred on a high fertile and low acidity soils relative to the other vegetation types, which agrees with the PCA ordination discussed earlier.

The *Brachystegia* community (*Rytigynia* and *Psydrax* sub-communities), had low to very low mean values of total cations, Ca, Mg, and phosphorus, but high mean values of soil acidity. There was a considerable inter-sample variation in the *Psydrax* sub-community, as indicated by the high standard deviation values of the means. Samples 39 and 44 in *Psydrax* sub-community had higher levels of K, Ca and Mg compared to the rest samples in that vegetation type. When those samples were excluded *Psydrax* sub-community had the lowest mean values of K (86.6mgkg^{-1}), Ca (146.6mgkg^{-1}) and Mg (96.5mgkg^{-1}) compared to the other that vegetation types. Sample 43 had very high level of acid saturation, but even after excluding that sample the mean value of the acid saturation in *Psydrax* sub-community (3.3%) remained the highest compared to the other vegetation types. Higher soil acidity in *Rytigynia* and *Psydrax* sub-communities than in other vegetation types was also reflected by the low pH values (pH $\cong$ 5), while in all other vegetation types the pH was relatively high (pH $\cong$ 6) (Table 4.3). The mean values of the *Brachystegia* community discussed above, agreed with the ordination in the PCA which projected that community (*Rytigynia* and *Psydrax* sub-communities) as a vegetation type found on low fertile and high acidic soils. The ordination of *Hugonia* and *Acacia* communities (on moderate fertile soils) was also supported by the statistical analysis of the soil variables for these vegetation types (Table 4.3).

Table 4.3: Mean values of soil chemical variables* for vegetation types identified in *kaya* Mtswakara (standard deviation in brackets)

Vegetation types	P	K	Ca	Mg	Zn	Mn	Exchange acidity	Total cations	Acid saturation	pH	Organic carbon (%)	Clay (%)
Commiphora-Asplenium	9.4^{bc}	319.4	1478.4^{ab}	223.3	15.3^{bc}	22.0	0.06^{ab}	11.7^{ab}	0.8^{a}	6.4^{c}	3.7	24.0
sub-community	(4.2)	(174.3)	(392.6)	(122.2)	(15.2)	(9.2)	(0.03)	(2.1)	(0.5)	(0.3)	(2.2)	(3.6)
Ricinodendron sub-	17.3^{c}	264.9	1733.8^{b}	192.0	12.4^{c}	66.6	0.06^{ab}	12.2^{b}	0.7^{a}	5.9^{bc}	4.9	22.3
community	(19.1)	(48.1)	(1168.31)	(61.5)	(10.9)	(51.8)	(0.03)	(6.0)	(0.7)	(0.7)	(1.4)	(4.1)
Ochna-Pancovia	8.7^{bc}	180.8	818.5^{ab}	152.4	16.3^{bc}	69.2	0.07^{b}	7.3^{ab}	1.1^{a}	5.6^{abc}	4.5	20.5
sub-community	(3.2)	(25.4)	(314.9)	(35.3)	(19.5)	(30.7)	(0.02)		(0.4)	(0.3)	(1.1)	(1.3)
Dobera	4.6^{a}	333.2	953.8^{ab}	212.5	1.9^{ab}	153.0	0.1^{b}	9.1^{ab}	1.8^{ab}	6.1^{bc}	5.4	26.8
sub-community	(2.0)	(184.4)	(482.9)	(136.9)	(0.9)	(222.7)	(0.01)	(4.1)	(1.3)	(0.8)	(0.9)	(5.5)
Rytigynia	3.4^{a}	106.8	344.5^{a}	119.5	0.9^{ab}	54.1	0.04^{a}	4.1^{a}	1.6^{ab}	5.1^{ab}	3.3	23.3
sub-community	(2.0)	(34.5)	(143.6)	(55.4)	(0.5)	(21.5)	(0.02)	(1.4)	(1.1)	(0.3)	(0.6)	(7.3)
Psydrax	4.6^{a}	196.7	478.3^{a}	211.3	1.1^{a}	54.7	0.19^{ab}	5.4^{ab}	7.7^{b}	4.8^{a}	5.9	28.1
sub-community	(5.2)	(193.6)	(599.1)	(204.2)	(1.6)	(34.1)	(0.26)	(4.4)	(12.1)	(0.4)	(0.2)	(12.4)
Acacia community	4.8^{ab}	298.9	837.4^{ab}	192.8	2.4^{b}	59.8	0.07^{ab}	8.4^{ab}	1.3^{a}	6.1^{bc}	2.7	22.0
	(3.0)	(153.0)	(355.8)	(44.0)	(2.4)	(35.1)	(0.04)	(2.6)	(0.5)	(0.5)	(2.4)	(2.7)

*For units of the soil variables see text;The means in the columns followed by different letters (a,b, c) are significantly different with a Sheffe multiple range test (for normally distributed data) or Mann-Whitney test (for data that is not normally distributed).

In the *Hugonia* community, the *Dobera* sub-community occurred on termite mounds, which were characterised by soils of relatively higher fertility compared to soils in the *Ochna-Pancovia* sub-community. Compared to *Ochna-Pancovia* soils, the soils on the mounds had higher mean values of Ca, Mg, K and clay. Although the mean value of pH on the mounds was also higher, the mean values of acid saturation, exchange acidity and Mn were higher too, but Zn values were much lower, compared to *Ochna-Pancovia* sub-community (Table 4.3). These observations illustrated interesting differences with soil acidity conditions in the mounds (*Dobera* sub-community), possibly associated with the termite activity, that could not be immediately explained. However, the considerable variation in the soil variables associated with the mound vegetation (*Dobera* sub-community) should be noted.

4.3.2 Vegetation-environment relationships in *kaya* Fungo

General vegetation-soil relationships

The PCA of soil data for soils from *kaya* Fungo, like in *kaya* Mtswakara, showed that PC 1 captured most of the variance in the soil data (Table 3.12) and was mainly a gradient of soil fertility. In a correlation analysis between PC 1 and descriptive characteristics of the vegetation there were significant negative correlations between PC 1 and species richness and vegetation cover in the herbaceous layer ($r = -0.38, -0.35$, at $p<0.01$ respectively) (Fig. 4.8, 4.9). The relationship between PC 1 and the vegetation structure was not considered as only two structural categories were represented. The number of vegetation layers, cumulative vegetation cover, vegetation cover in emergent, short tree canopy and shrub layers were not significantly correlated to PC1 at $p<0.05$, which meant that these vegetation characteristics could not be related to soil fertility.

Vegetation-soil relationships in specific vegetation types

The distribution of the main vegetation types in relation to the four main soil types is shown in Table 4.4. The *Uvariodendron* community was found on the black sandy-loams with infrequent occurrences on the other sandy-loam soils, this was particularly so for the *Blepharespermum* and *Excoecaria* sub-stages. The *Acacia* community was exclusively found on the pale grey sandy-loams while the *Bachystegia* community was found exclusively on the white sandy soils (Table 4.4).

Fig. 4.8: Variation in species richness along the first Principal Component, for vegetation and soil data collected from *kaya* Fungo

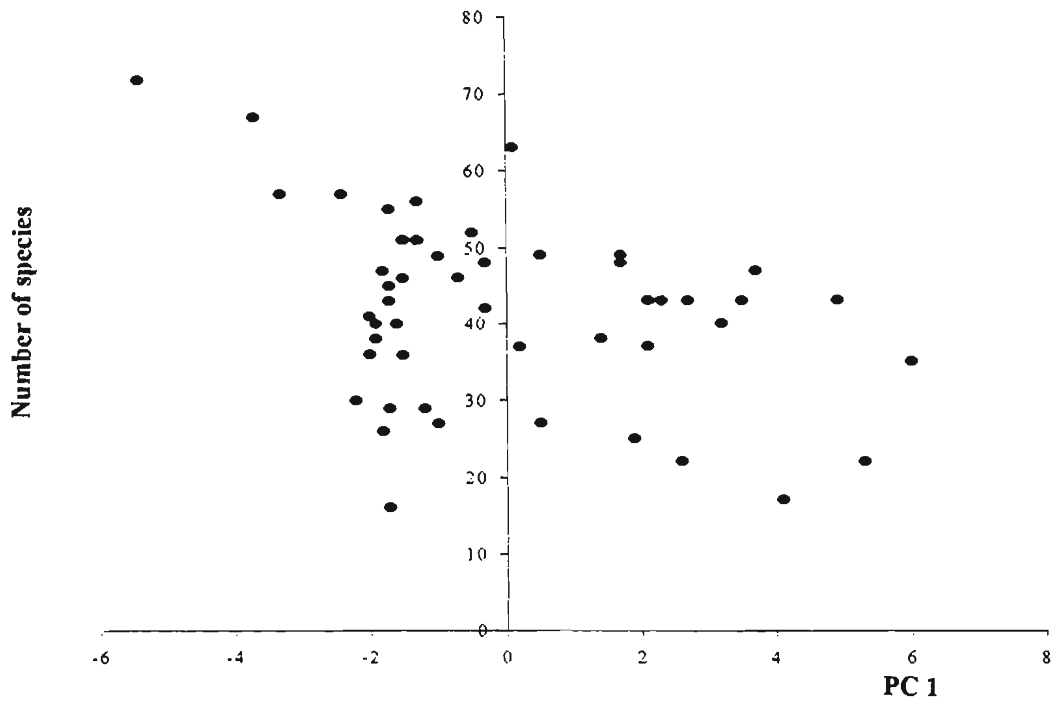


Fig. 4.9: Variation in vegetation cover in the herbaceous layer along the first Principal Component, for vegetation and soil data collected from *kaya* Fungo

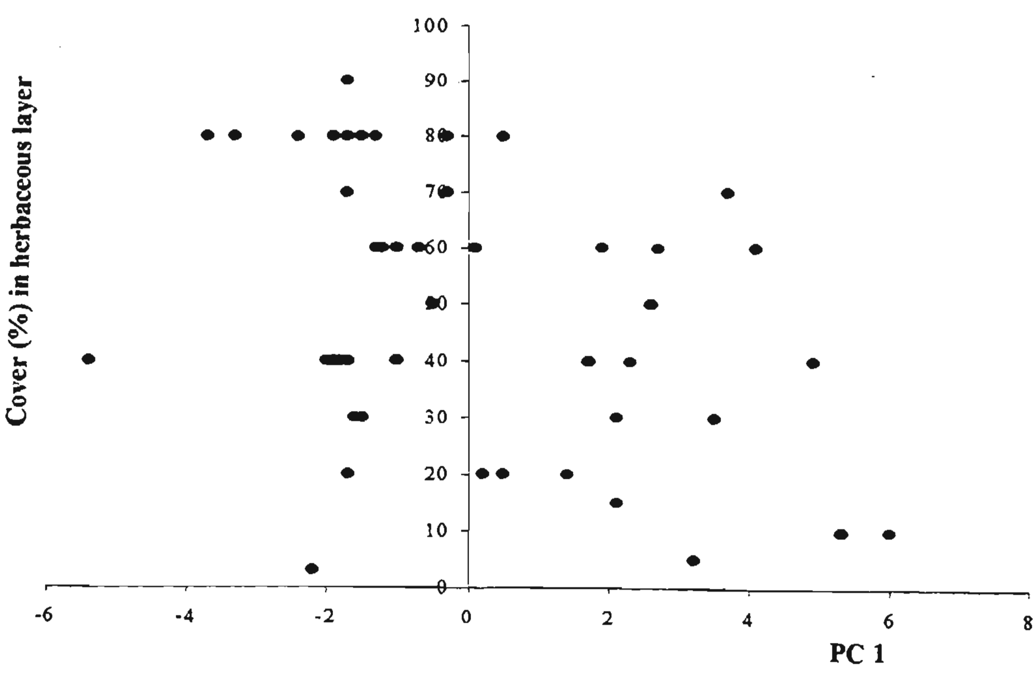


Table 4.4: Soil colour and texture in the vegetation types identified in *kaya* Fungo

Community	Sub-community/ stage/sub-stage	Relevés (%) on white sandy soils	Relevés (%) on pale grey sandy-loam soils	Relevés (%) on pale black sandy-loam soils	Relevés (%) on black sandy-loam soils
***Uvariodendron* dense forest community**	*Grandidiera* sub-community (n=17)	0	5.9	17.6	76.5
	***Uvariodendron senso stricto* sub-community**				
	Hunteria stage (n=4)	0	0	0	100
	***Salacia* stage**				
	Blepharespermum sub-stage (n=5)	0	20	20	60
	Haplocoelum sub-stage (n=5)	0	0	20	80
	Excoecaria sub-stage (n=6)	0	33.3	16.7	50
***Acacia* wooded community**	***Acacia reficiens* sub-community**				
	Chloris stage (n=5)	0	100	0	0
	Dalbergia stage (n=7)	0	100	0	0
	***Acacia robusta senso stricto* sub-community (n=16)**	0	93.8	0	6.3
***Brachystegia* woodland community (n=4)**		100	0	0	0
Undetermined vegetation unit (n=4)		25	75	0	0

The amounts of ground surface litter varied considerable between vegetation types (Table 4.5). Abundant litter was mostly recorded in *Uvariodendron* community; in *Acacia* community the amount of litter ranged from absent to abundant; and in *Brachystegia* community the litter was sparse (Table 4.5).

Table 4.5: Relative amounts of ground surface litter in the vegetation types identified in *kaya* Fungo

Plant community	**Sub-community /stage/sub-stage**	**Litter absent (Relevés %)**	**Litter sparse (Relevés %)**	**Litter common (Relevés %)**	**Litter abundant (Relevés %)**
***Uvariodendron* community**	*Grandidiera* sub-community (n=17)	0	5.9	17.6	76.5
	Hunteria stage (n=4)	0	0	25	75
	***Salacia* stage**				
	Blepharespermum sub-stage (n=5)	0	20	20	60
	Haplocoelum sub-stage (n=5)	0	0	20	80
	Excoecaria sub-stage (n=6)	0	33.3	16.7	50
Acacia robusta community	***Acacia reficiens* sub-community**				
	Chloris stage (n=5)	20	40	40	0
	Dalbergia stage (n=7)	14.3	28.6	28.6	28.6
	***Acacia robusta senso stricto* sub-community (n=16)**	12.5	37.5	12.5	37.5
***Brachystegia* community** (n=4)		0	100	0	0
Undetermined vegetation unit (n=4)		25	25	50	0

The vegetation data in the PCA hyperspace defined by PCs 1 and 2 showed that the vegetation distribution was influenced to a large extent by soil fertility along PC 1, and to a lesser extent by soil acidity along PC 2 (Fig. 4.10). Based on the length of the vectors, Ca, Zn, clay and total cations had the most influence along the soil fertility axis, while acid saturation, exchange acidity and pH had the most influence along the soil acidity axis (Fig 4.10). Mn and K were of least influence in the vegetation distribution.

In the PCA hyperspace the stages and sub-stages of *Uvariodendron* community (*Hunteria* stage, and *Blepharespermum, Haplocoelum,* and *Excoecaria* sub-stages) were mainly ordinated on the positive pole of PC 1. *Grandidera* sub-community includes the above named stage and sub-stages, except *Excoecaria* sub-stage. But *Grandidera* sub-community was partly ordinated on the negative pole of PC 1 axis. The vegetation sub-types of *Acacia robusta* community (*Chloris* and *Dalbergia* stages, and *Acacia robusta senso stricto* sub-community), and *Brachystegia* community were common towards the negative pole of PC 1 (Fig. 4. 11). This suggests that the dense forest *Uvariodendron* community, occurred on soils of relatively high fertility status, while the *Acacia* and *Brachystegia* communities occurred on relatively low fertile soils. The ordination of *Uvariodendron* and *Acacia* communities in the PCA hyperspace, and their ground distribution, supports the assumption that the disturbance level, which was negatively associated to soil fertility (Fig. 3.28), increases gradually towards the forest periphery. This assumption however, was not supported by life-form variety (Table 2.12) and vegetation structure (Table 2.13) in *Uvariodendron* community.

While the grass-dominated stage (*Chloris* stage) was found on both nutrient rich and nutrient poor soils, the shrub-dominated (*Dalbergia* stage) was exclusively found on nutrient poor soils (Fig. 4.11). The high soil fertility in parts of *Chloris* stage might be attributed to burning which resulted in higher levels of available nutrients and a temporary higher soil fertility. The ordination of *Acacia robusta senso stricto* sub-community on the negative pole of PC 1 (Fig. 4.11) emphasised that *Acacia* community was generally a vegetation type found on relatively nutrient poor soils. The *Brachystegia* community was ordinated to suggest that it occurred on the poorest soils compared to other vegetation types (Fig. 4.11).

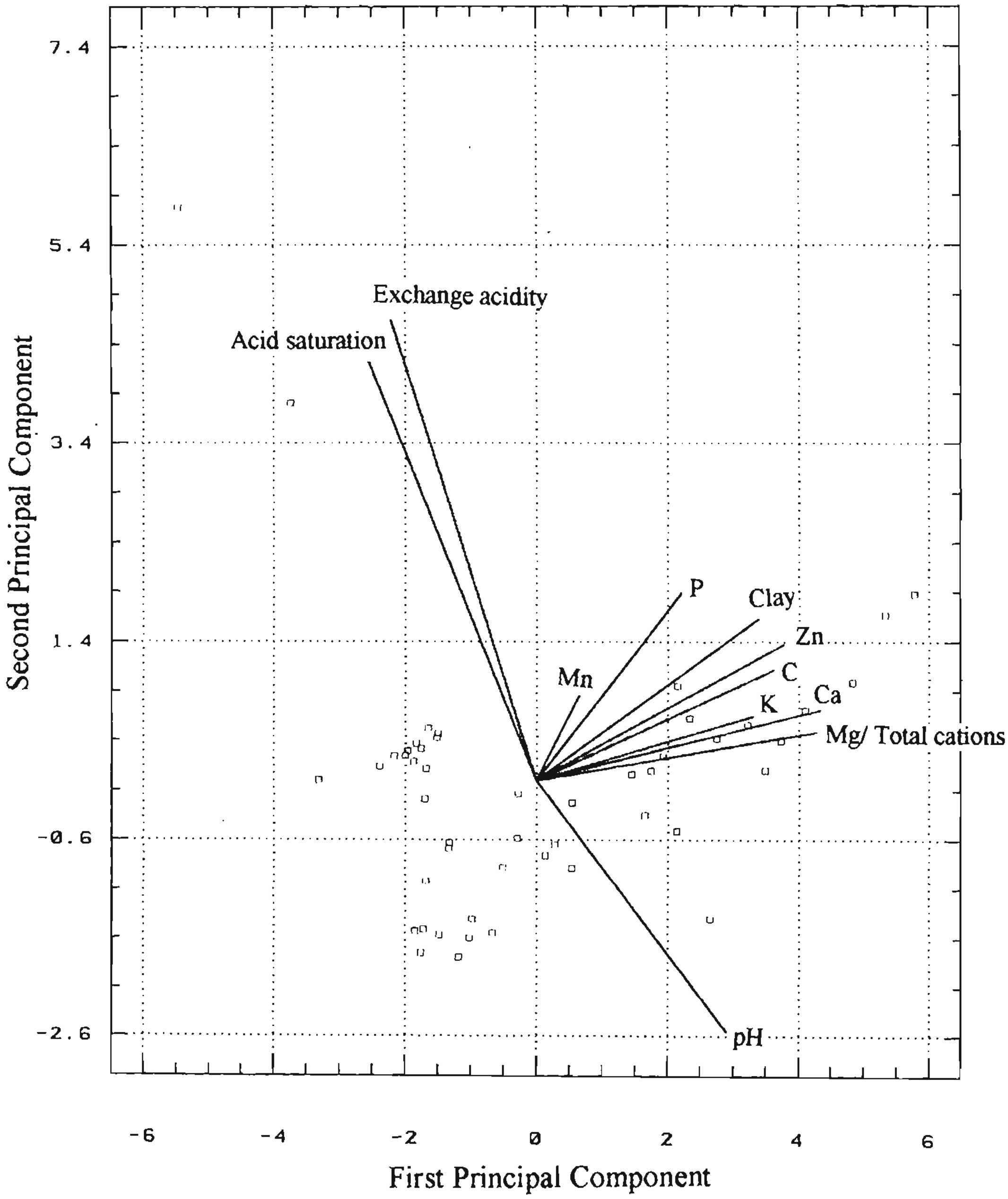
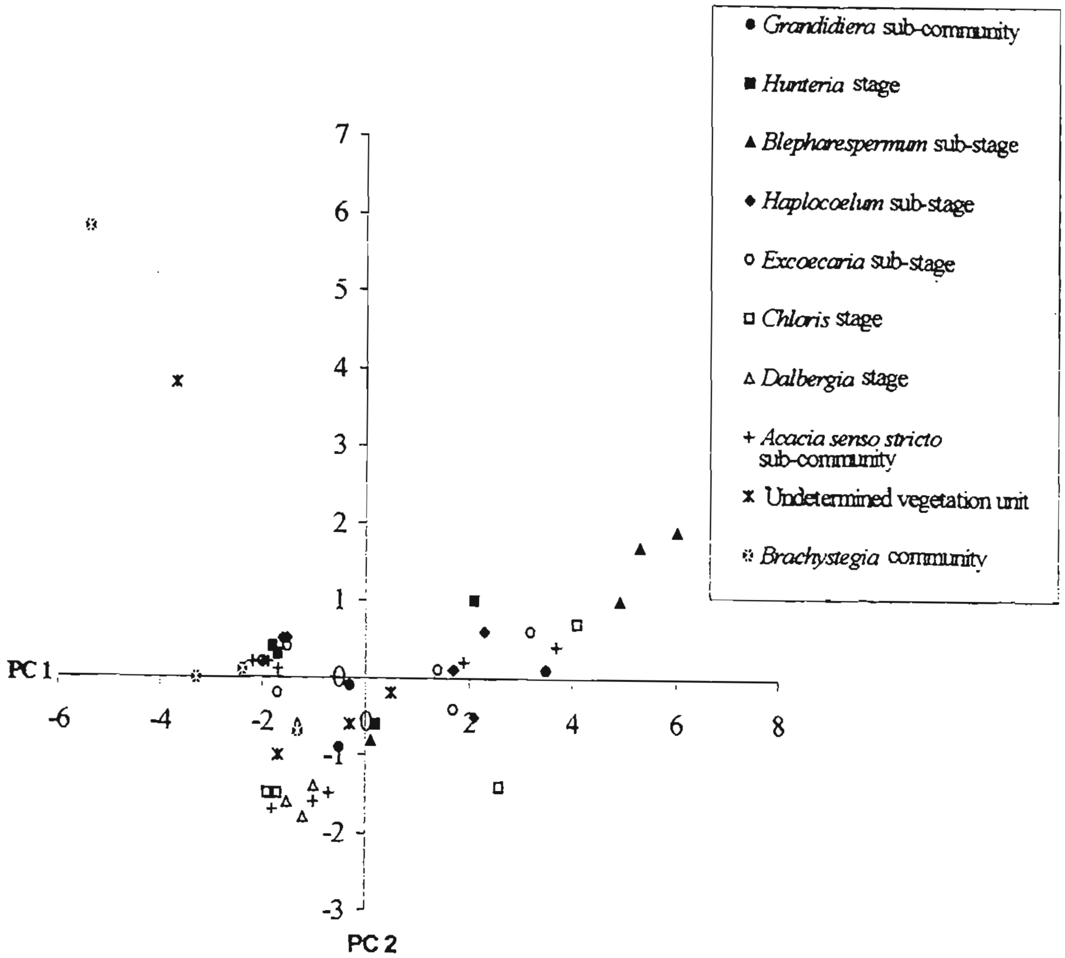


Fig. 4.10: Ordination of sampled relevés in relation to the soil variables (for soils collected from *kaya* Fungo)

Fig. 4.11: *Kaya* Fungo vegetation types plotted in the PCA space defined by the first and second Principal Components



Mean values of soil variables for each vegetation type are given in Table 4.6. In *kaya* Fungo, the relatively dense forest *Uvariodendron* community (specifically the *Blepharispermum* sub-stage), compared to the other vegetation units, had the highest mean values of total cations, Ca, Mg, K and Zn, phosphorus, organic carbon and pH, and the lowest mean values of acid saturation (Table 4.6). While the open woodland *Brachystegia* community had the lowest mean values of total cations, Ca, Mg, K and Zn, pH and organic carbon, but the highest mean values of exchange acidity, acid saturation and a high mean value for Mn (Table 4.6). These observations support the general comment in the PCA that the dense forest communities occurred on relatively high fertile and less acidic soils, while the *Brachystegia* woodland vegetation occurred on the low fertile, acidic soils (Fig. 4.11).

Within the *Uvariodendron* community, the *Grandidiera* and *Uvariodendron senso stricto* sub-communities shared vegetation sub-units, possible explaining the close similarities in the soil chemical properties between the two sub-communities. The mean values of the soil variables for sub-stages in the *Salacia* stage, with reference to the ground distribution, suggests that soil fertility, pH and organic carbon tend to decrease towards the forest periphery, while soil acidity increases (Table 4.6).

The soils in the *Acacia robusta* community, compared to the other communities, generally had moderate fertility and acidity (Table 4.6). The soils in the grass dominated *Chloris* stage, had higher mean values of Ca, Mg, clay, organic carbon and a high pH, compared to soils in the shrub dominated *Dalbergia* stage (Table 4.6). However, the soil data of *Chloris* stage was characterised by a considerable inter-sample variation as indicated by the high values of the standard deviation (Table 4.6). This is because the soil fertility and acidity within *Chloris* stage ranged from relatively nutrient poor (total cations = 2.9me100g^{-1}) to nutrient rich (16.1me100^{-1}), and from very low pH (4.9) to relatively high pH (7.0).

Table 4.6: Mean values of soil chemical variables* for different vegetation types identified in *kaya* Fungo

Vegetation type	P	K	Ca	Mg	Zn	Mn	Exchange acidity	Total cations	Acid saturation	pH	Organic carbon	Clay content
***Uvariodendron* dense forest community**												
Grandidiera sub-community	11.2^{d} (5.6)	219.0 (134.9)	1070.1^{bc} (576.0)	256.5 (144.0)	2.0^{ab} (1.2)	16.3^{abd} (10.0)	0.07 (0.04)	8.8 (4.1)	1.4 (1.5)	5.0 (0.5)	4.3^{ab} (1.1)	19.1 (3.7)
***Uvariodendron senso stricto* sub-community**	10.2^{d} (5.3)	191.7 (132.6)	1019.1^{bc} (546.9)	268.4 (150.0)	1.8^{ab} (1.2)	17.9^{abcd} (8.7)	0.08 (0.04)	8.6 (4.0)	1.6 (1.6)	4.9 (0.5)	4.3^{ab} (1.2)	19.1 (3.3)
Hunteria stage	9.8^{bcd} (6.6)	145.1 (82.6)	735.6^{abc} (368.5)	160.8 (37.3)	1.6^{ab} (1.1)	17.3^{bc} (4.6)	0.1 (0.05)	6.5 (2.5)	2.5 (1.7)	4.7 (0.5)	3.8^{ab} (0.8)	16.5 (2.5)
***Salacia* stage**	10.3^{d} (5.2)	204.1 (142.7)	1094.8^{bc} (571.3)	297.1 (156.4)	1.9 (1.3)	18.1^{abcd} (9.6)	0.08 (0.04)	9.2 (4.2)	1.3 (1.5)	5.0 (0.6)	4.4^{ab} (1.3)	19.7 (3.2)
Blepharispermum sub-stage	16.1^{d} (6.6)	344.6 (178.5)	1600.8^{c} (564.2)	432.2 (143.6)	3.2^{b} (1.4)	13.2^{abcd} (14.7)	0.06 (0.02)	12.6 (3.7)	0.5 (0.6)	5.4 (0.3)	5.2^{b} (1.4)	5.2 (1.4)
Haplocoelum sub-stage	8.0^{cd} (3.2)	165.6 (111.5)	980.6^{bc} (475.2)	211.7 (59.4)	1.6^{ab} (1.1)	24.4^{bc} (4.4)	0.08 (0.05)	8.1 (3.3)	1.6 (1.8)	4.9 (0.7)	4.2^{ab} (1.2)	19.4 (0.6)
Excoecaria sub-stage	8.4^{d} (2.4)	142.5 (78.2)	852.6^{bc} (504.0)	278.1 (176.0)	1.2^{ab} (0.5)	16.2^{abcd} (7.0)	0.08 (0.04)	7.9 (4.2)	1.7 (1.6)	4.7 (0.5)	4.1^{ab} (1.2)	17.8 (1.9)
Acacia robusta* wooded *community												
Chloris stage	3.3^{a} (1.3)	125.5 (48.1)	835.0^{ab} (660.7)	358.0 (357.9)	0.8^{ab} (0.7)	33.1^{cd} (37.5)	0.05 (0.02)	8.4 (6.2)	0.6 (0.6)	5.6 (0.8)	2.2^{ab} (0.8)	16.4 (11.7)
Dalbergia stage	3.8^{ab} (1.9)	193.4 (30.3)	430.2^{ab} (87.4)	161.5 (16.7)	1.1^{ab} (0.4)	13.6^{ad} (9.2)	0.04 (0.01)	5.1 (0.7)	1.3 (0.5)	5.3 (0.4)	1.6^{ab} (0.4)	12.0 (2.9)
Acacia robusta senso stricto sub-community	6.9^{abc} (7.9)	157.6 (82.2)	606.2^{b} (347.6)	189.6 (117.7)	1.1^{ab} (0.7)	6.9^{ad} (7.9)	0.07 (0.05)	6.1 (2.7)	1.6 (1.5)	5.0 (0.6)	2.6^{ab} (1.0)	14.1 (3.6)
***Brachystegia* woodland community**	6.3^{abcd} (3.6)	125.8 (60.5)	256.4^{a} (159.4)	92.0 (48.6)	0.7^{a} (0.4)	21.4^{abcd} (13.8)	0.2 (0.3)	3.3 (1.1)	12.0 (14.2)	4.5 (0.5)	1.3^{a} (0.7)	12.8 (1.7)
Undetermined vegetation unit	7.0^{abcd} (1.3)	180.4 (24.9)	706.9^{abc} (282.9)	176.8 (68.2)	1.1^{ab} (0.3)	10.5^{abcd} (1.8)	0.05 (0.01)	6.5 (2.1)	1.0 (0)	4.9 (0.2)	2.6^{ab} (0.9)	16.3 (2.9)

* For units of the soil variables see text; The means in the columns followed by different letters (a, b, c) are significantly different with a Scheffe multiple range test (for normally distributed data) or Mann-Whitney test (for data that is not normally distributed)

4.4 DISCUSSION

4.4.1 Influence of soil factors on vegetation

The observations made in this study indicated that vegetation characteristics and types could be described only in part by soil factors, particularly soil fertility or nutrient availability. The response of vegetation to soil fertility variability differed in *kaya* Mtswakara and in *kaya* Fungo. In both *kayas* species richness was significantly related to changes in soil fertility. In *kaya* Mtswakara the response (Fig. 4.1) showed that relatively low soil fertility was limiting to species richness; while in *kaya* Fungo increase in soil fertility corresponded to decrease in species richness (Fig. 4.8). It is a reasonable conclusion from the *kaya* Mtswakara data that, while very low base concentrations lead to strong limiting conditions for plant species, it favours specialist stress-tolerator species (Bazzaz 1996). The emergent layer and shrub layer cover values in *kaya* Mtswakara significantly increased with an increase in soil fertility (Fig. 4.5), suggesting that member species of these layers either were responding to increase in soil fertility or were perhaps significant in maintaining such fertility by counter-acting losses from the vegetation-soil system. The relatively higher species richness on infertile soils in *kaya* Fungo is difficult to explain but may have been due to secondary factors related to soil fertility, such as vegetation disturbance (Fig. 3.28), which created new opportunities for introductions of other species into the disturbed areas (Bazzaz 1996).

In this study it was established that, in both *kayas*, there was a clear distribution pattern of dense forest and open woodland vegetation types, that could be related to soil factors, particularly the base status (soil fertility). These conclusions were established from both the PCA of vegetation and soil data, and the statistical analysis of the soil data associated with different vegetation types. Generally the dense forest communities (in both *kayas*) were on the relatively nutrient rich, sandy-loam soils, that were less acidic; while the woodlands were on nutrient poor, sandy, acidic soils. In particular the dense forests in *kaya* Mtswakara were differentiated from woodland vegetation due to the high Zn and phosphorus concentrations, and low acidity in the soils; while in *kaya* Fungo, Ca and phosphorus concentrations were the most important, surprisingly acidity was not. The general cation deficiencies probably indicate that, in both *kayas*, the soils in *Brachystegia* communities were highly weathered

(Binkley & Vitousek 1989). A comparison between the soils in the *Brachystegia* communities in *kayas* Mtswakara and Fungo, shows that in addition to the physiognomic difference in the presence of outcrop rocks in *kaya* Mtswakara, the clay contents in *kaya* Mtswakara were statistically significantly higher than in *kaya* Fungo.

The observation that *Brachystegia* community occurred on infertile acidic sand soils, confirmed similar observations made by Moomaw (1960) and White (1993). In that, Moomaw (1960) noted that on the Kenyan Coast, *Brachystegia* community was an edaphic vegetation type developed only on freely drained sands, while White (1993) described *Brachystegia* vegetation to be a result of the edaphic conditions, and was a particularly stable vegetation on infertile sands or shales. Moomaw (1960) recorded stands of *Brachystegia* vegetation south of Bamba, and identified the soils to be fine-textured sands derived from Mariakani sandstone. In the Shimba Hills a vegetation type similar to *Brachystegia* community was found on colluvial soils derived from the Shimba grits and Mazeras sandstone (Schmidt 1991). According to Schmidt (1991) the soils in that vegetation type were shallow sandy-loams, which were excessively drained.

According to White (1983), *Brachystegia* woodland is usually found on nutrient deficient soil that is too unfavourable to permit the complete succession to a dense forest. In soils, nutrients can be depleted through plant uptake and leaching (Singer & Munns 1987), but the most likely cause of nutrient deficiency in *Brachystegia* soils was leaching. The low clay and carbon content in *Brachystegia* soils are likely to have led to lack of nutrient retention potential (Singer & Munns 1987) and excessive drainage (Schmidt 1991), which in turn facilitated leaching. According to Singer & Munns (1987) leaching can independently lead to high soil acidity. Therefore, the high soil acidity in the *Brachystegia* communities were probable facilitated by the base-cation deficiency. Acid-related factors are limiting to plant growth, through acidity itself, Ca deficiency, and toxicity due to associated cations like Al^{3+} (Singer & Munns 1987). Since plant species have different sensitivity to soil acidity, with sensitive plant species inhibited in high acidic conditions (Singer & Munns 1987), soil acidity was likely to be the principal factor selecting for specialist species in the *Brachystegia* community and selected against the sensitive species common to the other vegetation types.

Moomaw (1969) recorded a vegetation type similar to dense forest *Scorodophloeus* and *Hugonia* communities in Mtswakara, on sands of heavy texture and low essential cations. This is in contrast to the results in this study, because these communities were recorded in fine-textured sandy-loam soils with high levels of cations, particularly Ca and Mg (London 1991). A vegetation type similar to the *Uvariodendron* community in Fungo, identified in other parts of the Kenya Coast by Hawthorne (1993), was associated with high calcium-magnesium concentrations. In this study the Ca levels in *Uvariodendron* were noted to be significantly higher than in the other vegetation types, but the Mg levels were statistically not higher.

The disparity in the patterns within and between communities (the dense forest, the woodland and wooded communities) for both *kayas*, suggests that the floristic variations as identified in the TWINSPAN classification are not fully explained along soil gradients. In *kaya* Mtswakara the major soil division in the PCA ordination corresponded to the second division of the TWINSPAN vegetation classification, where the *Brachystegia* community was separated from the other vegetation types. In *kaya* Fungo the major soil division in the PCA ordination corresponded to the third vegetation classification in the TWINSPAN. The other divisions in the TWINSPAN classifications were not clearly accounted for along the soil gradients. An indication that the vegetation variation and distribution was not a result of the influence of soil *per se* (Eyre 1968) for both *kayas*. In addition, it must be clearly noted that soil can be dependent on other factors (Hawthorne 1993), which include the vegetation type itself.

Based on historical information and additional observational field data, another important factor, which affected the vegetation of the two *kayas* was human activities, a conclusion that was shared with Moomaw (1960) and Hawthorne (1993). According to those authors, the vegetation type represented by *Asteranthe* community group (in *kaya* Mtswakara), was previously found in extensive blocks at the Kenya Coast, but has completely disappeared in the south and is rapidly disappearing in the north. Moomaw (1960) identified anthropogenic fire and cultivation as the main factors responsible for the disappearance of the vegetation type. In *kaya* Fungo, recounted historical information by the *kaya* elders and the community guards, suggested that the thorny scrub and wooded grassland vegetation types (*Acacia* community) to have been spreading with time at the expense of the dense forest *Uvariodendron* community. The guards identified fire as the main cause of the local vegetation transformation in *kaya* Fungo.

4.4.2 Effects of historical factors on the vegetation

Historically, the *kayas* have been subjected to human activities in and around them from as early as the 16th Century (Spear 1978). Some of the human activities were noted to take place during the fieldwork of this study. These included pole cutting, medicinal plant collection, small mammal and bird hunting, grazing, burning and farming. Human activities over a period of time are a potential causal factor of vegetation transformation from one type to another (Mueller-Dombois & Ellenberg 1974). The human activities likely to be most important in vegetation degradation and/or transformation in the two *kayas* included pole cutting, clearing and farming, fire and browsing by domestic animals. The effects of these mechanical activities on the vegetation contrast the subtle effects of nutrients, because the effects of the former are usually rapid and almost immediately (Mueller-Dombois & Ellenberg 1974). However, mechanical activities can also act in a gradual way e.g. by inducing gradual change of a habitat, or through influencing invasion and introduction of new species, and the impact can be temporary or permanent.

Effects of plant resource extraction on vegetation

In both *kayas* plant resource collection was common, and the most common activities were pole cutting (Plate 4.1) and firewood collection (Plates 4.2a and 4.2b). The most exploited were the canopy tree species forming the emergent or the short tree canopy layers of the forest (Tables 4.7, 4.8). The quantity and frequency of extraction, therefore, determined the intensity of high canopy cover removal. Removal of the canopy layer is likely to result in creation of vegetation gaps that allows in sunlight; a condition that 'attract' opportunistic species adapted to full sunlight conditions (Bazzaz 1996). In this study, non-forest bushes i.e. shrub and climber species common outside dense forest, were noted in the dense forest areas (Tables 4.7, 4.8), an observation also made by Hawthorne *et al.* (1981) in kaya Kambe. According to Hawthorne *et al.* (1981) climber and some shrub species physiologically develop mechanisms that enable them to exploit the effects of disturbance, because of the ability to invade and exploit these ephemeral openings (Givnish 1984, 1995). Some shrub species have both erect and climbing forms and can be successful as the climbers when opportunities arise (Hawthorne *et al.* 1981). Climber species gain a competitive edge by allocating relatively little energy to support tissue to achieve an increase in height (Vázquez & Givnish 1998) and to rise up to the top of regenerating trees in the gap-openings, and sometimes persist even after shade has returned to the understorey.

Table 4.7: Canopy tree species extracted from dense forest vegetation and opportunistic[1] species recorded in the dense forest vegetation in *kaya* Mtswakara

Extracted canopy tree Species	**Opportunistic species**
Cynometra suaheliensis	*Thespesia danis*
Manilkara sulcata	*Vittelariopsis kirkii*
Craibia brevicaudata	*Lantana camara*
Scorodophleous fischeri	*Salvadora persica*
Cynometra webberi	*Heinsia crinita*
Julbernardia magnistipulata	*Monanthotaxis fornicata*
Brachystegia spiciformis	*Canthium mombazense*
	Carissa tetramera
	Ancylobotrys petersiana
	Uvaria lucida
	Psychotria amboniana
	Ochna mossambicensis
	Pentarhopalopilia umbellulata
	Psydrax polhilii
	Synaptolepis kirkii
	Psdrax recurvifolia

[1]Opportunistic species refers to species that are commonly found outside the dense forest areas, but are 'attracted' to and exploit the vegetation openings (gaps) in the dense forest vegetation.

Table 4.8: Canopy tree species extracted from dense forest vegetation and opportunistic species recorded in the dense forest vegetation in *kaya* Fungo

Extracted canopy tree species	**opportunistic species**
Combretum schumannii	*Acalypha neptunica*
Manilkara sulcata	*Heinsia crinita*
Milicia excelsa	*Uvaria acuminata*
Cola minor	
Craibia brevicaudata	

In *kaya* Fungo *Combretum schumannii* (Plate 4.3) and *Milicia excelsa* (Plate 4.4) were heavily extracted in the past. Over 80% of the standing mature trees of *Combretum schumannii* were sprouting from mother trees that had been extracted in the past.

Emergent and short tree species are important in modifying microclimates, hence important for the presence of shade tolerant species in the understorey. Both light intensity and quality change as the light passes through the canopy (Bazzaz 1996), with the upper tree (euphotic) layer receiving maximum (25 – 100%) illuminance, and the lower (oligophotic) layer receiving relative decreased illuminance (Longman & Jenik 1987). Species physiologically adapted to exploiting shade conditions e.g. *Sellaginela spp*, (Longman & Jenik 1987) suffer dessication when the emergent trees are removed and gaps are created (Hawthorne *et al.* 1981) due to environmental conditions that exceed their ecological tolerance (Givnish 1984). Therefore, in addition to the impacts on the extracted tree species, the canopy removal may be sufficient to induce local extinction of species adapted to shade (Halpern & Spies 1995).

Another important extraction activity from both *kayas* was firewood collection (Plates 4.2a and 4.2b). Traditionally firewood collection in the *kayas* applied only to dead wood. Although dead wood collection leads to the removal of nutrients from the system, specific consequences resulting from dead wood collection from the *kayas* were unclear. Most of the tropical soils are known to be nutrient poor, but carry luxuriant stands of forest, with a large proportion of the nutrients contained within the living biomass, the fallen logs and litter, and is recycled through closed cycles with great efficiency (Longman & Jenik 1995). Excessive dead wood collection, therefore, could lead to excessive losses and consequent open nutrient cycling, and ultimately affect the vegetation structure and type. Details on the amount of dead wood collected from the *kaya* and the impact of the collection on the vegetation types could be an interesting future study.

Effects of clearing and farming on vegetation

Clearing natural vegetation for agricultural purposes is one of the main ways in which successional habitats are created (Bazzaz, 1996). In both *kayas*, cases of clearing of forests for farming were encountered (Plates 4.5a and 4.5b). Observed impacts included the introduction of the exotic species such as *Thevetia peruviana*. In *kaya* Fungo, relevé 9 (Plate 4.6) was sampled on an area that had been cleared for farming in the previous year, and the vegetation was transformed such that herbaceous (*Agathisanthemum bojeri*) and shrub species (*Thespesia danis, Lamprothamnus zanguebaricus* and *Acalypha fruticosa*) dominated. Both emergent and short trees layers were absent in relevé 9. Also relevé 18 was sampled near an abandoned farm (about 2 years ago) and the common species included a non-forest invasive shrub species, *Lantana camara*. In this relevé the emergent layer was absent, and single individuals of *Lannea schweifurthii* and of *Croton talaeporos* represented the short tree layer. The community guards, however, identified the two sites (relevés 9 and 18) to have been part of the dense forest type about 20 years ago.

In *kaya* Mtswakara, relevés 3 and 12 (Plate 4.7) were previously farmed areas, and relevés 47, 50 and 51 were along the forest edge. Relevés 12, 47, 50 and 51 were physiognomically different from relevé 3, and in the TWINSPAN classification relevés 12, 47, 50 and 51 were identified as part of the *Acacia* community, and relevé 3 in the *Brachystegia* community. The differences between relevé 3 and the other relevés was likely to be due to the absence of continued disturbance in relevé 3, such that after abandonment from agricultural use (about 30 years ago) the vegetation re-developed back towards the original type without further stress. Although cultivation stopped in relevé 12 about two decades ago, the area has continuously been subjected to continuous stress by factors such as fire and grazing, which arrest possible regeneration processes back to the original vegetation type. Vegetation in relevés 47, 50 and 51 were continuously cleared by the neighbouring farmers, to maintain visibility of wild animals originating from the *kaya* that move onto their farms and damage their crops.

The effect of clearing and farming, therefore, facilitated transformation of dense forest to wooded grasslands and scrub-lands (*Acacia* communities) in both *kayas*, and creating suitable conditions for the introduction of exotic and invasive plant species that might pose an ecological threat on the indigenous vegetation.

Effects of herbivores on vegetation

Signs of grazing, which included faecal of domestic animals, observations of footprints of domestic animals, cattle footpaths and direct observation of domestic animals (cattle, sheep, goat and donkeys) in the *kayas*, were noted in both *kayas* Mtswakara and Fungo. In *kaya* Fungo animal rearing appeared to be more important than in *kaya* Mtswakara, both in terms of animal numbers and occurrence in homesteads. In *kaya* Mtswakara goats were the common livestock animals, while in *kaya* Fungo there was a mixture of different types of livestock.

Herbivores can function as determinants of the vegetation type (Cumming 1982) especially in converting forest areas to grassland. Selectivity by herbivores can influence ecosystem recovery process by differentially affecting species performance in a plant community (Bazzaz 1996). Plant species palatability to particular grazers, and the density of the animal populations, determine the effects on populations of the palatable plant species, where palatable species may be eliminated and unpalatable species promoted (Burrows, 1990). Despite the generally known effects of herbivores on vegetation (Cumming 1982), in the *kayas* there were no exclusive grazed areas and non-grazed areas; there were no data on intensity and frequency of grazing; and there was no information on particularly biological adaptive features of specific plant species to grazing. Thus, it was difficult to make conclusions on the effects of grazing in the *kayas*. However, based on field observations it was probably the case that grazing was not acting independently of other factors, particularly burning; and in fact grazing was probably a secondary factor to forest clearing and burning.

Effects of Fire on vegetation

In both *kayas* incidents of fire were common (Plates 4.8a and 4.8b). Relevés 8, 11, 13, 45, 47, 50 and 51 in *kaya* Mtswakara; and relevés 4, 7, 26, 34, 35 and 47 in *kaya* Fungo were established in areas that had been affected by fire, and subjected to grazing. All the fire incidents in and around the *kayas* were anthropogenic in origin. From historical information, the fires were usually started by hunters who burn forest areas to create better visibility of their hunt, honey gatherers who use fire to harvest honey from tree beehives, and by farmers who burn their fields after or before clearing. The fires would in some cases spreads into the *kayas*. Although frequent burning is considered to favour grassland habitat, in the absence of fire or sites subjected to low intensity fires, there can be encroachment by woody shrub species (Ellery 1992). The fires in the *kayas* were not consistent nor planned.

Regeneration of the vegetation after a burn begins by establishment of herbs and shrubs from the soil seed banks or by sprouting of many of the shrubs from unburned basal or underground organs (Burrows 1990). According to Burrows (1990) seeds of some herbaceous species may be in a dormant condition for 40-50 years and germinate when favourable conditions prevail. The most common herb species recorded in burnt areas (releves 8 and 11 in *kaya* Mtswakara) were: *Panicum maximum, Commelina sp, Cyperus sp., Agathisanthemum bojeri, Waltheria indica, Asystesia gangetica* and *Blepharis maderaspatensis*. Other less frequent species were *Aspilia mossambicensis, Heteropogon contortus, Tragia furialis, Jatropha hildebrandtii, Cissampelos pareira* and *Tinnea aethiopica*. In *kaya* Fungo the most common herb species recorded in recent burnt areas were *Panicum maximum*, *Eragrostis superba, Dactyloctenium geminatum, Enteropogon sechellensis, Chloris roxiburghiana, Agathisanthemum bojeri,* and *Vernonia hildebrandtii*. Macdonald (1978) noted that fire improved site conditions for the germination of grasses, particularly *Panicum spp*.

The shrub species in the fire-affected sites were commonly noted to sprout from the base or roots (Plate 4.9). Re-sprouting from dormant epicormic buds on the stem or at the stem/root junction, or from sub-terranean roots and lignotubers after a fire, is a common feature for shrub species (Granger, 1984), and leads to the relative abundance of shrub species in burnt sites. Macdonald (1978) noted that after a fire *Euphorbiacea spp., Solanum spp.,* and *Lantana camara* exploit the conditions. In this study, these species were not of particular importance or presence in the burnt areas, instead a variety of shrub and short tree species were common in the areas affected by fire (Tables 4.9, 4.10).

Table 4.9: Common and rare species in areas burnt (a year or less before) in *kaya* Mtswakara

Common species recorded in areas affected by fire	Less frequently recorded species in areas affected by fire
Grewia plagiophylla	*Triumfetta rhomboidea*
Hoslundia opposita	*Heinsia crinita*
Ximenia americana	*Maerua triphylla*
Deinbolia borbonica	*Diospyros squarrosa*
Thespesia danis	*Commiphora edulis*
Terminalia spinosa	*Cyphostema adenocaule*
Allophylus rubifolius	*Mildbraedia carpinifolia*
Premna chrysoclada	*Tephrosia villosa,*
Dalbergia melanoxylon	*Thecocaris bussei*
Catunaregam nilotica	*Hyphaene compressa*
Strychnos spinosa	*Uvaria acuminata*
Bridelia cathartica	*Uvaria lucida*
Acacia etbaica	*Diospyros bussei*
Acacia mellifera	*Ochna mossambicensis*
Strychnos madagascariensis	*Grewia densa*

Table 4.10: Common and rare species in areas burnt (a year or less before) in *kaya* Fungo

Common species recorded in areas affected by fire	Less frequently recorded species in areas affected by fire
Acacia reficiens	*Ximenia americana*
Grewia plagiophylla	*Thevetia peruviana*
Allophylus rubifolius	*Melhenia vellutina*
Thespesia danis	*Terminalia spinosa*
Catunaregam nilotica	*Haplocoelum inoploeum*
Grewia densa	*Fluegea gueenense*
Croton talaeoporos	*Capparis vimenea*
Lamprothamnus zanguebaricus	*Maerua triphylla*
Dalbergia melanoxylon	*Ochna mossambicensis*
Hoslundia opposita	*Polysphaeri pervilei*
Deinbolia borbonica	*Premna chrysoclada*
Bridelia cathartica	*Lecaniodiscus fraxinifolius*
Acacia nilotica	*Cissampelos pareira*

Table 4.10: Continued

Acacia mellifera	*Pyrenacantha vogeliana*
Acacia robusta	*Ancylobotrys petersiana*
Flueggea virosa	*Zanthoxylum chalybeum*
	Carissa tetramera
	Diospyros sp
	Abutilon mauritianum

Hyphaene compressa is a good indicator species of areas affected by fire (Luke pers. comm.), but for the other species it was not clear whether they were actually favoured by the fire. There were no previous data for the sites prior to fire activities for a comparison to be made. The shortfall in the *kaya* Mtswakara data is that it is based on only two relevés (8 and 11). In addition, for both *kayas*, these observations were made from relevés that were affected by both fire and by grazing, therefore, the results could not be said to be due to fire alone.

Based on the above observations, fires tend to favour wooded grassland and scrubland vegetation at the expense of forest vegetation. However, in both *kayas*, fire appeared to be secondary factor on already cleared areas, and only maintained the wooded grassland/scrub-land vegetation. A combination of grazing and fire is known to result in a scrubby vegetation type in which the common trees include *Acacia spp.* (Burrows 1990) as observed in this study (Plate 4.10). It might be that burning and grazing enhanced the development of the *Acacia* communities, and maintain the existence of these vegetation types in both *kayas* Mswakara and Fungo.

Plate 4.1: Pole cutting from the dense forest area in *kaya* Mtswakara (Photo taken in September 1998)

Plate 4.2a: Firewood collection activities inside *kaya* Mtswakara (Photo taken in December 1998)

Plate 4.2b: Firewood collection activities in the outskirts of *kaya* Fungo (Photo taken in April 1999)

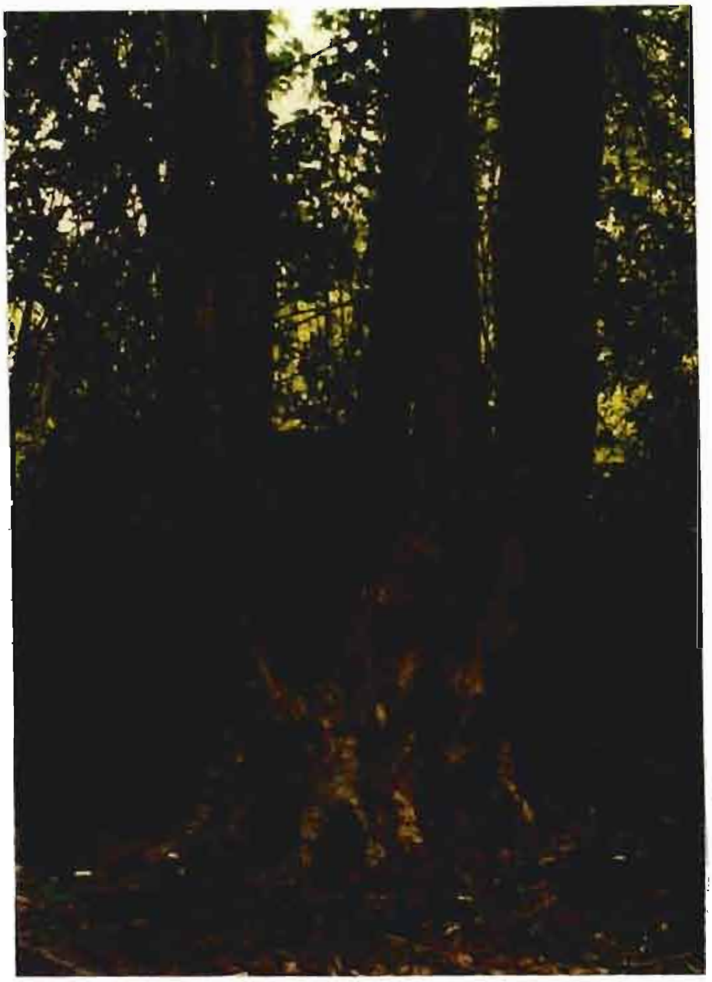


Plate 4.3: Coppicing tree of *Combretum schummannii* following harvesting in *kaya* Fungo (Photo taken in June 1999)

Plate 4.4: Dead stump of *Milicia excelsa* harvested over 30 years ago for timber in *kaya* Fungo (Photo taken in June 1999)

Plate 4.5a: Farming activities and forest encroachment in *kaya* Mtswakara (Photo taken in January 1999).

Plate 4.5b: Farming activities inside *kaya* Fungo area (Photo taken in May 1999).

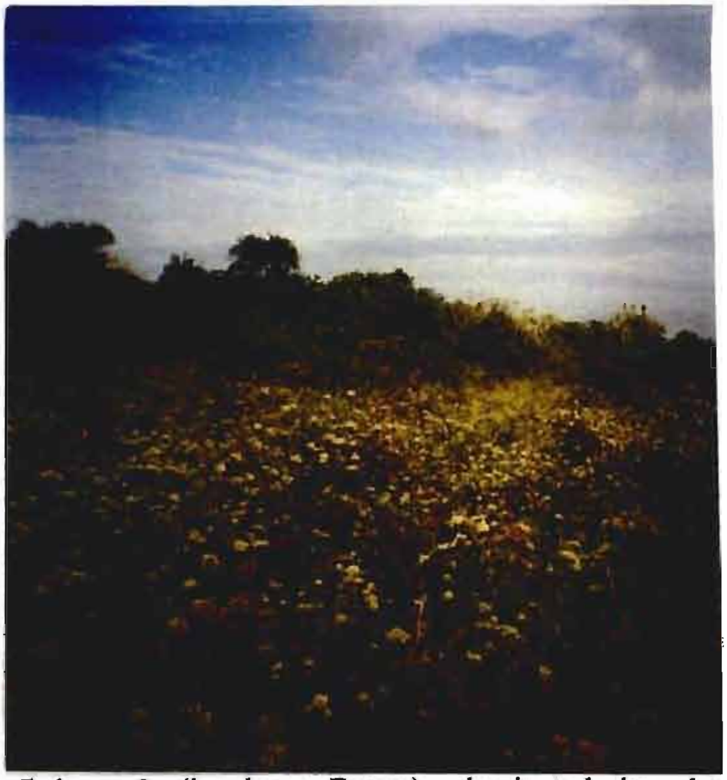


Plate 4.6: Releve 9 (in *kaya* Fungo), dominated by the herbaceous species *Agathisanthemum bojeri*, on which farming occurred in the previous year (Photo taken in May 1999).

Plate 4.7: Releve 12 (in *kaya* Mtswakara), was subjected to crop farming in the past, but grazing and burning continue to affect the vegetation in this area. (Photo taken in December 1999).

Plate 4.8a: Impacts of fire on the vegetation in *kaya* Mtswakara (Photo taken in February 1999)

Plate 4.8b: Impacts of fire on the vegetation in *kaya* Fungo (Photo taken in April 1999)

Plate 4.9: Sprouting shrub species *Flueggea virosa* after a fire in *kaya* Fungo (Photo taken in May 1999).

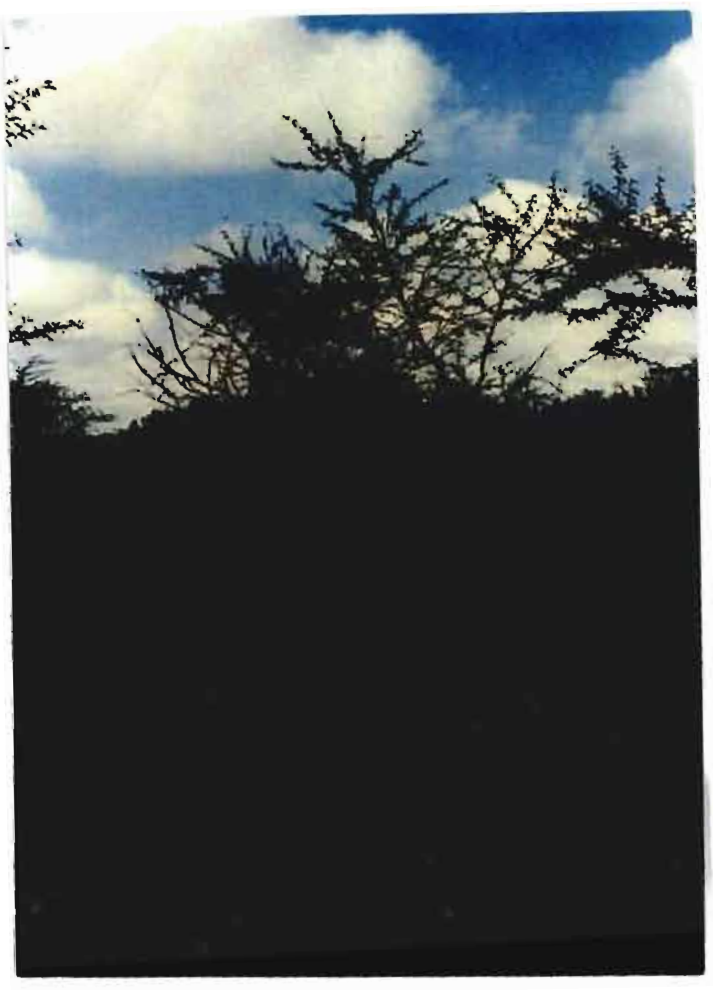


Plate 4.10: The *Acacia robusta* community in *kaya* Fungo is shown to be a product of fire (Photo taken in May 1999).

CHAPTER FIVE
PLANTS USED BY THE DURUMA, GIRIAMA AND DIGO COMMUNITIES

5.1 INTRODUCTION

The dependence of humankind on plants is as ancient as our evolutionary history (Hutchings *et al.* 1996). The indigenous people of the world possess an immense knowledge of their environment based on centuries of living as part of natural systems. Such knowledge is based on observation and on direct use over generations, representing an accumulation of hundreds of years of cultural experience with plant and forest dynamics, and ecosystem phenomena (UNESCO, 1994). In rural communities in 'developing' countries, the locally occurring plant species are relied upon directly for many uses: food, fuel wood, building materials (poles and thatch), crafting, basketry materials, fish poison, lianas for ropes, medicine and magic (UNESCO, 1994). One of the greatest tragedies most likely to happen in the near future, is the rapid loss of this customary and traditional knowledge before it has accurately been recorded for the benefit of current and future generations (Hutchings *et al.* 1996). Significant loss of biological and cultural diversity is very possible as a result of habitat destruction and the gradual weaning away of people from local traditions through the ridicule of local cultures (UNESCO 1994).

In the last few years, ethnobotany has gained momentum as a scientific discipline in Africa (Cunningham & Höft, 1997). General ethnobotanical information has made appearances in a number of publications, these include work by Greenway, 1940 (Swahili), Glover *et al.*, 1969 (Digo); Kokwaro, 1976 (Luo); Morgan, 1981 (Turkana); Mabogo 1990 (Venda); Schmidt 1991 (Digo); Beentje 1994 (an assorted range of the Kenyan tribes); Mbuya *et al.* 1994 (Tanzania), Hutchings *et al.* 1996 (Zulu) and Mugisha, 1997 (Kiga, Ankole).

The *Midzichenda* have a rich heritage of indigenous knowledge on the uses of the biotic diversity in their area. This knowledge, like many other kinds of African cultures, has been transferred form one generation to another orally. Memory has been the fundamental characteristic in keeping this knowledge in existence. This requires cultural responsibility from the individual who receives the knowledge. With the on-going social change, more and more young people distance themselves from the traditions that include ethnobotanical knowledge. The elders in the communities thus do not always have the opportunity to pass on their knowledge to the next generation. Further more the traditional cultural context has been changed by the processes of industrialisation and urbanisation (UNESCO, 1994).

Among the *Midzichenda* community, spirits (*pepho*), souls of the dead and a great fear of sorcery form the pivotal concepts of the traditional life style and beliefs. The spiritual powers, often understood to be negatively influential in human affairs, can be manipulated by medicine men for the achievement of human desires. Relatively, extensive documentation of ethnobotanical information on the Digo (Greenway 1940, Glover *et al.* 1969; Schmidt 1991; Beentje 1994, Pakia 1997) and the Giriama (Beentje, 1994) has been done, but less has been done on the Duruma (Beentje 1994). Too often the *Midzichenda* tribes have been uncritically regarded as one group (Hawthorne *et al.* 1981). Most of the north coast *Midzichenda* tribes have been collectively misidentified as Giriama. This probably accounts for the presence of the ethnobotanical work on the "Giriama" and absence of specific ethnobotanical information on the other groups: Ribe; Rabai; Kauma; Kambe; Chonyi; and Jibana. Despite this generalisation, the nine tribes are linguistically separated and the individual cultures and life styles differ in significant aspects. This study explored the differences in ethnobotanical information between the different *Midzichenda* communities, and inparticular, the Duruma, Giriama and Digo. Especially important is the inclusion of the previosly poorly-represented Duruma community.

5.2 MATERIALS AND METHODS

Ethnobotanical information was collected by interviewing selected respondents from among the local community living around the *kaya* forests. The respondents were selected with the help of the *kaya* guards and *kaya* elders. Only individuals with a good knowledge of plant' names and uses, based on their reputation or their involvement in the utilisation of plant species in their professional activities (local healers, local house constructors and local blacksmiths) were interviewed. Three individuals were involved in the ethnobotanical interviews in each community. In *kaya* Mtswakara (Duruma community) the respondents were Kalume[i], Foyo[ii], and Chuphi[iii]; and in *kaya* Fungo (Giriama community) the respondents were Ngoba[iv], Mwagwaha[v] and Kadzomba[vi]. These respondents were conducted along specific transect walks, individually, through the different identified physiognomic vegetation segments of the *kaya* forest, so that as many plant taxa as possible was encountered. Using a list of plant species developed in the phytosociological study, the respondents were consulted for the ethnobotanical information on the different plant species that were encountered. Ethnobotanical information included plants' vernacular names, use(s), threat levels and harvesting methods. However, plant species not listed in the phytosociological study were also included in the ethnobotanical interviews. In each *kaya*, the three respondents were walked along the same transects, and the same information was sought from each of them. In addition, each respondent was required to repeat information on a plant species a number of times, so as to include any further details that had not been given on the first encounter with the species. This also allowed for confirmation of the respondents' understanding about a particular species.

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[i] Hamisi Kazungu Kalume – A *kaya* guard, aged 48 years. Training to be healer.
[ii] Gatoka Foyo – A practising spiritual healer, aged 65 years
[iii] Mwayaya Chuphi – A *kaya* elder, and retired local house constructor. Aged 80 years.
[iv] Charo Ngoba – A local constructor, and involved in local building poles business.
Aged 55 years.
[v] Mungwari Mwagwaha – A practising spiritual healer. Aged 60 years.
[vi] Mtaveta Kadzomba – A local blacksmith making household implements (including farm implements).
Aged 50 years.

The respondents being local experts in different aspects of plant utilisation, did not and were not expected to give exactly the same information nor to emphasise the importance for each plant species. The difference between them was considered as alternative names and uses rather than right and wrong. Thus most of the information from each of them was considered genuine, except where by subjective assessment, the information seemed unreliable. Additional information on plant names and uses was also obtained from two of the *kaya* guards, Mwatela Chuphi (*kaya* Mtswakara) and Kazungu Pius Torophe (*kaya* Fungo).

In addition, the personal knowledge and understanding of the culture and social system of the *Midzichenda* by the author (being a member of that community and grown up in it), contributed to making decisions on approach and selection of information. Also, the author being a *Midzichenda*, helped to create an atmosphere of mutual trust, conducive for sharing the indigenous knowledge and information.

The information for the Digo used extensively and comparatively throughout this Chapter is original work of the author, produced previously as a report for the UNESCO-People and Plants/CFCU (Pakia 1997).

5.3. RESULTS AND DISCUSSION

5.3.1 Introduction

The information concerning the species names, uses, conservation status and other anecdotal evidence were combined from the three respondents for each *kaya*. Thus an ethnobotanical inventory of species for each *kaya* was compiled. This ethnobotanical inventory which is presented as a description of each species is presented in full as Appendix V. The information in Appendix V is entirely based on the explanations provided by the respondents in the field. Different plant names and uses for a species, either given by the same respondent or by different respondents, are given. The author's subjective opinions and conclusions are based on the information given by the respondents. The ethnobotanical data has been analysed mainly from a qualitative point of view, and discussed in this Chapter as specific themes: plant uses; traditional taxonomy; possible origins of plant uses; comparative plant utilisation among the Midzichenda ethnic groups; and between the Midzichenda and other ethnic groups at a regional scale. The results of this study, particularly the plant names, have been compared with other publidhed ethnobotanical research work.

5.3.2 Uses of plant species by local communities

In this study a total of 321 taxa, representing 219 genera in 76 families, were identified by the respondents to be ethnobotanical important to the local communities living around both the *kayas*, specifically the Duruma and Giriama. About 12% of the plant families contributed about 35% of the taxa used, with the family Euphorbiaceae (in which 24 taxa are used) being the most utilised (Fig. 5.1). Although 10 taxa in family Gramineae were included in the inventory, there was no use identified for six of these taxa. The major plant uses, based on the number of taxa used (in descending order) were: medicinal, magical/spiritual, food (spices/flavours), fibre/tying material, building/construction, sawn timber, symbolic/cleansing, carving/crafting/weaving and poison. Firewood is a major use, but was excluded from this list because although its applicability was possible to most woody species, in the interviews it was not frequently mentioned. The recorded data for firewood therefore was an underestimate. The medicinal and magical uses of plants were the most common uses, for which 55% of the taxa were used. The relative importance of each use is summarised in Figure 5.2. Information on the main plant uses derived from the information gathered from the respondents is discussed below.

Building, construction and crafting

A variety of species were used for building structures that ranged from the residential house, granary, livestock house, to cultural and sacred huts. A wide range of strong, hard and durable timber species (e.g. *Cynometra suaheliensis, C. webberi, Manilkara sulcata, Craibia brevicaudata* and *Scorodophloeus fischeri*) were identified as useful in house building, while reeds such as *Cyperus exaltatus*, and grasses e.g. *Panicum maximum* and *Panicum* sp., are used for building and roof-thatching the houses. The hardwood and good quality wood species (e.g. *Afzelia quanzensis, Milicia excelsa, Bombax rhodognaphalon*) are sources of sawn timber.

Fig. 5.1: The most utilised plant families in the *kaya* forests

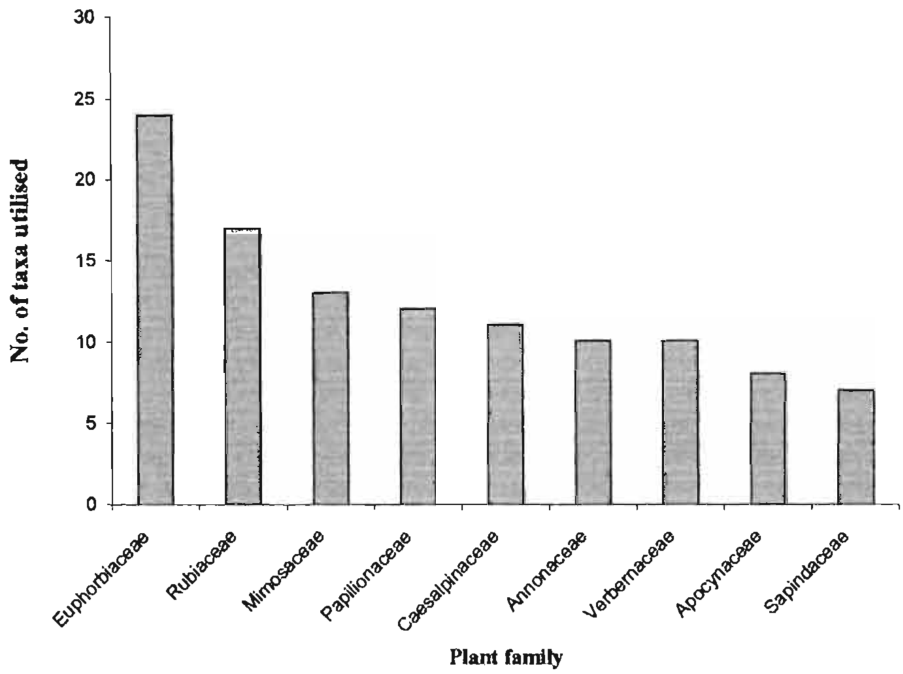
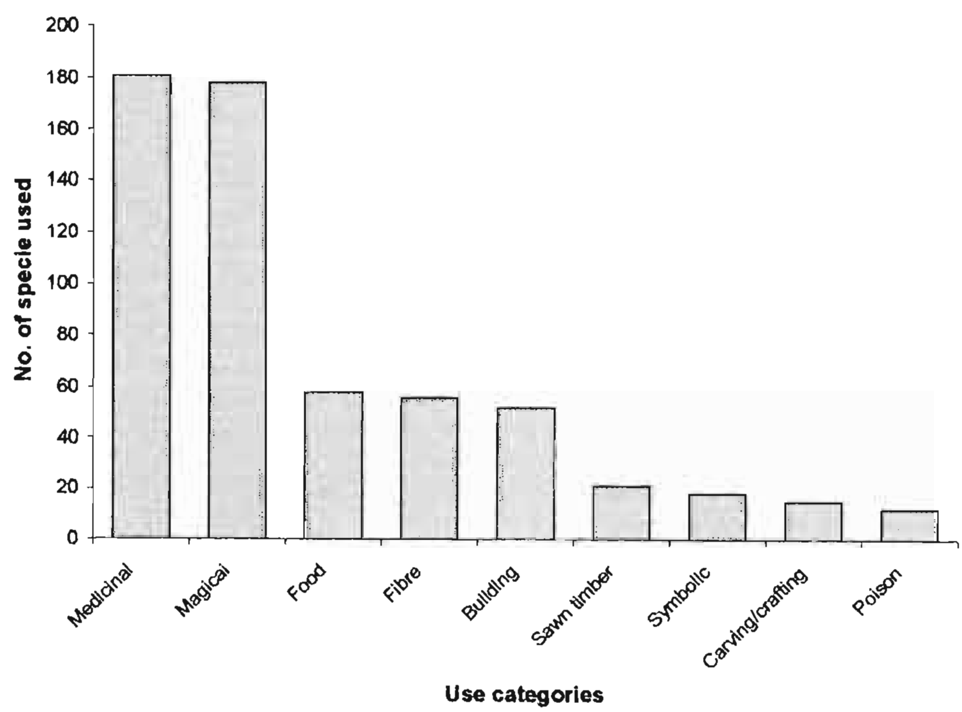


Fig. 5.2: The importance of each of the major uses of forest plant species



Plant species with carvable and durable wood are used for making a variety of traditional household items: mortars (*Dobera loranthifolia, Afzelia quanzensis*); pestles (*Manilkara sansibarensis, Terminalia spinosa*); coconut-graters (*Bombax rhodgnaphalon*); traditional plates (*Milicia excelsa)*; and cooking sticks (*Garcinia livingstonei)*. Flexible branches of hard wood species (e.g. *Grewia plagiophylla*) are used for making bows, and straight growing and relatively lighter stems (e.g. *Heinsia crinata*) are used for making arrows shafts. Because of their flexibility, some lianas (e.g. *Combretum illairi*) and scandent shrub species (e.g. *Grewia plagiophylla*) are used to make fish traps (*migono*) by the Duruma. The Digo use scandent shrub species, *Milletia usramensis*, to make fish traps (*tola*), while the Giriama use flexible scandent shrub species such as *Lantana camara* to make bird-traps (*susu*). The Duruma use water-resistant inner bark fibres of *Brachystegia spiciformis* and *Julbernardia magnistipulata* to make fish traps (*tsasa*). Leaf fibres of *Hyphaene compressa*, which are weavable, are used for making mats, baskets and hats, while leaf rachis of *Encephalartos hildebrandtii* are used for weaving traditional baskets (*lungo*). The spreading inflorescence of *Panicum maximum* and *Panicum* sp., and the spreading branches of *Indigofera sp.* were used for making brooms.

Fuel wood

Culturally, firewood collection is entirely the responsibility of women and girls. From personal observation, the gathering of wood by women was a communal activity, done by two or more individuals belonging to the same or neighbouring families. Axes and hatchets are usually used for cutting wood. Mostly, dry wood was gathered, but incidences of fresh wood collection of preferred species (*Cynometra spp.*) was noted especially in *kaya* Mtswakara. Fallen twigs and dead logs were usually the major target of collectors. There was a notable trend of firewood collectors visiting and collecting from sites that other plant resources (building poles, tool-handle wood and bark fibres) had recently been collected, because in these sites there were substantial amount of "dead" wood remains, which were in fact left-overs of the previous collectors. Although collection of dead wood for fuel was allowed in both *kayas*, the pole collections that usually result in the availability of the dead wood, in most cases had not been authorised.

Collected wood was then piled and tied by ropes into loads that were usually carried on the head. Normally one headload was gathered per trip. The headloads differed in size and weight depending on the age and strength of the collector. Younger collectors carried relatively smaller and lighter loads (5 – 20 kg) while adult and stronger gatherers collected and carried heavier wood loads (>20 kg).

Wild Vegetables

In addition to the cultivated vegetable crops species (pumpkins, sweet potatoes, cabbage, cassava, *nduma, sukuma-wiki,*), the *Midzichenda* community groups heavily rely on the wild vegetable species as well. These include *Amaranthus sp., Launea cornuta, Oxygonum sp, Bidens pilosa, Talinum caffrum, Talinum portulacum* and *Cleome sp.* In addition, mushrooms are also used and they are usually collected from the wild.

Gathering of cultivated and wild vegetables, is traditionally the role of women and girls. An individual or a peer group consisting of family members or friends would collect together. Gathering of vegetables in the wild is seasonal, reaching its peak during the rainy seasons. It is usually combined with other activities such as ploughing, fetching water, and gathering firewood. The vegetable gathering involves knowledge of the edible species, compatible species that can be cooked together, and patience and skills for picking the young soft leaves. The quantities of wild vegetables collected depend on the availability, individual preference, and the distance to the collection site. Wild vegetables are usually available as weeds on cultivated and cleared areas close to the homesteads and farms. However, when demand exceeded supply on the areas close to homes and farms, collections are made from more distant sites, and these include the *kaya* forests.

Wild edible fruits

To the *Midzichenda* communities the fruits of *Deinbollia borbonica, Lecaniodiscus faxinifoilias, Tamarindus indica, Adansonia digitata, Diospyros squarosa, Carissa tetramera, Vitex payos* and *Ancylobotrys petersiana*, are edible. The fruits are eaten especially during activities such as hunting, pole cutting and fishing, when the individuals would be away from home for quite sometime. However, for some community members, the collection of wild fruits might be a routine and almost a daily activity, when the fruits are in season. These are usually collectors for whom the wild fruits are a source of income. The species noted to be collected heavily from the *kayas* Mtswakara and Fungo included *Tamadindus indica* and *Ancylobotrys petersiana*. Apart from the bulk fruit collection for sale, minor collections for domestic use occur but are less frequent.

Wild edible tubers

Very few wild species were utilised for their root tubers as source of food. Possibly this has been due to the introduction of cultivated tuber plant species (Cassava, Sweet potato, *Nduma*) which are drought resistant and easy to grow. The wild edible tuber species identified in this study are: *Dioscorea dumetorum, Thilachium africanum, Gonatopus boivinii* and 'Mutunguri'.

Collection and utilisation of wild root tubers was reported to be restricted to famine periods. All the respondents had only vague memories of the last time they ate wild tubers but they clearly acknowledged to have used wild tuber species for food. *Dioscorea dumetorum* tubers after collection, are peeled, sliced into smaller pieces and then soaked in running water for 2-3 days (Ganzori pers. com). This was necessary because the tubers contained the alkaloid *dioscorine* which is toxic (Watt & Breyer-Brandwijk, 1962), and the running water reduced the toxicity effects. The tubers are then sun dried before cooking, and would be eaten with fish or meat.

Medicinal plants

Use of plants for their medicinal values formed one of the most important relations between the communities living around the *kaya* forests and the plant species in the *kayas*. From the respondents, it was clear that the medicinal and magical use of plant species was popular to people of all ages and gender. Despite the presence of other religious faiths (Islam and Christianity) cultural and traditional beliefs in healing were still strong. According to Cunningham (1988) the advantages of the use of traditional medicines and healing methods over the orthodox medicine are:

- traditional medicines are cheap and more accessible to most of the population in the rural area, while good health facilities are expensive and far placed from these communities.
- the traditional medicine is accepted among the local population, as it blends readily into socio-cultural life of the African people. Soforowa (1982) noted that a large population of the people in Kenya, Nigeria, Ghana and Ethiopia consult traditional healers as first choice despite living close to hospitals.

Among the Duruma, Giriama and Digo, there was no clear distinction between the medicinal and magical uses of the plants. This was because of the perception and understanding of the concept of "disease" among the communities. Although diseases had clearly observable or detectable symptoms, causes and cures were usually attributed to unclear supernatural powers. Diseases were attributed to spiritual causes, ancestral demands, curses, sorcery or witchcraft activities, and the treatment would be to ward off, cleanse, neutralise and remove the effects of these undefinable powers; to be followed by "treatment" for protection against such effects in future. It was common to mix plant materials and non-plant materials in the treatment procedures (Foyo pers comm.), which could not be explained scientifically. A known example is the inclusion of recipes such as "head of a snake, a thorn, blood from the slaughtered black chicken, during the preparation of a concotion used for treatment and protection against snakebite.

Medicinal plants could be used in combinations of two or more species. Some practitioners who mix the plants possible do so because of being uncertain of the most effective one. This would be so especially with medicine men who inherited the knowledge but were not properly informed of the superiority of the species in a mixture. However, the main objective of the mixing was reported to make the species compliment each other in the curative powers so as to enhance effective and rapid treatment (Foyo pers. comm.). Also an individual or a combination of plant species can be used to treat more than one ailment, just as the ailments can be treated by different plant species.

Most of the medicinal plants were collected from the wild. The healers usually made excess collections of most of the plants species they use so that the stocks would last longer. The relatively rare species were usually collected in higher amounts whenever found. In some cases other people made the collections for the healers. These include trainees, for whom the collection formed part of their training procedures; and non-healers who made the collections for a fee (Sindano pers. com). The latter group of collectors would most likely be the least concerned for the future of the medicinal species, and would rather make a quick short term income by harvesting more plant material especially where payments were based on the amounts collected. This would be at the expense of any conservational objectives for the species.

Although scarcity of some medicinal plant species was acknowledged by some healers, cultivation of these species on farmland areas were not common around both *kaya* areas. According to Mama Khadija (a traditional healer and local mid-wife in Mtswakara) the medicinal plant species acquire the healing properties only when they grow in their natural conditions, in association with the other plant species, and cultivating them in isolation would reduce or make them lose their curative power.

Preparation methods for medicines

An interesting consideration in traditional medicines are the 'drug' preparation methods. The method used for drug preparation depends on the plant part used and the disease to be treated (Mabogo 1990). The method in turn determines how the drug will be administered. The plant parts commonly used for medicinal purposes are roots, tubers, leaves, sticks, and fruits. Some preparation methods are quick, simple, and straight forward, while others, especially those related to supernatural forces, are more complicated. Some of the popular drug preparation methods are described below.

i) Soaking

Leaves or roots are soaked, usually in water to make an infusion that can either be taken orally for internal complaints (stomach upsets, indigestion, constipation, worm infection, veneral diseases, pregnancy and menstrual complaints); or used as herbal baths (*nyungu*) for spiritual treatments; or used as an application on affected parts (e.g. as eye or ear drops).

ii) *Boiling*

Bark, roots and leaves, are commonly boiled to make a decoction which is usually taken orally, for abdominal complaints, general body pains and spiritual ailments. Occasionally the decoction is used as an external application.

iii) Burning

This method is used mainly for leaves, and occasionally for roots. The plant part is burnt to make a powdered medicine (*muhaso*) that is stored in gourds (*ndonga*) or bottles. The powdered medicine (sometimes believed to have more magical powers than pharmaceutical healing and other medicinal forms) can be applied in any of the following ways:

- by licking the powder for internal treatments; or to induce extra vocal powers and abilities.
- by applying the powder on incisions (*ndembo*) made on strategic body parts that relate to the problem addressed e.g. on hand palms for increasing financial earning power, and on feet for running faster.
- by rubbing the powder on affected body parts e.g. numbed limbs.
- by sprinkling in target areas, e.g. courtroom, to influence the judgement in ones favour.
- by adding the powder in water to bathe or to sprinkle on affected parts of the body.

iv) Warming and heating

This drug preparation method is common with succulent plants and epiphytic orchids. The medicines are prepared mainly for external uses. The plant is warmed/heated to soften and then squeezed so that its fluid can be used as drops for earache or eye problems; or to warm body part for pains and colds.

v) Crushing and inhaling

This method is common with leaves especially those with a strong aroma. It is commonly used for treating colds, nausea, headaches and dizziness.

vi) Chewing

Leaves, roots, bark and sticks can all be chewed. The patient is expected to swallow the extract so that it can fight the disease, for flu, coughs, stomach problems, snakebites and veneral diseases. For toothache, sticks are chewed or used as toothbrush but the extract is not necessarily swallowed. Sometimes, the chewing poultice is applied on the affected part of the body e.g. on fresh cuts, boils, mumps, wounds and skin diseases.

The most utilised plant parts by among the Duruma and Giriama, were the roots/tubers, leaves, stem, fruits and bark; seeds were minimally used and flowers were not used at all (Fig. 5.3). For epiphytes and some herbaceous species, the whole plant was used. Combined use of roots and leaves, particularly for medicinal purposes, was noted to be very common. On the basis of life form, the shrub species were the most utilised plants, while the epiphytes were the least (Fig. 5.4). The shrub species were the most important for medicinal, magical and food values, while the tree species were the most important for building materials and sawn timber, and the vines/climbers were important for fibre and tying material (Table 5.1). Apart from the considerable contribution of vines/climbers and herbs/creepers in medicinal and magical, and food uses to a lesser extent, the tree and shrub life forms were the main plants with ethnobotanical importance to the local communities.

Table 5.1: Utilisation of different plant life-forms for different ethnobotanical uses

Use category	No. of tree species used	No. of shrub species used	No. of vine/climber species used	No. of herbaceous species used	No. of epiphyte species used
Medicinal use	43	80	25	27	6
Magical	21	110	20	22	5
Food	18	19	4	15	0
Fibre	4	6	8	0	0
Building	35	18	0	5	0
Sawn timber	15	0	0	0	0
Symbolic	3	10	1	7	0
Carving/crafting	27	18	4	3	0
Poison	2	6	3	1	0

Fig. 5.3: Percentage of species (n=321) used for each of the main plant parts

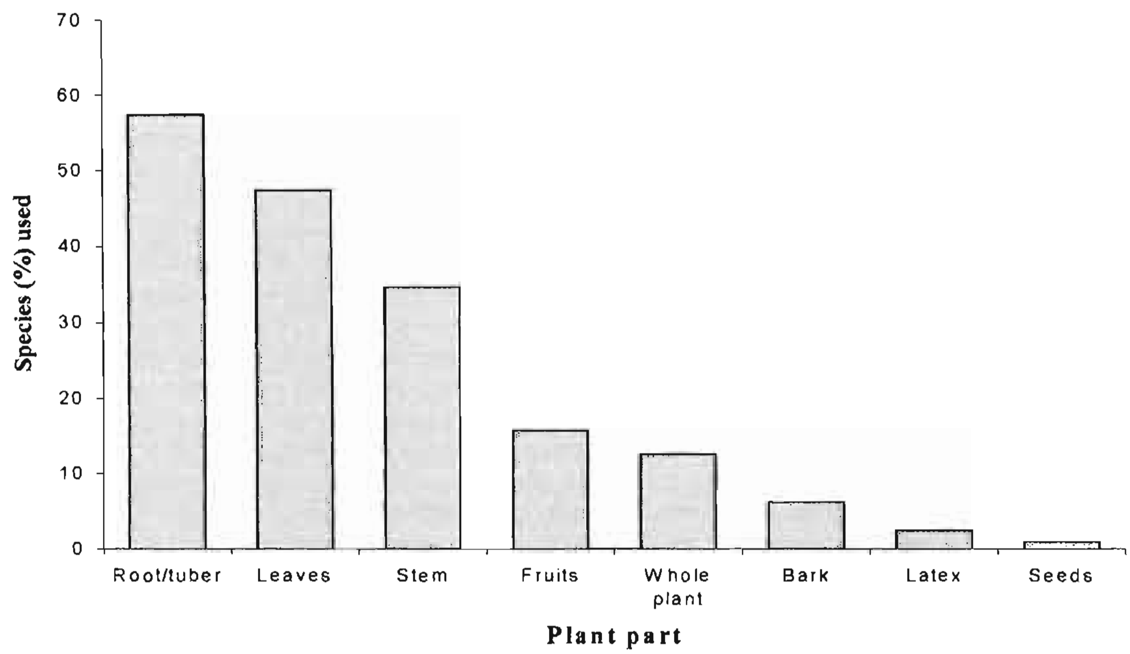
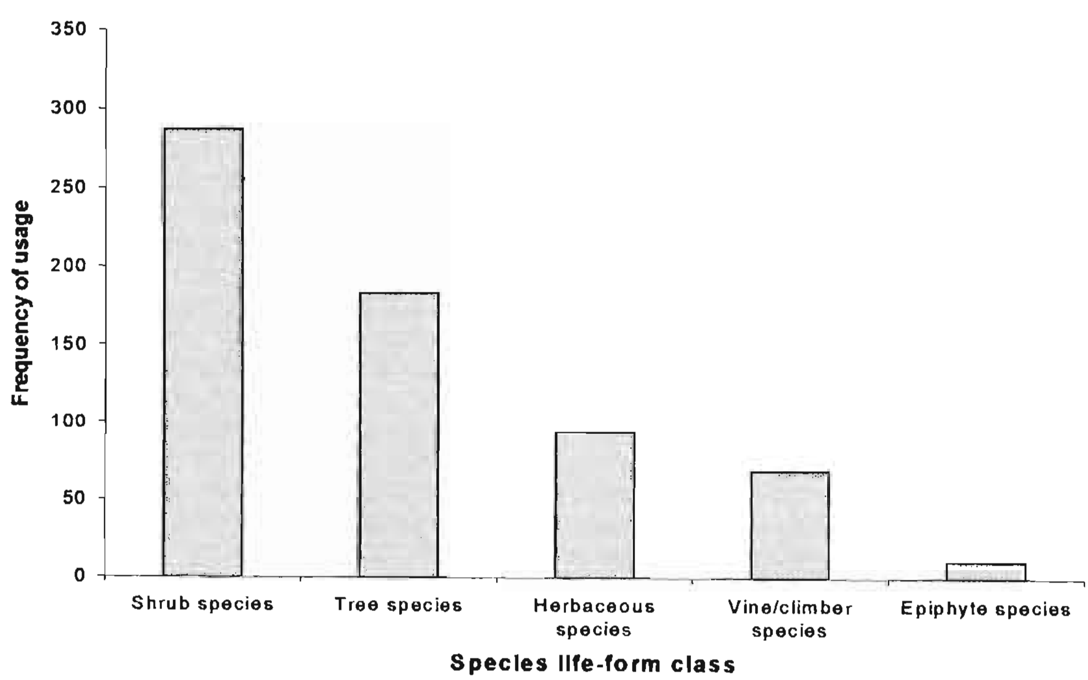


Fig. 5.4: Frequency of usage (n=644) identified in each plant life-form class



5.3.3 Traditional taxonomy and plant identification

The ethnobotanical interviews revealed that in most cases, there was a reason for individuals or a community to recognise and identify a plant taxon by name. A plant species was recognised to have either positive or negative values, and sometimes both, by which people distinguish and identify the plant taxa, and associate it with its respective value. For some plant taxa, being common in an area was enough for them to be recognised and identified by name. These would include species whose vernacular names were identified but there was no known use identified for the plant e.g. *Memecylon amaniense*, *Cynanchum gerrardii*, *Clerodendrum sansibarense*, *Chlorophytum suffruticosum*, *Cenchrus ciliaris*, *Dactylotenium geminatum*, *Enteropogon sechellensis*, *Megastachya aucronata*, *Sporobolus fimbriatus* and *Setaria* sp. However, not all forest species were identified by vernacular names. Less common taxa, at least in the eyes of the local community, with no known value to the local community, might not be important enough to be recognised and identified by name. Examples of such species noted in this study were: *Acridocarpus alopecurus*, *Aspilia mombassae*, *Dorstenia* sp., *Huernia acheri*, *Ipomoea schupangensis*, *Siphonochilus kirkii* and *Crossandra pungens*. However, this conclusion needs to acknowledge the fact that the vernacular names and tribal uses of plant species is a large field of knowledge. The species not identified by name or not associated to any use could probably be due to the respondents' limited knowledge, rather than portraying a lack of tribal knowledge.

In the field, the respondents identified the plant taxa through observation of colour, texture and shape of parts of the plants. Plant parts used for identification included leaves, fruits/seeds, stem, bark, roots and flowers. Occasionally, taste, especially of roots was employed to differentiate closely resembling taxa. However, neither the identification criteria nor the plant part used for identification were consistent for all taxa, and the identification methods were not necessarily similar between respondents. Leaf variation (shape, texture and size) between plant taxa was the most commonly used for the identification. The leaves were frequently used for identification of, for example, *Craibia brevicaudata*, *Cynometra suaheliensis*, *Cynometra webberi*, and *Julbernardia magnistipulata*. In contrast, all the respondents failed to identify correctly *Schlechterina mitostematoides* as the same in its different stages, as leaves (being the main identification part) transform from small linear and deeply dentately-lobed, into relatively larger elliptic, with cunate base, and acute apex (Beentje 1994). One respondent in Mtswakara, acknowledged not knowing *S. mitostematoides* when he saw it at its sapling stage, but he consistently and correctly identified it when seeing it at its mature stage. The differentiation between *Cynometra suaheliensis* and *Scorodophloeus fischeri* using the leaves was not consistently correct, and the bark of the stem was mostly used in this case. Also the respondents were noted to correctly identify *Hugonia castaneifolia* only after seeing the stem. Wrong identifications of this species by some respondents occured in cases where leaves were to be used for identification. The colour of the bark of the stem was important to distinguish between *Euclea natalensis* whose stem was conceived as being dark compared to that of *Euclea racemosa* (*Muyesa*) which was conceived as being lighter. The root colour and taste was important to distinguish between *Uvariodendron kirkii* and *Artabotrys modestus*, but the details in this differentiation were not clearly understood by this author.

The local taxonomy was found, in most cases, to identify plants down to the parallel of species level in the scientific classification. An example of different species in the same genera that were recognised as different in the local naming include: *Cynometra suaheliensis* (mufunda-uche) and *Cynometra webberi* (mufunda-ulume), *Acacia adenocalyx* (munga), *Acacia etbaica* (mugundi), and *Acacia mellifera* (chikwata-kombe) by the Duruma; and *Acacia mellifera* (kikwata), *Acacia nilotica* (muoti), *Acacia reficiens* (kirerengwa), *Acacia robusta* (mutsemeri), and *Acacia zanzibarica* (muhega-kululu) by the Giriama. However, there were cases where different species sometimes from even different families, were identified as the same in the local taxonomy. Such identifications include *Muvundza-jembe*, which was used to identify *Grandidiera boiviniana, Acalypha fruticosa*, *Acalypha echinus*, and *Mildbraedia carpinifolia* by the Duruma. Schmidt (1991) also noted the use of the vernacular name Muvundza-jembe to identify different plant species among the Digo community. *Ceoropegia seticorona, Ceoropegia* sp. and *Ipomoea schupangensis* were all identified as *Mufunga-mambo* by the Giriama, while the Duruma used the vernacular name (*Mufunga-mambo*) to identify climber species *Pentarhopalopillia umbelullata* and *Rhoicissus revoilii*.

Some names were used for the identification of life forms rather than a specific taxon. The vernacular name 'nyasi' (in all three communities) for example referred to graminoid species in general, which could be different species and even different genera in Gramineae, Commelinacea or Cyperaceae. Identification of individual grass taxa was noted to be poor in all respondents. Schmidt (1991) recorded 51 different taxa identified with the vernacular name *Nyasi* among the Digo. Woody climbers are usually identified as *Libugu/Mbugu* by Duruma, Giriama and Digo. Size specificity in this identification is made by adding a size prefixes to the syntax *–bugu*. The size prefixes include '*dzi/ri/lu*' which define large size, and '*chi/ka*' which define small size. Most respondents opt to the life-form identification when not certain of the taxon's specific name. Epiphytic and parasitic plant taxa were commonly identified as *Mutula-manzie* by the Duruma and the Giriama, which means sitting on others. This vernacular name would be used to identify a range of epiphytic orchids and parasitic non-orchid taxa collectively and inclusive. '*Ndago*' is an identification terminology for all sedge species, which in this study were mainly recorded in the *Cyperus* and *Kyllinga* genera.

In general, most vernacular names (in the *Midzichenda* dialects) for different plant taxa start with a prefix *M* or *Mu-*. This prefix was most likely derived from the general vernacular name for a tree/plant *Muhi* (singular) *Mihi* (plural) in which case the taxa name follows suit in identifying the singular and plural contexts. This was especially true for all the plant species bearing fruits that were important, e.g. edible fruits. Examples of these species recorded in this study are *Muungo, Muuyu, Mukwadzu, Mudzaje, Muhonga, Mukwakwa, Mukone* and *Muviru*. Contrasting this naming criteria were taxa identified as *lwavi, kikwata, ndago* and *Chikuro*, whose fruits were not of any known value.

The identification of taxa by using particular vernacular names was based on a number of criteria, which included the plant species use, effects, habitat, and its relation to other plant or animal species. Examples of vernacular plant names that are derived from different identified aspects of the plant are given in Table 5.2.

Table 5.2: Examples of vernacular names identifying plant taxa based on defined plant aspects

Species	Vernacular name	Dialect	Meaning	Criteria
Acacia adenocalyx	Muvwada-paka	Dur	Pricking-cat.	The species possession of thorns, an pricking habit like a cat
Acacia zanzibarica	Muhega-kululu	Gir	Noisy trapping	Whistling habit in windy conditions Similar to standard name Whistling thorn
Aerangis kirkii, Microcoeilia exilis Solenangis wakefieldii,	Mutula-manzie	Dur/Gir	sitting on others	The species epiphytic (or parasitic) nature related to host species
Allophylus rubifolius	Munyanga-kitswa	Gir	Cure headache	The species use in treating headaches
Ancylobotrys petersiana	Muhonga-udide	Dur	Small form of *Muhonga*	The small form of *Saba comorensis*
Capparis fascicularis	Muvwada-paka	Dur	Pricking-cat.	The species possession of thorns, and pricking habit like a cat
Capparis vimenea	Muvwada-paka	Dur	Pricking-cat.	The species possession of thorns, and pricking habit like a cat
Chlorophytum comosum	Asichana-amwaka	Gir	girls of long rains	The species habit of 'flowering' (becoming beautiful) just before long rains
Commiphora africana	Tola	Gir	-	The normal form of *Tola* in relation to another closely related species
Commiphora lindensis	Katola-katite	Gir	Small 'Tola'	The small form of *Tola* (*C. africana*)
Ficus lingua	Muzikaha	Gir	to treat	The species known curative use powers
Hyphaene compressa	Mulala	Dur/Gir /Dig	Leaves of palm tree species	Refers to the juvenile stage of the species when the leaves form the main plant part
Hyphaene compressa	Mukoma	Dur/Gir/Dig	-	Older stage when leaves do not form the main part of plant
Laportea lanceolata	Lwavi	Gir	-	The species itching effect
Pteliopsis sp.	Mutula-makwalala	Gir	Sit for *makwalala*	Association with a bird species (*makwalala*) that prefers to sit on the tree
Saba comorensis	Muhonga	Dur	-	The normal form of *Muhonga* in relation to another closely related species
Siphonochilus kirkii	Mutunguu	Dur	Onion-like	The species resemblance to onion
Toddaliopsis sansibarensis	Mudimu-tsaka	Gir	Forest form of lime-tree	The species possession of an aroma simila to lime-tree, but growing only in the forest
Tragia furialis	Lwavi	Gir	-	The species itching effect

5.3.4 Origin of uses of plant species

The species use, like the naming, was based on an informal 'guide'; especially for species used for medicinal and/or magical purposes. The doctrine of signatures, which was first postulated by Paracelsus (1490-1541) (Thomson 1978), was clearly adopted for some medicinal uses. The climber species, with snake-like crawling characteristic e.g. *Hugonia castaneifolia* were identified as important medicines for treatments and protection against snakebites. Epiphytic and parasitic plant species (seen as dominants on others) were identified as successful members of the plant kingdom and hence used in making magical charm that promotes dominance (leadership and popularity) of oneself among colleagues.

The physiological characteristics of species also play a role on the use-value the community accord a species. *Croton talaeporos* is not preferred as a source of firewood because it produces heavy smoke with a strong unpleasant smell. While *Dalbergia melanoxylon, Cynometra spp., Combretum schumannii, Acacia refisciens, Acacia robusta* and *Acacia nilotica*, burn strongly, making good fire without producing similar repulsive smoke, were preferred for firewood. The taboo placed on *Grewia forbesii* and *Grewia truncata* (*Mubavu-ng'ombe*) as a source of firewood was likely to have been based on the importance of these species for their medicinal values, thus placing a restriction on excessive use of the species for firewood when alternatives were available. Thus the placement of the taboo on a species, could have been a traditional protection against over-exploitation of a highly valued species.

Other uses, e.g. food values, weaving, crafting and building are likely to have been established through numerous trials and errors, which were conducted over a long period of time resulting in cumulative experiences that generated the existing indigenous knowledge. Other medicinal uses are possible more linked to the psychological beliefs and the uncertainties of the super-natural powers.

5.3.5 Plants utilisation by different Midzichenda ethnic groups

The Duruma, Giriama and Digo have both similarities as well as differences in both the plant names and uses of plants. The prefix *chi-* was noted in Digo, and it generally indicated a "small" size of the subject. While the prefix *ka-* was noted in Giriama, as the description of "small" size. In the Duruma dialect there were both prefixes *chi-* and *ka-*, defining small size. In the plant names small described the visualised size of the plant in comparison with another close resembling species. However, sometimes these prefixes can be used to describe "small" in terms of "age" of the plant, and not necessarily a small form of another species as described above.

The plant species identified with similar vernacular names in the three ethnic groups probably reflect the shared origin and history of these Midzichenda ethnic groups. The plant species with shared vernacular names, however, were noted to have minor variations in pronunciation and hence the spelling, but otherwise were similar in sound (Table 5.3).

For other plant species the vernacular names were substantially different with no obvious indications that the names were shared (Table 5.4). These differences support the view of separation between these communities and so their language evolved (Spear 1978), and the existence of different ethnic groups among the *Midzichenda*, whom sometimes have wrongly been identified as one group (Hawthorne *et al.* 1981).

With regard to plant uses, the three *Midzichenda* communities shared the general needs for plants to be used as medicine, fuel, food, timber building materials, crafting, basketry and fish poisoning. The use of similar species for a common purpose was noted in fuel, food, timber building materials, crafting, basketry and fish poisoning; except in cases where the species was not available locally or where a better alternative species existed. For example: *Cynometra suahiliensis*, *Cynometra webberii* and *Scorodophloeus fischeri* were notable absentees in *kaya* Fungo, thus although they were identified as important for building poles and for firewood in Mtswakara, this could not be expected in Fungo. On the other hand *Loseneriella africana* was a notable absentee in Mtswakara, while the Giriama identified it as a preference in building (used as a tying material).

Table 5.3: Close similarities in plant names between the three *Midzichenda* ethnic communities

Species	**Duruma**	**Giriama**	**Digo**
Afzelia quanzensis	Mubambakofi	Mubambakofi	Mbambakofi
Ricinus communis	Mubono	Mubono	Mbono
Thespesia danis	Muhowe	Muhowe	Muhowe
Grewia plagiophylla	Mukone	Mukone	Mkone
Hibiscus micrantha	Mutsunga-ng'ombe	Mutsunga-ng'ombe	Mtsunga-ng'ombe
Brachystegia spiciformis	Murihi	Murihi	Mrihi
Albizia anthelmintica	Muporojo	Muporojo	Mporojo
Dichrostachys cinerea	Mukingiri	Mukingiri	Mchinjiri
Abrus precatorius	Muturituri	Muturituri	Mwamsusubika
Combretum schumanii	Muryanyani	Muryanyani	Mryanyani
Croton pseudopulchellous	Muyama	Muyama	-
Craibia brevicaudata	Muphande	Muhande	-
Dalbergia melanoxylon	Muphingo	Muhingo	Mphingo
Premna chrysoclada	Muvumo	Muvuma	Mvuma

Table 5.4: Differences in plant names between the three *Midzichenda* ethnic communities

Species	Duruma	Giriama	Digo
Pyrenacantha vogeliana	Mugandzi	Ria	
Synadenium persica	Kimangio	Mwatsa	
Euphorbia nyikae	Ganga	Kithongothongo	
Acalypha neptunica	Mvundza-jembe	Mutsatsa-ulume Mubarawa	
Acalypha fruticosa	Mvundza-jembe	Mutsatsa	
Bridelia cathartica	Mubunduki	Musumbiji	Mbunduchi
Ochna thomasiana	Mwarika/Charika	Mkwalino/Mdhahabu	
Monodora grandidiera	Mukeli	Mucherere/Muvipo	
Uvariodendron kirkii	Mwangajine	Murori	Mangajine
Lamprothamnus zanguebaricus	Mutsome	Munyukufu	
Heisia crinata	Mfyefye	Mulanza	Mfyofyo
Agathisanthemum bojerii	Muvundza-kesi	Kaithima	Chivuma-nyuchi Chivundza-kesi

However, common species like *Manilkara sulcata, Craibia brevicaudata, Dalbergia melanoxylon, Croton pseudopulchellus* and *Grewia plagiophylla* were all identified as popular for building poles in both Duruma and Giriama communities. Species such as *Afzelia quanzensis, Milicia excelsa, Brachystegia spiciformis* and *Bombax rhodognaphalon* were popular timber species in all communities. *Synadenium pereskiifolium* was commonly used for fish poisoning both in Mtswakara and Fungo. However, *Mundulea sericea* was also used for fish poisoning in Fungo, but not in Mtswakara where the species was not recorded.

Significant difference in plant species use between the three communities was noted in the medicinal and magical uses. Although these communities have common health problems such as malaria (identified as *nyuni* in children), stomach and urinary infections (probably resulting from the contamination of water sources), as well as shared beliefs in supernatural powers, spiritual ailments, and sorcery activities, few species are commonly used to treat similar ailments. However, differences in specific medicinal uses of a plant species, and sometimes even the plant part used, were noted shared even between respondents from the same community. This meant, therefore, that differences in medicinal uses of a plant species could be at the individual person level, likely to cross-cut through ethinic groups i.e. members of different ethnic groups sharing the same specific use, but not sharing it with other members of their ethnic group. The differences therefore, are a reflection of the diversity in medicinal and magical utilisation rather than strict ethnical differences.

Overall, in wild plant resource utilisation the Duruma made use of the highest number of species, and possible highest reliance, compared to Giriama and Digo, particularly for medicine, building, food, carving and sawn timber (Table 5.5). The Duruma and Giriama utilised more species for magical uses than the Digo. Most of the other uses were restricted to very few species, probably due to frequency of those uses.

Table 5.5: Number of species (n=321) used by the three *Midzichenda* ethnic groups for different ethnobotanical purposes

Ethnobotanical Use	Number of species used by Duruma	Number of species used by Giriama	Number of species used by Digo
Medicine	109	57	83
Magical, spiritual and witchcraft	90	86	27
Building and construction	51	34	18
Food (Spice/ food flavours)	49	39	37
Carving, crafting and weaving	32	22	22
Others	21	15	20
Tying materials	13	7	5
Sawn timber	8	7	8
Tabooed for use	6	2	1
Local furniture	5	3	0
Symbolic	5	7	6
Live fence	3	2	0
Poisonous to human	2	2	2
Fish poisoning	2	3	3
Arrow poison	2	0	0
Poison for pests and parasites	2	0	1
Season indicator	1	1	3
Veterinary and poultry medicine	0	5	0
Total	401	292	236

Other differences in plant uses by the *Midzichenda* communities found in this study included:

- use of plants for veterinary medicines was more common among the Giriama than among the Duruma and Digo. This was likely to be due to the fact that Giriama living in harsher semi-arid conditions keep more livestock than the other two groups. The Giriama, therefore, are likely to be frequently met with veterinary challenges than the Duruma and Digo, which they solve using the plant species.
- Use of fibres (inner bark of *Brachystegia spiciformis, Julbernardia magnistipulata*) and flexible sticks (*Grewia plagiophylla, Combretum illiari*) for making fish traps (*tsatsa* and

migono respectively) were common among the Duruma, and use of *Milletia usaramensis* for making fish traps (*tole*) was common among the Digo. Use of plant species for making fish traps was less common among the Giriama, although all the species used for making fish traps by the other communities were recorded in *kaya* Fungo. This probably was due to the Duruma and Digo communities' proximity to the sea and some semi-permanent rivers that prompted the inventories, while the Giriama living near the *kaya* are far inland from the sea, and big rivers are not common, hence did not have similar needs. Rather, they opted for trapping wild birds using structures (*susu*) made from scandent shrub species (*Lantana camara*).

- The Duruma and Digo cultivate coconut palm trees from which they collect a traditional palm sap (*mnazi*), while the Giriama (at least those living around *kaya* Fungo) do not share this practice. It is not surprising, therefore, that the use of *Cissus spp.* as tying material in the tapping process was not common among the Giriama.

5.3.6 Plant utilisation by the Midzichenda compared to other ethnic groups

There are some similarities between southern and eastern Africa in the botanical and ethnological information and practises (Watt & Breyer-Brandwijk 1962). Utilisation of plants by the *Midzichenda* in comparison to other communities was made mainly through consulting other ethnobotanical literature, which included: Watt & Breyer-Brandwijk (1962); Mabogo (1990); Beentje (1994) and Hutchings *et al.* (1996). Information on pharmaceutical properties of the plants was collated mainly from Watt & Breyer-Brandwijk (1962) and Hutchings *et al.* (1996). Details of the comparative use and pharmaceutical components of the plant species are given in Appendix VI.

In a list of 181 species used for medicinal purposes by the Duruma, Giriama and Digo, about 33% were shared with other communities (Table 5.6). For most species the specific medicinal use was not shared, but the medicinal value of the species was shared, with different communities treating different ailments, and sometimes, using different plant parts. About 20% of the medicinal plant species shared have pharmaceutical attributes related to the medicinal uses by the Midzichenda community. This observation only signifies the possibilities of local medicinal uses of plants being more of psycho-medicine, where only in few cases can some scientific explanation or understanding be made. However, it is likely also that there has been little pharmaceutical investigation of the medicinal plants, particularly with reference to the target ailments identified by the local communities.

Table 5.6: List of medicinal plant species whose curative value is shared between the Midzichenda and other communities

Species	Sharing community
Abrus precatorius	Boni, Yao (in Tanzania) and Zulu (in S. Africa)
Acacia nilotica	Maasai (in Kenya)
Acacia robusta	Zulu
Achyranthes aspera	Zulu, Kwena, Tswana (in S. Africa) and communities in Egypt, Madagascar, Botswana and in Australia.
Adansonia digitata	Vendah (in S. Africa) and some communities in Sierra Leone.
Adenia gummifera	Zulu and Ronga (in S. Africa)
Adenia kirkii	Tonga (in S. Africa)
Afzelia quanzensis	Communities in Zimbabwe and Malawi
Agathisanthemum bojeri	Zulu (in S. Africa) and Karanga (Zimbabwe)
Albizia anthelmintica	Maasai (in Kenya), Swati (in Lesotho), Ronga, Vendah (S. Africa), and some communities in Ethiopia, Somalia and in Tanzania.
Albizia versicolor	Zigula (in Tanzania)
Asparagus sp.	Mponda, Sotho (in S. Africa) and communities in Tanzania
Blepharispermum zanguebaricum	Shambala (in Tanzania)
Bridelia cathartica	Communities in Zimbabwe, South Africa (Zulu) and in East Africa
Capparis fascicularis	Maasai and some communities in Tanzania
Cassia siguena	Chagga and Sukuma (in Tanzania)
Cissampelos pareira	Some communities in Tanzania and in Madagascar
Cissus rotundifolia	Tugen (in Kenya)
Commelina africana	Sotho, Zulu (in S. Africa) and some communities in Zaire (Democratic Republic of Congo).
Commelina banghalensis	Sotho, and some communities in Tanzania and in Philippines
Commiphora africana	Ronga, and some communities in East Africa and in West Africa
Commiphora edulis	Zigula (in Tanzania)
Croton pseudopulchellus	Nyamwezi (in Tanzania) and some communities in Ghana.

Table 5.6: Continued

Species	Sharing community
Dichrostachys cinerea	Pedi, Vendah, Tonga and Zulu (in S. Africa), Zigua and Chagga (in Tanzania), Nyanja (Zimbabwe) and some communities in Liberia.
Euclea natalensis	Zulu, Shangana and Tonga (in S. Africa)
Flagellaria guineensis	Sanga (in Tanzania) and some communities in Philippines
Flueggea virosa	Nyamwezi and Shambala (in Tanzania)
Gonatopus boiviniana	Sukuma in (Tanzania)
Grewia plagiophylla	Taita (in Kenya)
Harrisonia abyssinica	Samburu and Kamba (Kenya)
Hoslundia opposita	Kipsigis and Maasai (in Kenya), Haya, Shambala and Nyamwezi (in Tanzania)
Landolphia kirkii	Vendah (in S. Africa)
Lannea schweinfurthii	Swahili (in Kenya), Nyamwezi (in Tanzania), Vendah (in S. Africa) and some communities in Zimbabwe.
Lantana camara	Some communities in West Africa
Lonchorcarpus bussei	Some communities in Tanzania
Manilkara mochisa	Zulu (in S. Africa).
Maytenus mossambicensis	Zulu (in S. Africa)
Markhamia hildebrandtii	Some communities in Kenya and Tanzania
Microcoelia exilis	Zulu (in S. Africa).
Microgramma lycopoides	Zulu (in S. Africa)
Ochna mossambicnsis	The Nyanja and Luvale communities
Ormocarpum kirkii	Boni (in Kenya)
Ozoroa obovata	Zulu (in S. Africa) and some communities in East Africa.
Pandanus rabaiensis	Some communities in Tanzania and in Zanzibar
Premna chrysoclada	Swahili (in Kenya)
Ricinus communis	Vendah, Sotho, Zulu (in S. Africa), the Chewa and Chagga (in Tanzania), Kikuyu (in Kenya) and some communities in Zimbabwe.
Sclerocarya birrea	Pokot (in Kenya), Zulu, Thonga, Shangani and Vendah (in S. Africa).
Sideroxylon inerme	Zulu (in S. Africa) and some communities in Tanzania.
Solanum incanum	Sotho, Zulu (in S. Africa) and some communities in Tanzania and in Botswana.
Sterculia appendiculata	Some communities in Tanzania
Sterculia rhynchorcarpa	Some communities in Tanzania

Table 5.6: Continued

Species	Sharing community
Strychnos spinosa	Zulu, Vendah, Tongah (in S. Africa), and some communities in Zimbabwe, West and Central Africa.
Suregada zanzibarensis	Zulu (in S. Africa) and some communities in Tanzania
Synaptolepis kirkii	Zulu (in S. Africa) and some communities in Tanzania
Tamarindus indica	Some communities in Tanzania, Madagascar, Nigeria, West Africa and in Mauritius
Uvaria lucida	Zulu (in S. Africa) and some communities in Tanzania
Vangueria infausta	Swati, Vendah (in S. Africa), Lamba (in Zimbabwe) and some in communities and Mozambique
Vernonia hildebrandtii	Some communities in East Africa
Zanthoxylum chalybeum	Maasai, Pokot, Samburu (in Kenya), Nyamwezi (in Tanzania),
Ziziphus mucronata	Xhosa, Zulu, Vendah, Thlaping and Tonga (in S. Africa) and some communities in Botswana, Angola and in West Africa.

From a wider perspective, the local naming of a species on the basis of size in comparison with a close resembling 'sister' species was also common among the Vahvenda community in southern Africa (Mabogo 1990). Although the floral similarities at the Kenya Coast and in Venda are limited, the traditional naming and use of species share some similarities. For example *Strychnos pungens* is identified as *Mukwakwa* by the Vahvenda (Mabogo 1990), while the Duruma, Giriama and Digo all identify *Strychnos madagascariensis* with the same vernacular name (*M(u)kwakwa*). The difference remains though, as the Vahvenda identify *Strychnos madagascariensis* as *Muramba* (Mabogo 1990). Most of the uses by the Vahvenda tend to be different from those by the Duruma, Giriama and Digo communities. However, the basic concepts are fairly similar. For instance, Mabogo (1990) noted the cultural implications of a taboo on species for a certain use, and the use of species in the light of the doctrine of signatures, which were both noted in this study.

5.3.7 Comparison with other Midzichenda ethnobotanical work

Previous ethnobotanical studies on the Duruma and Giriama (Beentje, 1994) and on the Digo (Beentje, 1994; Schmidt 1991) were consulted for comparison with the current results. The vernacular plant names and plant uses in Beentje (1994) is a collection of work of different botanists who did botanical inventories at the Kenya Coast, and made some ethnobotanical comments. The vernacular plant names in Schimidt (1991) included the researcher's own ethnobotanical study, and work of other researchers such as Glover et. al (1969) and Kokwaro (1976). Similarities and differences between these previous inventories and the current study can be identified. The similarities obviously help the credibility of the all these studies, while the differences would indicate either a diversity of information, or incorrect information in some work. Based on the results of the current study, in Beentje (1994) and in Schmidt (1991) there were some spelling errors for some vernacular names (Table 5.7).

Some species in Beentje (1994) were identified as having a completely different vernacular names from those recorded in this study (Table 5.8). These differences might not necessarily mean that the information in the other references is wrong, but it is a reflection that although substantial published ethnobotanical information for the *Midzichenda* exist, both the accuracy and quality need to be reviewed. In addition there may be still much more ethnobotanical information that remains unwritten.

Table 5.7: Noted misspelled vernacular names of plant species in the other ethnobotany work

Species	Beentje (1994)	Schmidt (1991) all names in Digo	Current study
Terminlia sp.	Manga msuri (Dur)	Mwanga/Mwangati	Mwanga-msuhu (Dur); Mwanga (Dur/Gir/Dig)
Pandanus rabainsis	Mukurasa (Dur)	-	Mkarazo (Dur)
Carissa spp.	Mulolwe/Mulowe (Dur)	-	Muloe (Dur)
Lecaniodiscus fraxinifolius	Myandakanda (Dur)	-	Munyanyakanda (Dur)
Ziziphus mucronata	Mguguna (Gir)	Mugugune	Mugugune (Gir)
Harrisonia abyssinica	Mkindhunga (Gir)	Kidori	Mukidhunya (Gir); Chidori (Dur/Digo); Mvwada-paka (Dur)
Craibia brevicaudata	Mvandi (Gir)	-	Muhande (Gir)
Julbernardia magnistipulata	Msahe (Gir)	Mkuha, Mkuwa-upwe	Muzahe (Gir); Mukuwa (Dur); Mkuwa/Ukwe (Dig)
Landolphia kirkii	Mtongasi (Gir)	Kitori, Mpira, Libugu	Mutongazi (Gir); Mpira (Dig)
Dichrostachys cinerea	Muchinjiri (Gir)	Mchinjiri	Mukingiri (Gir); Mchinjiri (Dig)
Manilkara sulcata	Muchedzi (Gir)	Mzezi	Mutsedzi (Gir); Mtsedzi (Dig)
Gardenia volkensii	Mukingwene (Gir)	-	Kimwemwe (Gir)
Asteranthe asterias	Mundahera-ngurwe (Gir)	-	Muzshondoheranguluwe (Gir)
Diospyros squarosa	Mupweki (Gir)	Mpweke	Mupweke (Gir); Mpweke (Dig)
Commiphora edulis	Mutula (Gir)	-	Katola (Gir)
Strychnos madagascariensis	Kakwakwa (Gir)	Mhonga	Mukwakwa (Gir) the ka- syntax possible was added as size descriptive term plant. Muhonga (Dig)
Maytenus mossambicensis	Ndungatundu (Gir)	Mudziyadziya	Mudungatundu (Gir); In Digo, 'dziya' is close to 'miya' which means thorns, a likely descriptive character for the thorny *Maytenus mossambicensis*
Vernonia hildebrandtii	Mlakasoma (Gir)	Chivatsa	Mlazakoma (Gir); Phatsa (Dig). In Schimidt (1991) 'Chi-' was probably descriptive of the plant size

Table 5.8: Species identified with different vernacular names in Beetje (1994)

Species	Beentje (1994)	Current study
Scorodophloeous fischerii	Kifungazanzau (Dur)	Muphande (Dur)
Croton pseudopulchellous	Msandusi (Dur)	Muyama (Dur)
Gossypoides kirkii	Msufi mwitu (Dur)	Pamba-mwitu (Dur)
Heinsia crinata	Mushoka (Dur)	Mfyefye (Dur)
Strychnos panganensis	Mbeyu (Gir)	No record was made, but Mbeyu means seeds
Asteranthe asterias	Mchere (Gir)	Muzshondoheranguluwe
Haplocoelom inopleum	Muchumbi (Gir)	Mufungatsandzu (Gir)
Grewia plagiophylla	Mfukofuko (Gir)	Mukone (Gir)
Ochna mossambicensis	Mkata-mti (Gir)	Mucherere (Gir)
Combretum illiari	Mshindaalume (Gir)	Muchira-ng'ombe (Gir)
Lamprothamnus zanguebaricus	Mtosmolo (Gir)	Munyukufu (Gir)
Cissus rotundifolia	Mtsuchi (Gir)	Mtsuma-pengo (Gir)
Schlechterina mitostemmatoides	Mukiriango (Gir)	Mwangira (Gir)
Commiphora lindensis	Mutongtongo (Gir)	Katola/Katola-katite (Gir)
Strychnos panganensis	Ria (Gir)	Ria in this study referred to *Pyrenacantha vogeliana.*

CHAPTER SIX
FOREST PLANT RESOURCE UTILISATION AND MANAGEMENT

6.1 INTRODUCTION

Conserving biological diversity in the tropics has become an issue of increasing priority and urgency, however, the options available to address management and utilisation in order to slow or arrest decline in ecosystem function and loss of biological diversity are limited (Gomez-Pompa, Whitmore & Hadley 1991). People have had a significant impact upon naturally-vegetated areas world-wide often resulting in widespread habitat destruction (Osborn 1997). Forest resource extraction can also have significant effects on the structure, regeneration potential and ultimately the species composition of forests (Burgess 1998). Successful management of the forest areas need to be considered in terms of the needs of the communities living around them, and the traditional societies that belong to and form a relation with the forests (Gomez-Pompa et al. 1991). While fundamental human needs are relatively universal, the way they are 'satisfied' vary according to culture, region, and historical conditions (Max-Neef et al. 1989).

A forest can be regarded from an ethnobotanical perspective as providing many and diverse types of resources. In this study two plant resources have been addressed. The selected resources for investigation were building poles and firewood, all being frequently used-resources whose utilisation is always in relatively high volumes. Pole cutting and firewood removal were noted to be major problems in Arabuko-Sokoke forest (Mogaka, 1992), while pole cutting was a major problem in *kaya* Waa and Mrima forest reserve (Waiyaki 1995). In a socio-cultural investigation, Nyamweru (1997) identified building poles as a valuable resource from the *kaya* forests, and the utilisation of wood for fuel, by the communities living around the *kaya* forests, was common. Difficulties in acquiring firewood were identified in these communities, and among the plant resources, firewood demand is probably the most contentious issue facing the conservation management of the *kaya* forests (Nyamweru 1997).

In modern forest management, conservation strategies have been moving from an emphasis on "restrictive protection" of natural resources, to promoting sustainable resource utilisation and the increased participation of local communities (Freese 1997). The question, therefore, would not be whether 'to use the wild species or not', but rather how to move from a system of use that is unsustainable towards one that is. While it is widely believed that such approaches can lead to effective conservation strategies and contribute to the improvement of livelihoods of the local population, in the case of the *kaya* forests relatively little is known about the local communities' basic needs and interests in relation to these forests. The specific ways of meeting basic needs from the *kaya* forest were not addressed in previous studies. The strategies employed and problems faced by traditional management systems that have been responsible for maintenance and conservation of these forests are only vaguely known. With the current human pressures on the *kaya* forests, it is becoming urgently important that practical utilisation and management policies are in place for these indigenous forests, based upon knowledge of the existing relationships between the prevailing resource demand and the supply. It was from this point of interest that the utilisation and management of plant resources, the potential resource-base, potential resource alternatives and commercial concerns of these resources were investigated in this study. The study on the resource utilisation and management was intended to answer the questions:

i) are the *kayas* major sources of plant resources (building poles and firewood) used in the homesteads around the forests? And do alternative resources exist that can be used in place of these plant resources at homestead level?

ii) are harvestable plant resources (poles and firewood) available in the selected *kaya* forests?

iii) do the local communities make any effort towards domestication of plant species which could provide these plant resources?

iv) are plant resources important in the local trade in the study areas?

v) what traditional strategies do the *kaya* elders use in the conservation and management of the *kaya* forests? Are these strategies effective in plant resource extraction control from the *kayas* to ensure sustainable resource utilisation?

The utilisation and acquisition of building poles and firewood are discussed separately in sections 6.2 and 6.3 respectively, while the available stocks of these plant resources (building poles and firewood) in the *kaya* forests are discussed in section 6.4. Tree domestication in the homesteads, local trade in building poles and firewood, and traditional *kaya* forests management strategies are discussed in section 6.5.

6.2 PLANTS USED AS BUILDING MATERIALS

6.2.1 Materials and methods

In the *Midzichenda* culture, there is an eminent division of labour. The men are responsible of most of the activities in house construction and repair. Based on this premise, issues related to collection and utilisation of building poles were investigated by interviewing the men. Using a structured questionnaire (Fig. 6.1), male members of the community were interviewed. The interviews were conducted during home visits to randomly selected homesteads in the villages around the *kayas*. Although it was intended that the male members of the community be the main sources of the information on building poles, divorced, widowed or single female members of the community in charge of homesteads were also recognised as potential interviewees.

The Questionnaire

The questionnaire (Fig. 6.1) consisted of five sections. The first section was an introductory statement in which the interviewer introduced himself/herself and requested for the interviewee's participation. The second section was used to identify and describe the homesteads. The homesteads were identified using serial numbers (1000 + the homestead count number for *kaya* Mtswakara community; 2000 + homestead count number for *kaya* Fungo community) which were in the sequence of when the interviews were conducted. The house-type(s), material possessions and information on basic economic status were used to categorise the homesteads. A homestead referred to a unit of the a population that shared the acquisition and utilisation of plant resources (for this case building materials). These included 'small' families that comprised of only parents and their children, or 'large' extended families that included grand parents, and the families of their sons and daughters, living in one or more houses but have a central demand and utilisation of the plant resources. The homesteads were recognised to be found in villages which were classified into three groups: 'near' villages (0-3 km from the *kaya*); 'middle-distance' villages (3-5 km from the *kaya*); and 'far' villages (>5 km from the *kaya*).

The third section of the questionnaire sought the particulars of the interviewee, in terms of age, gender, employment, religious faith and relationship to the local *kaya* custodians. During the interviews the adults and most active members of the homestead were selected. Except for obvious information like gender, details of all the particulars of the interviewee were sought from the interviewee himself/herself. Where the interviewee did not know his/her age, or where age details were intentionally withheld, the interviewer estimated the age. Presence of family members or friends during the interviews was recorded.

In the fourth section of the questionnaire details of the plant species used for building the house(s) in the homestead were recorded. For each plant species used, information on the preference, source and collector were sought. During the interviews the interviewee identified the plant species by vernacular names, and the interviewer observed to confirm the identification of the species in question. These vernacular names were then matched with the scientific names using the ethnobotany inventory presented in this thesis as Chapter Five, and the scientific names were included in the text in this Chapter. Where a vernacular name was not matched with any scientific name, the vernacular name was maintained in the list. Preference levels were defined using three descriptive categories: Best, Good and Poor. 'Best' referred to the most preferred species for building poles due to their excellent quality and durability; 'Good' referred to the fairly preferred plant species for building poles on basis of quality; and 'Poor' referred to the least preferred species for building poles due to poorer quality. When the interviewee was not able to identify a preference level, 'no answer' was considered as the response. The sources of building poles were broadly categorised as 'bought' (for poles that the users purchased) and 'collected' (for poles that the users gathered). Where the building poles were bought, the localities of purchase were categorised as 'near' (<5km from the *kaya*) or 'far' (>5km from the *kaya*). There were three possible areas that the building poles could be collected i.e. the '*kaya*', 'private farmland', and 'bushland'. The '*kaya*' referred to all the area defined as *kaya* Mtswakara or *kaya* Fungo. The category "private farmland' referred to the land area that belonged to the family of the interviewee. 'Bushland' referred to communal land areas and/or farmland areas of other families from which building poles could be collected. The collector groups were classified into three: adults, children, and adults with children together.

The information on the name, preference, source and collector for each species was separately sought for every species identified by the interviewee as being used for building in the homestead. For most species the identification given by the interviewee was used (as the wood was dry and/or covered in the mud, thus it was often difficult for the interviewer to confirm the identification).

In the fifth section of the questionnaire the house-life i.e. the period that a house remained in good condition, was sought from the interviewee. The interviewee, based on past experience suggested the possible period (in years) that the house would remain in good condition, beyond which he/she would have to either build a new house or make a major repair to the existing house. Other building materials used in place of building poles in a homestead were also recorded.

The home visits and interviews were conducted in company of *kaya* guards, who guided the visits from one village to another, after specification of the objectives of the study were explained to them. The *kaya* guards identified the names of the villages, and the distances of the villages from the *kaya* were estimates. The interviews were conducted in the language of the interviewees (Duruma in Mtswakara, and Giriama in Fungo), and where need be the *kaya* guards were consulted for clarity. All the interviews and recording of the responses were made by this researcher.

Although most of the people living in the immediate vicinity of the *kayas* were generally poor, for relative local comparison, the families/homesteads were classified into different economic classes: the 'rich', the 'middle-class' and the 'poor' (Fig. 6.2), on basis of the house type(s), material possessions and financial earnings.

Fig. 6.1: Structured questionnaire used for collecting information on acquisition and utilisation of building poles around the *kayas* Mtswakara and Fungo

Questionnaire for Home visits

INTRODUCTORY STATEMENT

I am (name of interviewer), researching on the domestic utilization of wild plant resources. I am interested in finding out some details regarding firewood/building poles. Please help me to understand your acquisition and utilisation of the resource.

DESCRIPTION OF THE HOMESTEAD:

Homestead No.	Number of houses	Estimate population:	Village	Nearest Kaya

Wealth indicators:

House type(s): (a) Block/Iron sheet. (b) Block/Shingles[1] (c) Mud/Iron sheet (d) Mu/ Shingles (e) Grass.

Is any family member employed (earning average subsistence salary > KSh. 800.00) (Yes) (No)

Does the family own:(a) Vehicle (b) Bicycle (c) TV (d) Radio (e) Livestock (e) Poultry

MAIN INTERVIEWEE:

Name: ....

Age: [Very old] [Old] [Mid age][Young]

Gender: [Male] [Female]

Employed: [Yes] [No]

Religion: [Islam] [Christian] [Traditional] [Others]

Relation to Kaya elder/guard: [Yes] [No]

OTHER PEOPLE PRESENT DURING THE INTERVIEW:

Name	Age	Gender	Religion	Relation to interviewee

DETAILS OF SPECIES USED

Plant resource investigated: BUILDING POLE

1. **What is the name of the plant?** .... (Don't know).

(Identification by the interviewer) ....

2. **Preference level:** (Best) (Good) (Least) (No answer)

3. (a) **Source:** (a) Bought (i) Local (ii) Far (b) Collected (i) Kaya (ii) Private farmland (iii) Bushland

3. (b) **If collected, who was the collector?** (i) Child (ii) Adult (iii) Adult and child

1. **What is the name of the plant?** .... (Don't know)

(Identification by the interviewer) ....

2. **Preference level:** (Best) (Good) (Least) (No answer)

3. (a) **Source:** (a) Bought (i) Local (ii) Far (b) Collected (i) Kaya (ii) Private farmland (iii) Bushland

3. (b) **If collected, who was the collector?** (i) Child (ii) Adult (iii) Adult and child

HOUSE LIFE AND ALTERNATIVE BUILDING MATERIALS

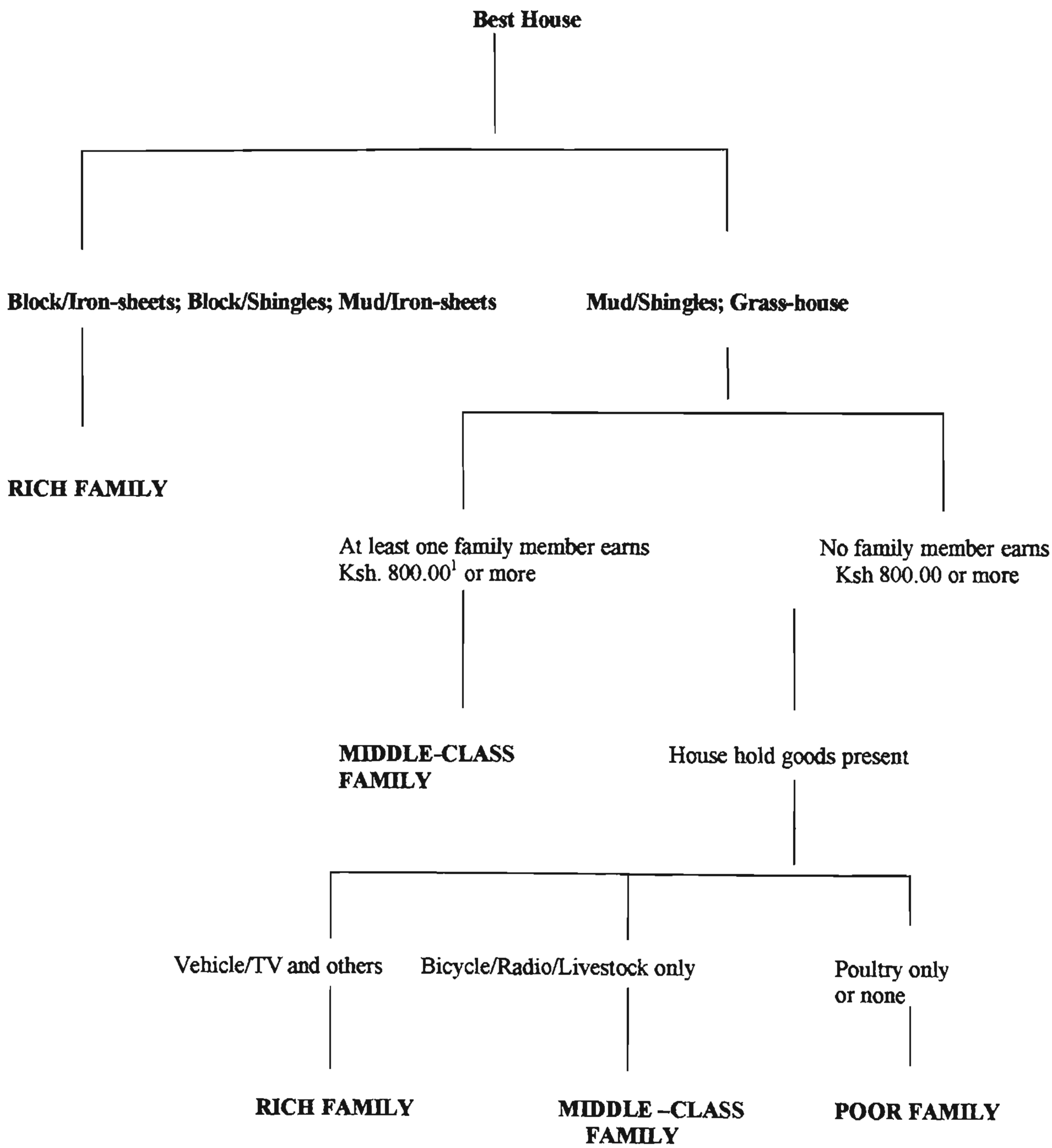
Estimated life of the house (in years): ....

Alternative/additional building materials: (a) Roofing shingles (b) Iron-sheets (c) Stone blocks (d) None

---

[1] Shingles refers to thatching materials made using leaflets cut from the palm fronds of coconut tree, which are bent across a length of a stick and tied together.

Fig. 6.2: Criteria for economic classification of local families in the homesteads around the *kayas*



[1] Ksh. 800.00 was here considered as the lowest wage at the local level

6.2.2 RESULTS: Plant species for building poles (*kaya* Mtswakara community)

Interviewees

The local community living in the immediate vicinity of *kaya* Mtswakara was clustered in identifiable villages, which were concentrated mainly on the western and northern areas of the *kaya*. Polygamy was common and the families were generally large. Homesteads in fifteen villages at different distances from the *kaya* were visited for the interviews on building poles. Five villages were 'near': (Chigojoni, Misheni, Chiliboli, Bopo-ra-peku and Fulugani); another five villages were 'middle-distance' (Chikole, Mgaza, Ziyani, Chinguluni and Mrabaini); and the remaining five were 'far' (Katundani, Majengo, Vikolani, Miguneni and Mnyendzeni).

In total, 100 homesteads were visited and an interview was conducted each of these homesteads. The visited homesteads included 39 in the 'near' villages, 33 in the 'middle distance' villages and 28 in the 'far' villages. Only one interviewee (number 1025) was female, all the others were male. In terms of age, six young (<15 years old), 49 mid-age (15 – 35 years old), 39 old (36 – 50 years) and six very old (>50 years old) interviewees were involved. Among the interviewees, 53% were Muslims, 45% were Christians and 2% had retained their traditional religion. Despite the acknowledgement of faiths of 'new' religions, most interviewees appreciated their traditional cultural beliefs, which were practised jointly with the other religious beliefs. Seven of the interviewees were related to *kaya* elders or *kaya* guards. In 62 interviewing sessions, the interviewees were in the company of family members or friends, whom in most cases made contributions to the responses. It was noted that the company of relatives and friends helped in collecting more information than where the interviewee were alone.

A minority (27%) of the interviewees had a formal employment. Based on the local wealth categorisation (Fig. 6.2) none of the families around *kaya* Mtswakara were poor, 83% were 'middle-class', and 17% were 'rich'. Both the number of people per homestead and the number of houses per homestead tended to increase with distance from the *kaya* (Table 6.1), but were not statistically significant (Kruskal-Wallis statistical test).

Table 6.1: Population, number of houses and estimated house life in homesteads at different distances from *kaya* Mtswakara

Distance category	Population per homestead	Number of houses (range)	Houses per homestead	House-life range (years)	House life (mean)
Near (n=39)	11.2	1 - 8	3.3	1 – 4	2.0
Middle-distance (n=33)	13.2	1 - 10	4.1	1 – 4	2.0
Far (n=28)	14.6	1 - 11	4.5	2 – 4	2.4

Plant species used, resource-base and collectors

A total of 48 plant species (Table 6.2) were used in house building, of which only 15 were the major species (used for building poles in 10% or more homesteads). The major species include dense forest species *Cynometra suaheliensis, Scorodophloeus fischeri, Manilkara sulcata* and *Craibia brevicaudata*; bushland/forest species *Grewia plagiophylla, Croton pseudopulchellus, Combretum schumannii,* and *C. illairii*; woodland/forest species *Canthium mombazense* and *Diospyros consolatae*; wooded grassland species *Terminalia spinosa* and *Dalbergia melanoxylon*; intertidal-zone Mangrove species and cultivated plant species *Agave sisalana* and *Casuarina equisitifolia*. All the major species were identified as 'best' species for building poles, except for *Grewia plagiophylla, Canthium mombazense* and *Combretum illairii*, which were identified as 'good' species. Among the minor species (utilised for building poles in less than 10% homesteads) were species identified as 'best' for building poles. These include tree/shrub species *Milletia usaramensis, Asteranthe asterias, Lamprothamnus zanguebaricus* and *Julbernardia magnistipulata*. This meant that the use of the species for building poles were specific in favour of the 'best', however, species rarity (in the local sense) was likely to contribute to its low utilisation. Therefore, less preferred species for building poles, but which are relatively common and were accessible, were likely to be used more extensively than the most preferred species which were locally rare.

Table 6.2: Percentage of homesteads (n=100) in which each of the identified species was used for building poles around *kaya* Mtswakara, and the species preference level (as a percentage of the utilised amount of the species)

Species	**Percentage of homesteads in which the species was utilised**	**Best**	**Good**	**Poor**
Cynometra suaheliensis	66	100	0	0
Manilkara sulcata	55	100	0	0
Terminalia spinosa	55	98.2	0	0
Scorodophleous fischeri	47	100	0	0
Grewia plagiophylla	46	41.3	56.5	2.2
Diospyros consolatae	37	100	0	0
Croton pseudopulchellus	36	94.4	5.6	0
Combretum schumannii	34	97.1	2.9	0
Mangrove species	31	100	0	0
Agave sisalana	28	100	0	0
Canthium mombazense	26	42.3	57.7	0
Casuarina equisitifolia	24	100	0	0
Combretum illairii	18	22.2	77.8	0
Dalbergia melanoxylon	13	100	0	0
Craibia brevicaudata	11	100	0	0
Thespesia danis	9	22.2	0	77.8
Thevetia peruviana	9	0	33.3	66.7
Diospyros bussei	9	33.3	66.7	0
Vittellariopsis kirkii	7	28.6	71.4	0
Diospyros squarrosa	7	42.9	57.1	0
Asteranthe asterias	7	71.4	28.6	0
Milletia usaramensis	6	83.3	16.7	0
Lamprothamnus zanguebarica	5	80	20	0
Brachystegia spiciformis	5	40	60	0
Acacia mellifera	4	25	75	0
Julbernardia magnistipulata	4	75	25	0
Albizia anthelmintica	4	25	75	0
Strynos madagascariensis	4	25	75	0
Catunaregum nilotica	3	33.3	66.7	0
Ziziphus pubescens	3	66.7	33.3	0
Flueggea virosa	3	0	66.7	33.3
Cassia singueana	3	0	100	0
Garcinia livingstonei	3	33.3	66.7	0
'Mtanga'	3	100	0	0
Markhamia zanzibarica	2	100	0	0
Tamarindus indica	2	0	0	100
Acacia sp.	2	0	50	50
Dalbergia boehmii	1	100	0	0
Psidium guajava	1	0	0	100
Afzelia quanzensis	1	0	0	100
Maytenus sp.	1	0	100	0
Cordia monoica	1	100	0	0
Azadiratchta indica	1	0	100	0
Euclea natalensis	1	0	0	100
Acacia zanzibarica	1	0	0	100
Hunteria zeylanica	1	0	100	0
Brachylaena huilensis	1	100	0	0
Nectropetalum sp.	1	100	0	0

Generally, the *kaya* was the main source of building poles and the 'private farmland' was the least important source of building poles (Fig. 6.3). The sources of building poles were species specific. Most of the dense forest species *Craibia brevicaudata*, *Scorodophleous fischeri*, *Croton pseudopulchellus*, *Combretum schumannii*, *Manilkara sulcata* and *Cynometra suaheliensis*, and woodland/forest species *Diospyros consolatae* were collected from the *kaya* (Table 6.3). Considerable amounts of each of these dense forest species (apart from *Craibia breivcaudata*) and the woodland species were 'bought near'. The 'bushland' was an important source of a woodland species *Canthium mombazense*, wooded grassland species *Grewia plagiophylla*, *Terminalia spinosa* and *Dalbergia melanoxylon*, and forest/bushland species *Combretum illairi*, which were relatively common outside the *kaya* forest area. Building poles 'bought far' were mainly of Mangrove species, and cultivated species *Casuarina equisitifolia* and *Agave sisalana* (Table 6.3). The 'private farmland' was not an important source of poles, and the only species considerably collected from the 'private farmland' was *Thevetia peruviana*, an exotic 'poor' species grown on homesteads mainly as an ornamental.

Table 6.3: Percentage of the total utilised amount of each major species acquired from different sources in the homesteads (n =100) around *kaya* Mtswakara

Species	**Collection from *kaya***	**Collection from Private farmland**	**Collection from Bushland**	**Bought 'near'**	**Bought 'far'**
Craibia brevicaudata	100	0	0	0	0
Scorodophleous fischeri	72.3	0	0	23.4	4.3
Croton pseudopulchellus	69.4	0	13.9	16.7	0
Diospyros consolatae	64.9	0	0	35.1	0
Manilkara sulcata	63.6	0	0	34.5	1.8
Cynometra suaheliensis	60.6	0	1.5	31.8	6.1
Combretum schumannii	52.9	0	5.9	41.2	0
Terminalia spinosa	43.6	3.6	36.4	14.5	1.8
Dalbergia melanoxylon	38.5	0	53.8	7.7	0
Canthium mombazense	34.6	0	61.5	0	3.8
Combretum illairii	27.8	0	72.2	0	0
Grewia plagiophylla	19.6	2.2	76.1	2.2	0
Cassuarina equisitifolia	0	4.2	0	0	95.8
Mangrove species	0	0	0	19.4	80.6
Agave sisalana	0	0	0	0	100

Fig. 6.3: Sources of building poles for communities living around *kaya* Mtswakara

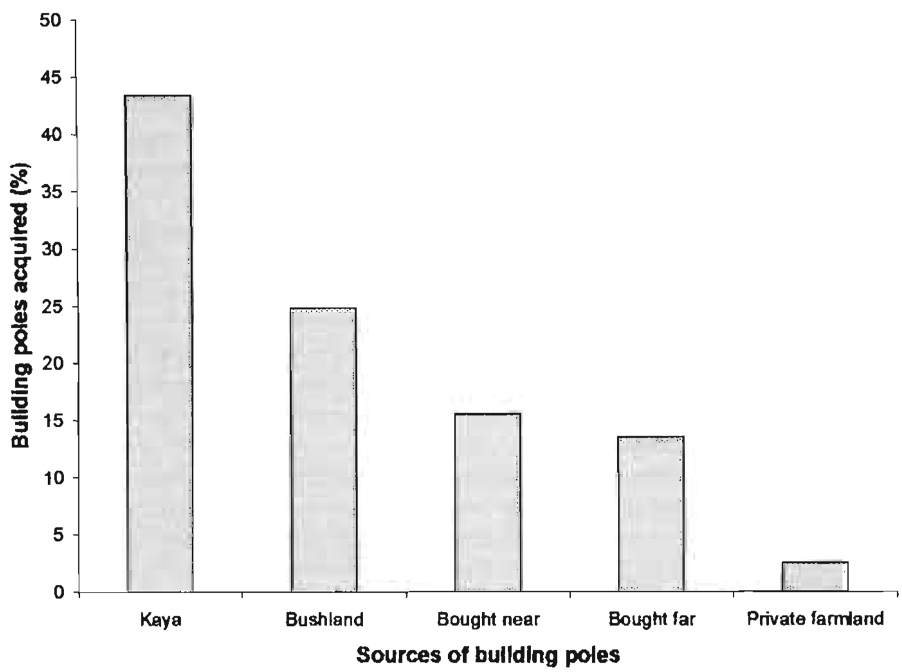
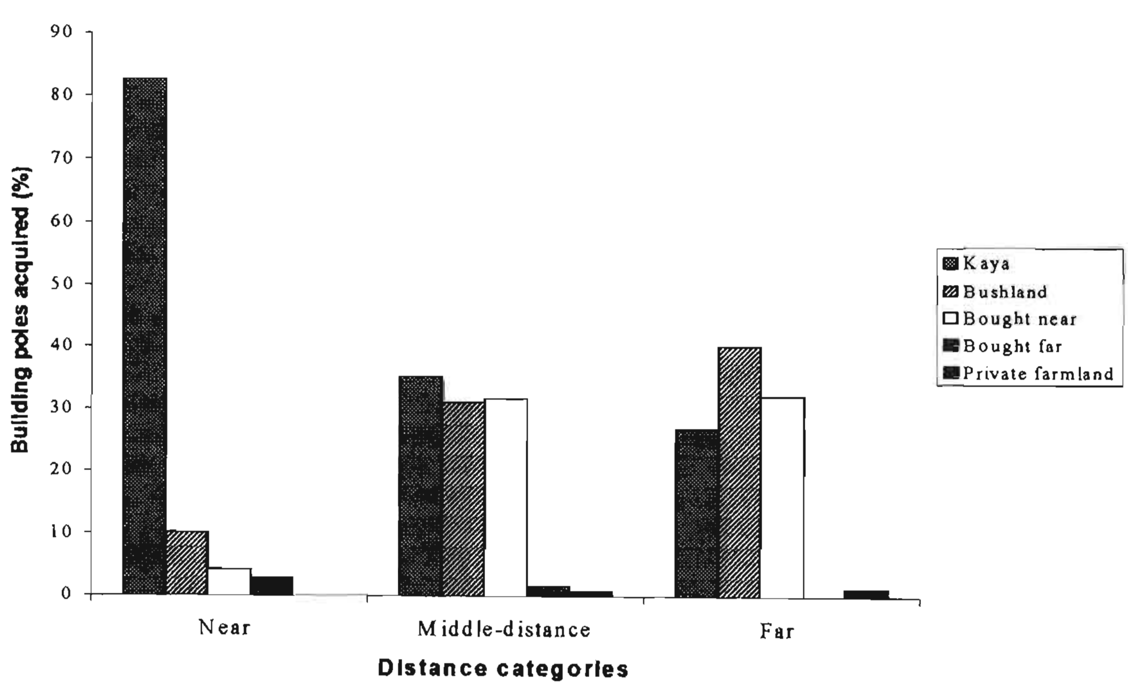


Fig.6.4: Percentages of building poles acquired from different sources in the different distance categories around *kaya* Mtswakara



The species 'bought near' were well matched with the species collected from the *kaya*, which suggests that collections from the *kaya* were made by both user-gatherers and by gatherer-sellers. This meant that an informal trade in building poles at the local level existed, although the *kaya* guards described it as being illegal. The adults were the main collectors of the building poles, while children contributed minimally, and only when in company of adults. Collection by the adults was strongly associated with the '*kaya*'. Joint collection by adults with children was associated with the 'private farmland' and 'bushland'.

Relationships between use and source of building poles to distance from the kaya

The importance of sources of building poles for the community members in the three different distance categories varied considerable (Fig. 6.4). The acquisition of the major species used for building poles show that the importance of the *kaya* as a source of poles reduced with distance from the *kaya*, but remained important in all distance categories (Fig. 6.4). While collections from the 'bushland' and poles 'bought near' became important with increasing distance from the *kaya*. The 'private farmland' and amount of poles 'bought far' were not important for poles in all distance categories. This shows the importance of the *kaya* as source of poles to the communities around *kaya* Mtswakara, but the importance decreased with increasing distance, thus away from the *kaya* the 'bushland' was used more to augment the collection from the *kaya*.

Table 6.4 gives the details of the utilisation patterns of the major species across different distance categories. Some species were utilised more in the 'near' homesteads. These included dense forest species *Cynometra suaheliensis*, *Scorodophloeus fischeri*, *Manilkara sulcata* and bushland/forest species *Croton pseudopulchellus*. The high utilisation of dense forest species in the 'near' homesteads was likely to be due to the proximity of these homesteads to the *kaya*. However, dense forest species *Craibia brevicaudata* and wooded grassland species *Dalbergia melanoxylon* were utilised in low levels in all distance categories. The wood of both species was identified as 'best' pole quality (Table 6.2), thus the low utilisation was probably due to unavailability. The unavailability of *Dalbergia melanoxylon* was likely to be due to scarcity, as the species was locally rare both in the *kaya* forest area and in the outside 'bushland' area. The low utilisation of *Craibia brevicaudata* was not based on rarity, at least for the 'near' homesteads, because it was fairly common in the *kaya*.

The bushland/forest species *Combretum schumannii* and *Combretum illairii*, the wooded grassland species *Terminalia spinosa*, the cultivated species *Agave sisalana* and *Casuarina equisitifolia*, and the intertidal-zone Mangrove species were utilised more in the homesteads away from the *kaya*. Although most poles of *Combretum schumannii* were collected from the *kaya*, considerable numbers of these poles were also purchased (Table 6.3), which explains why the species was utilised more in the homesteads away from the *kaya*, where both the *kaya* and purchasing ('bought near') were important sources. The low utilisation of *Combretum illairii* in the 'near' homesteads was likely to be due to its low preference level (Table 6.2). *Combretum illairii*, which was mainly collected from the 'bushland', was not a priority in the 'near' homesteads where there was availability of better alternatives ('best' species) for poles. However, with increase in distance the species became relatively more important as the availability of better the alternatives reduced. It was not established whether pole densities of the species differed between the 'bushland' and the *kaya*, which could have also led to the difference in utilisation level between different distance categories. The cultivated species *Agave sisalana* and *Casuarina equisitifolia* could only be obtained either from the 'private farmland' or 'bought'. Cultivation of plant species for poles, and purchase of poles, are both likely to be instigated by shortage experiences and/or difficult in accessibility to a resource from other sources e.g. the *kaya*. The community in the 'near' homesteads, due to the proximity to the *kaya* experience less shortage of poles compared to communities away from the *kaya*. Thus the communities in 'middle-distance' and 'far' homesteads were forced to opt to other sources, particularly purchasing (Fig. 6.4), from which the cultivated species and Mangrove species were mostly acquired.

Terminalia spinosa, *Grewia plagiophylla*, *Diospyros consolatae* and *Canthium mombazense* were utilised in about similar levels across the different distance categories. However, *Grewia plagiophylla* and *Canthium mombazense* were utilised considerable lower in the 'middle-distance' homesteads. This probably was due to fluctuating pole densities of these species in the 'bushland' (the main source of these species) across different distances from the *kaya*. *Terminalia spinosa* was utilised considerably in the 'middle-distance' homesteads, where probably extensive collections from both the *kaya* and the 'bushland' (main sources) were made.

Table 6.4: Percentage of homesteads in which each of the major species for building pole was utilised in the different distance categories around *kaya* Mtswakara.

Species	Utilisation in 'near' homesteads (n=39)	Utilisation in 'middle-distance' homesteads (n=33)	Utilisation in 'far' homesteads (n=28)
Cynometra suaheliensis	82.1	51.5	60.7
Scorodophloeus fischeri	69.2	36.4	28.6
Manilkara sulcata	61.5	48.5	53.6
Terminalia spinosa	51.3	60.6	53.6
Grewia plagiophylla	48.7	39.4	50
Croton pseudopulchellus	43.6	27.3	35.7
Diospyros consolatae	38.5	33.3	39.3
Canthium mombazense	28.2	18.2	32.1
Combretum schumannii	23.1	39.4	42.9
Dalbergia melanoxylon	23.1	6.1	7.1
Mangrove species	23.1	33.3	39.3
Agave sisalana	20.5	30.3	35.7
Craibia brevicaudata	17.9	9.1	3.6
Casuarina equisitifolia	17.9	30.3	25
Combretum illairii	10.3	12.1	35.7

The importance of the *kaya* as a significant source of building poles (Fig. 6.4), was because of the availability of forest and woodland species which were 'best' for poles, collected considerably in all distance categories (Table 6.5). For example, *Craibia brevicaudata* was collected exclusively from the *kaya*, and most collection of the other dense forest species were made from the *kaya*. The high reliance of the *kaya* for the dense forest species was because those species were not common outside the *kaya*, as the forested and woodland habitats had been cleared for farming. For the other species unavailability in the *kaya*, availability in the 'bushland' and low preference levels, were responsible of the collection patterns in Table 6.5. *Terminalia spinosa* was a preferred species, and was considerable available in the 'bushland', thus the communities in the 'middle-distance' and 'far' homesteads did not have to make significant reliance on the *kaya* for this species. *Grewia plagiophylla*, *Canthium mombazense* and *Combretum illairii* were less preferred (Table 6.2) and were considerable common in the bushland, therefore, it was not surprising that the collection of these species from the *kaya*, particularly by communities in the 'middle-distance' and 'far' homesteads was low. The percentage collection of the wooded grassland species *Dalbergia melanoxylon* from the *kaya* was about the same. This observation could not be immediately explained, as it was complicated by the fact that the species was both a preferred species and locally rare, and is not a dense forest species. The cultivated species were naturally not available in the *kaya*; thus it was expected that their collections were not from the *kaya*.

Table 6.5: Collection (%) of the major species used for building poles from the *kaya* Mtswakara by community members in different distance categories from the *kaya*.

Species	***Kaya* collection in 'near' homesteads**	***Kaya* collection in 'middle-distance' homesteads**	***Kaya* collection in 'far' homesteads**
Cynometra suaheliensis	81.3	41.2	41.2
Scorodophloeus fischeri	85.2	66.7	33.3
Manilkara sulcata	91.7	50	6.7
Terminalia spinosa	85	30	37.5
Grewia plagiophylla	47.4	0	0
Croton pseudopulchellus	88.2	55.6	50
Diospyros consolatae	86.7	45.5	54.5
Canthium mombazense	72.7	16.7	0
Combretum schumannii	88.9	46.2	33.3
Dalbergia melanoxylon	44.9	50	50
Mangrove species	0	0	0
Agave sisalana	0	0	0
Craibia brevicaudata	100	100	100
Casuarina equisitifolia	0	0	0
Combretum illairii	100	0	10

None of the major species used for building poles was collected from the 'private farmland' in the 'near' homesteads (Fig. 6.4). In the 'middle-distance' homesteads the 'private farmland' was a source of *Grewia plagiophylla* (7.7%) and *Casuarina equisitifolia* (10%), and the source of *Terminalia spinosa* (13.3%) in the 'far' homesteads. Probably in the 'near' homesteads, the proximity to the main resource-base (the *kaya*), has led to the absence of any effort to explore tree domestication for building pole requirements. However, even the effort put in to tree domestication in the 'middle-distance' and 'far' homesteads was minimal.

In all distance categories the poles 'bought far' were mainly of the cultivated species *Casuarina equisitifolia* and *Agave sisalana*, and the Mangrove species. The purchase of cultivated species from 'far' and the absence of or insignificant collection of these species from 'private farmland', further supports the argument that tree domestication was not an important source of building poles near *kaya* Mtswakara.

Although the purchase of building poles reflected a relationship to distance from the *kaya* (Fig. 6.4), it was probably that the economic status of the families also contributed to the proportion of poles that were 'bought'. Table 6.6 compares differences in the purchase of poles by the two economic classes, the 'middle-class' and the 'rich'. The species purchased were the same, but the 'rich' families/homesteads purchased more poles than the 'middle-class' families/homesteads.

In addition to the use of woody species for building poles, the grass species *Hyperthelia dissoluta* and *Heteropogon contortus* were commonly used as thatching materials especially for grass-houses in all distance categories. The grass-houses were recorded in 23% of the 'near' homesteads, 48.5% in 'middle-distance' and in 32.1% in 'far' homesteads. The use of the grass species did not have an obvious pattern related to the distance from the *kaya*, mainly because the grass species were collected from the 'bushland'. Alternative building materials, roofing shingles, stone-blocks and iron-sheets, were also recorded. The utilisation of these alternative building materials in the three distance categories did not show any pattern that can be defined in terms of distance variation from the *kaya* (Table 6.7). In all distance categories, roofing shingles, which are locally woven, mainly by female members of the community, were the most utilised. Iron-sheets and stone-blocks were only bought, thus putting a financial commitment to the users. It is likely therefore that the low use of iron-sheets and stone-blocks was due to inability of most community members to meet the financial requirements for these alternative materials.

Table 6.6: Source (%) of the major species used for building by the 'middle-class' (n=17) and the 'rich' (n=83) economic groups around *kaya* Mtswakara.

Species	Purchase by 'middle-class' (n=83)	Purchase by 'rich' class (n=17)
Cynometra suaheliensis	20.5	41.2
Manilkara sulcata	13.3	41.2
Terminalia spinosa	8.4	11.8
Scorodophloeus fischeri	8.4	29.4
Grewia plagiophylla	1.2	0
Diospyros consolatae	9.6	29.4
Croton pseudopulchellus	6	5.9
Combretum schumannii	12	23.5
Canthium mombazense	1.2	0
Combretum illairii	0	0
Casuarina equisitifolia	22.9	23.5
Mangroves species	27.7	47.1
Agave sisalana	25.3	41.2
Dalbergia melanoxylon		
Craibia brevicaudata		

Table 6.7: Utilisation (%) of the alternative building materials in the homesteads found in the different distance categories from

Distant category	Roofing shingles	Iron-sheets	Stone-blocks
Near (n=39)	100	12.8	2.6
Middle-distance (n=33)	100	12.1	3.0
Far (n=28)	100	25	3.6

6.2.3 RESULTS: Plant species for building poles (*kaya* Fungo community)

Interviewees

The community living in the immediate vicinity of *kaya* Fungo was scattered over the entire area surrounding the *kaya* forest. Homesteads in eight villages surrounding the *kaya* were visited, and community members in those homesteads were interviewed. The villages visited included three 'near' villages: Gogo-reruhe, Kinagoni and Miyani; three 'middle-distance' villages: Nzoweni, Gotani and Tiwi; and two 'far' villages: Kinagoni and Gandini. A total of 60 questionnaires were administered, 34 in the 'near' villages, 10 in the 'middle-distance' villages and 16 in the 'far' villages.

The interviewees included 14 females and 46 males, among whom one was young (<15 years), 18 were mid-age (15 – 35 years old), 35 were old (36 – 50 years) and six were very old (>50 years old). The community constituted mostly of Christians (71.7%), some community members (25%) maintained their traditional beliefs exclusive of new faiths, and Muslims formed a minority of the population (3.3%). Three of the interviewees were related to either *kaya* elders or *kaya* guards. In 14 interviewing sessions the interviewees were in company of family members or friends. Only 5% of the interviewees were employed, that is getting additional cash income apart from subsistence farming. The communities were of two economic classes, i.e. the 'middle-class' (93.3%) and the 'poor' (6.7%). Human population variation with distance from the *kaya* did not show any clear pattern (Table 6.8). The house life showed a slight increase with distance from the *kaya*, but this was not statistically (Kruskul-Wallis test) significant.

Table 6.8: Population, number of houses and estimated house life in homesteads at different distances from *kaya* Fungo.

Distance category	Population per homestead	Range of number of houses	Houses per homestead	House life range	Mean of house life
Near homesteads (0-3km) (n=34)	10.3	1 – 8	3.0	1 – 4	1.9
Middle-distance homesteads (3-5km) (n=10)	15.1	2 – 6	3.9	1 – 3	2.2
Far homestead (>5km) (n=16)	9.9	1 - 9	3.0	1 – 4	2.3

Plant species used, resource-bases and collectors

A total of 55 plant species (Table 6.9) were used for building in the homesteads surrounding *kaya* Fungo. Out of the 55, only 15 were major species (used for building in 10% homesteads or more). The major species included bushland/forest species *Croton pseudopulchellus, Combretum* *schumannii, Combretum illairii, Manilkara mochas, Diospyros bussei* and *Dombeya taylorii*; wooded-grassland/bushland species *Grewia plagiophylla, Thespesia danis, Lamprothamnus zanguebaricus, Dalbergia melanoxylon, Terminalia spinosa* and *Croton talaeporos*; and *Acacia* scrub-land species *Acacia reficiens, A. robusta* and *A. zanzibarica*.

It is interesting to note that although most of the major species were 'best' species, but less preferred species such *Acacia robusta, Croton talaeporos, Diospyros bussei, Acacia zanzibarica* and *Manilkara mochisa* were also used extensively. Also among the minor species (used in less than 10% of the homesteads) were species that were identified as most preferred for building e.g. *Combretum schumannii, Manilkara sulcata, Manilkara sansibarensis* and *Craibia brevicaudata*. Alternative plant species (i.e. not commonly collected from the *kaya*) used for building, *Agave sisalana* (sisal), *Coconus nucifera* (coconut) and Mangrove species were used in only small amounts around Fungo.

Generally around *kaya* Fungo the 'bushland' was the principal source of building poles, contributing more than three times the poles collected from any of the other sources, and a very small amount of poles were 'bought near' and 'far' (Fig. 6.5). Except for *Croton pseudopulchellus* and *Combretum schumannii*, more than 60% of the poles of all the major species were collected from the bushland (Table 6.10). *Croton pseudopulchellus* and *Combretum schumannii* were the only species substantially (>80%) collected from the *kaya*. Also most species, although in small amounts, were collected from 'private farmland'. The species 'bought near' included *Grewia plagiophylla, Acacia robusta, Thespesia danis, Acacia reficiens, Dombeya taylorii, Dalbergia melanoxylon* and *Croton pseudopulchellus*, most of which were collected from the 'bushland'. This suggests that, like in *kaya* Mtswakara,in *kaya* Fungo pole collections were made by user-gatherers and by gatherer-sellers, and therefore an informal trade in building poles existed at a local level. Only the species not common in the *kaya* forest and its surrounding area, i.e. Mangrove species, and the cultivated species *Agave sisalana* (sisal poles) and *Coconus nucifera* (coconut poles), were 'bought far' (Table 6.10). The adult male members of the community were the main pole collectors, children participated minimally and only in the company of the adults.

Table 6.9: Percentage of homesteads (n=60) in which each of the identified species was used for building poles around *kaya* Fungo, and the species preference level (as a percentage of the utilised amount of the species)

Species	Percentage of homesteads in which the species was utilised	Best	Good	Poor
Grewia plagiophylla	88.3	83	17	0
Acacia robusta	75	40	48.9	11.1
Thespesia danis	58.3	54.3	45.7	0
Terminalia spinosa	55	93.9	6.1	0
Croton talaeporos	50	3.3	0	96.7
Combretum illairii	46.7	60.7	35.7	3.6
Acacia reficiens	21.7	46.2	23.1	30.7
Dombeya taylorii	21.7	76.9	23.1	0
Dalbergia melanoxylon	21.7	100	0	0
Croton pseudopulchellus	18.3	100	0	0
Diospyros bussei	18.3	36.4	45.4	18.2
Acacia zanzibarica	15	22.2	11.1	66.7
Lamprothamnus zanguebaricus	13.3	50	37.5	12.5
Combretum schumannii	11.7	100	0	0
Manilkara mochisa	10	33.3	66.7	0
Manilkara sulcata	6.7	100	0	0
Albizia anthelmintica	6.7	0	0	100
Flueggea vilosa	6.7	50	25	25
Agave sisalana	6.7	100	0	0
Euclea natalensis	5	0	1	2
Manilkara sansibarensis	5	100	0	0
Ochna thomasiana	5	100	0	0
Craibia brevicaudata	5	100	0	0
Ziziphus mucronata	5	33.3	66.7	0
Garcinia livingstonei	5	33.3	66.7	0
Acacia mellifera	5	0	33.3	66.7
Premna chrysoclada	3.3	100	0	0
Loesoneriella africana	3.3	100	0	0
Brachylaena huilensis	3.3	100	0	0
Dobera loranthifolia	3.3	50	0	50
Diospyros sp.	3.3	0	0	100
Coconus nucifera	3.3	50	50	0
Mangrove species	3.3	100	0	0
Lantana camara	3.3	0	0	100
Lecaniodiscus fraxinifolius	3.3	50	50	0
'Mtsungula'	3.3	100	0	0
Euclea racemosa	1.7	100	0	0
Cola minor	1.7	100	0	0
Uvaria acuminata	1.7	100	0	0
Allophylus rubifolius	1.7	100	0	0
Harrisonia abbysinica	1.7	0	0	100
Tabernaemonta elegans	1.7	0	0	100
Pentarhopalopilia umbellulata	1.7	0	0	100
Tamarindus indica	1.7	0	100	0
Diospyros consolatae	1.7	100	0	0
Diaelium orientalis	1.7	0	100	0
Thevetia peruviana	1.7	100	0	0
'Mvundza-jembe'	1.7	100	0	0

Table 6.9: Continued

Azadirachta indica	1.7	0	0	100
Commiphora edulis	1.7	0	0	100
'Mukironda'	1.7	100	0	0
'Mkayukayu'	1.7	0	100	0
Diospyros squarrosa	1.7	100	0	0
Cyperus exaltatus	23.3	64.3	35.7	0
Hyperthelia dissoluta	43.3	100	0	0

Table 6.10: Percentage of the total utilised amount of each major species acquired from different sources in the homesteads (n=60) around *kaya* Fungo

Species	**Collection from the '*kaya*'**	**Collection from 'private farmland'**	**Collection from 'bushland'**	**'Bought near'**
Grewia plagiophylla	7.5	9.4	77.4	5.7
Acacia robusta	4.4	13.3	77.8	4.4
Thespesia danis	8.6	5.7	80	5.7
Terminalia spinosa	3.0	15.2	81.8	0
Croton talaeporos	0	6.7	93.3	0
Combretum illairii	0	3.6	96.4	0
Acacia reficiens	0	30.8	61.5	3.7
Dombeya taylorii	23.1	0	69.2	7.7
Dalbergia melanoxylon	23.1	7.7	61.5	7.7
Croton pseudopulchellus	81.8	0	9.1	9.1
Diospyros bussei	0	9.1	90.9	0
Acacia zanzibarica	0	0	100	0
Lamprothamnus zanguebaricus	0	0	100	0
Combretum schumannii	85.7	0	14.3	0
Manilkara mochisa	0	16.7	83.3	0

Relationship between building pole use and distance from the kaya

Given the data shown in Fig. 6.5 it is not surprising that the 'bushland' was the most important source of building poles in all distance categories (Fig. 6.6). The main difference in the 'near' homesteads from other distance categories was the absence of use of any purchased building poles. The importance of collection from the *kaya* was low but surprisingly absent completely in the 'mid-distance' homesteads but present in the 'near' and 'far' homesteads.

Fig. 6.5: Sources of building poles for communities living around *kaya* Fungo

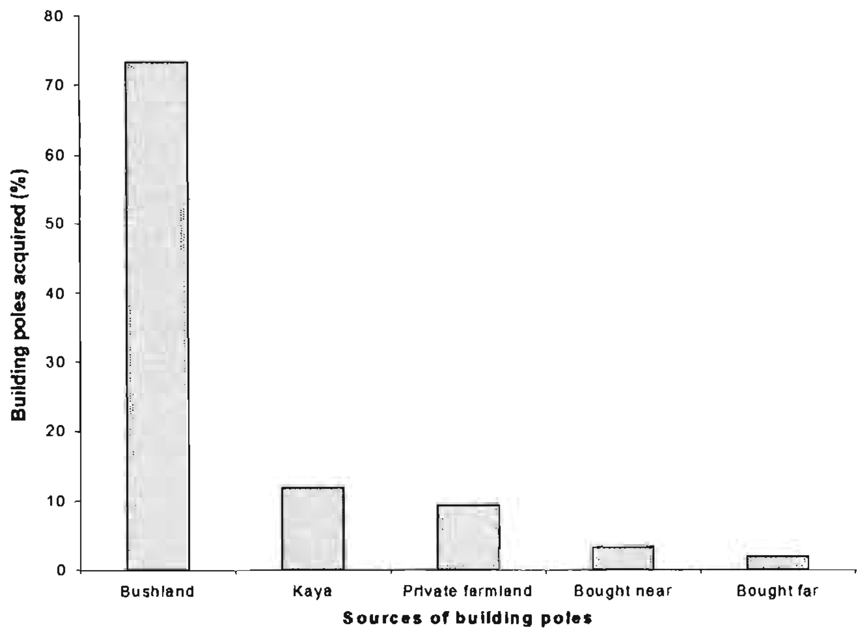
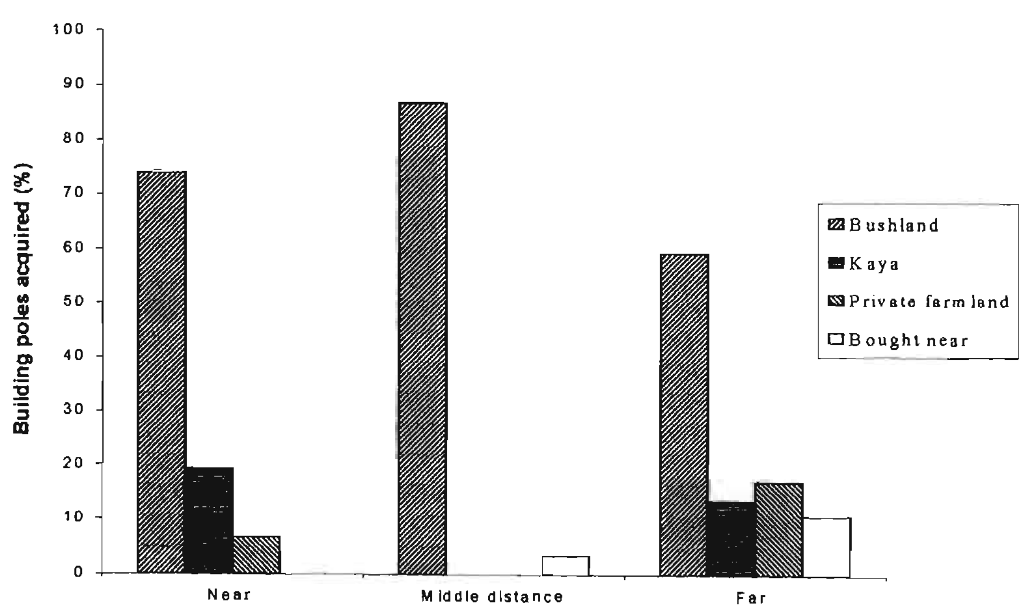


Fig. 6.6: Percentages of building poles acquired from different sources in the different distance categories around *kaya* Fungo



The utilisation pattern (i.e. the percentage of homesteads in which the species was used) of the major species showed a little difference between homesteads found in different distance categories (Table 6.11). In all distance categories, the most utilised species were *Grewia plagiophylla* and *Acacia robusta*. *Combretum illairii* was also used in large amounts in the 'near' homesteads, and *Thespesia danis* was used in large amounts in the 'middle-distance' homesteads. The variation in the use of *Combretum illairii* and *Thespesia danis* was probably only an indication of the differences in pole densities of these species in the 'bushland'.

In all distance categories utilisation of *Croton talaeporos* for poles was considerable common although the species was considered as a 'poor' species for building poles (Table 6.9). While the utilisation of *Dalbergia melanoxylon* and *Combretum schumannii* were generally low in all distance categories (Table 6.11), although the species were known for their 'best' pole quality (Table 6.9). This indicates that high utilisation of less preferred, but common species e.g. *Croton talaeporos*, and low utilisation of 'most' preferred but locally rare or inaccessible species e.g. *Dalbergia melanoxylon* and *Combretum schumannii*, were shared in all distances. From the author's personal observation, *Dalbergia melanoxylon* was locally rare in and out of the forest. However, *Combretum schumannii* was considerable common in the *kaya*, and therefore, low utilisation might be attributed to the restrictions on the plant resource extraction from the *kaya*.

The 'bushland' was the main source of all the major species in all distance categories except for *Croton pseudopulchellus* (Table 6.10), which was mainly collected from the *kaya*. In the 'near' homestead all *Croton pseudopulchellus* poles, considerable percentages of poles of *Dalbergia melanoxylon* and *Dombeya taylorii* were collected from the *kaya*, while small amounts (<20%) of the other major species were collected from the *kaya*. In the 'far' homesteads only *Croton pseudopulchellus* was significantly collected from the *kaya*. Surprisingly, there were no pole collections made from the *kaya* in the 'middle-distance' homesteads.

Among the major species, *Grewia plagiophylla*, *Acacia robusta*, *Thespesia danis*, *Terminalia spinosa*, *Acacia reficiens*, *Combretum illairii* and *Dalbergia melanoxylon*, were collected from 'private farmland' in the 'near' and 'far' homesteads. Pole collection from 'private farmland' was more common in the 'far' homesteads compared to 'near' homesteads, with *Acacia reficiens* being the most collected. Most of the major species were also 'bought near' in the 'middle-distance' and 'far' homesteads. Although *Terminalia spinosa* was identified as a 'best' species for building poles and was commonly domesticated, the species wood was commonly purchased for grave 'markers' (*vigango*) and much less common for building poles (it was not recorded, in this study, as being bought for poles).

Table 6.11: Percentage of homesteads in which each of the major species for building poles was utilised in the different distance categories around *kaya* Fungo

Species	Utilisation (%) in 'near' homesteads (n=34)	Utilisation (%) in 'middle-distance' homesteads (n=10)	Utilisation (%) in 'far' homesteads (n=16)
Grewia plagiophylla	82.4	100	93.8
Acacia robusta	73.5	80	75
Combretum illairii	70.6	20	12.5
Terminalia spinosa	64.7	40	43.8
Thespesia danis	52.9	90	50
Croton talaeporos	44.1	60	56.3
Acacia reficiens	20.6	20	31.3
Dombeya taylorii	20.6	10	31.3
Diospyros bussei	20.6	20	12.5
Dalbergia melanoxylon	17.6	10	37.5
Croton pseudopulchellus	14.7	0	37.5
Lamprothamnus zanguebaricus	14.7	0	18.8
Combretum schumannii	14.7	0	12.5
Acacia zanzibarica	11.8	30	12.5
Manilkara mochisa	5.9	0	12.5

The use of grass species *Hyperthelia dissoluta* and *Cyperus exaltatus* for building grass-houses was common in all distances; recorded in 61.8% in 'near' homesteads, in 90% 'middle-distance', and in 81.3% 'far' homesteads. However, the number of grass-houses were generally few (1 – 3) in the homesteads, and were mainly used as granaries, livestock houses or as a kitchen house, while the mud-walled angular framed houses were used as the main residential houses. In few cases some elderly members of the community preferred the grass-houses for residence.

Use of alternative building materials

The utilisation of alternative building materials in the homesteads was not related to the distance from the *kaya* (Table 6.12). In general, roofing shingles, which were bought but relatively cheaply, were used in all the distance categories. The roofing shingles were the only alternative building material used by the 'poor', while among the 'middle-class', iron-sheets and stone-blocks were also used. The use of iron-sheets and stone-blocks was determined by economic status rather than the settlement pattern of families in relation to distance from the *kaya*.

Table 6.12: Utilisation (%) of the alternative building materials in the homesteads found in the different distance categories from *kaya* Fungo

Distant category	Roofing shingles	Iron-sheets	Stone blocks
Near homesteads (n=34)	100	11.8	0
Middle-distance homesteads (n=10)	100	40	0
Far homesteads (n=16)	100	12.5	6.3

6.2.4 DISCUSSION: Housing and plant species used for building poles

The traditional dwelling of the *Midzichenda* is a grasshouse (Plate 6.1) which is still the only type of construction allowed inside the *kaya*, an observation that was also noted by Hawthorne *et al.* (1981). However, this housing type is today on the decline and in its place a variety of house-types are being built. In the current times, in the Duruma and Giriama areas that border the *kaya* forests, the most common house type is the earth-walled angular-framed type thatched with roofing shingles (Plate 6.2), locally known as *nyumba-ya-chidzomba* i.e. the Swahili house. Comparatively, grasshouses were recorded in more homesteads (71.7%) of the Giriama than among the Duruma (34%). The transition from grasshouses to earth-walled angular-framed houses is believed to have been part of the adoption of the Arab culture, which the *Midzichenda* made at the same period as they were adopting the Islamic religion in about 14th century (Hawthorne *et al.* 1981). According to Hawthorne *et al.* (1981) even the Christian missionaries favoured the earth-walled angular framed houses to the circular grasshouses because the former house type appeared less 'primitive' and more hygienic than the latter type. The aesthetic symbol of the *Midzichenda* housing, i.e. the grasshouse, is being phased off by the social change.

In some cases the earth-walled house type was modified to different sub-types, that lasted, relatively, longer. These include earth-walled angular- or circular-framed, thatched with grass (*nyumba-ya-msongo*); and earth-walled angular-framed strengthened by partially cementing the walls (Plate 6.3), or stone-blocks angular-framed wall, thatched with either roofing shingles or iron-sheets. The use of the stone-blocks and iron-sheets was not common amongst both the Duruma and Giriama mainly because of the low economic status of most of the community members. Building poles, therefore, were and will remain the main building materials for these communities living around the *kayas*.

The earth-walled frame and the grass house types were built from a very wide range of plant species (Tables 6.2; 6.10), most of which are available in and could be collected from the *kaya* forests. The wood consumption in housing was not only for the construction of new premises, but also for maintenance of the relatively old houses, which increases the demand for poles. Around *kaya* Mtswakara, some houses were built over 20 years ago, when the community had a relatively free access to the plant resources from the *kaya* (interviewee 1001). However, the houses have to be repaired frequently because of damage. For example, the damage caused to houses by unusual heavy rains during the 1997-1998 short rain season (Plate 6.4). It was also necessary to build new houses that were completely washed out during these rains. The house structures, therefore, normally represent a range of both old and new, a situation that is likely to remain the same in future, more so if hazards such as the unusual heavy rains become more common. This suggests, therefore, that the demand for building poles by the communities living around the *kayas* is and will continue as present. Since the needs for housing are dependent on population size, the amount of wood that will be required in future, due to expected population increase, is likely to be more than the present demand.

A house-life is likely to have an inverse relationship to the building pole demand. On the other hand the house-life depends on good workmanship in the house construction (interviewee 2026) as well as the utilisation of strong (high quality) poles and the 'best' species (interviewee 2008). From informal discussion it was noted that for most families the houses were self-built, using little knowledge or skills that are based on the indigenous house construction technique of the local community i.e. no formal or informal training. However, a few families, mostly those with a relatively stable income, paid local house constructors who took responsibility for the collection of building poles and the house construction (interviewee 2052). The houses built by hired constructors were reported to have a relatively longer life (interviewee 2049). Interestingly, the rare traditional grasshouses were frequently identified to have a considerably longer life compared to the more common earth-walled house types. Although the house-life estimations were sometimes questionable, there were consistent comments on the durability of grasshouses compared to earth-walled houses. Under favourable conditions, the grasshouse was estimated to last almost a lifetime, while most earth-walled houses were estimated to have a life period of three years or less. However, grasshouse construction requires more poles (Hawthorne *et al.* 1981) and the technical knowledge and workmanship involved is not as easily available today as was in the past (Yawa pers. comm.).

Around *kaya* Mtswkara, poles from other sources only complimented the pole collection from the *kaya*, particularly for homesteads close to the *kaya*. The situation in *kaya* Fungo was different, as the 'bushland' was the main source of building poles. However, although it was likely that the 'bushland' contributed a much greater proportion of poles, the data on pole collection from *kaya* Fungo might be an underestimate of the real situation. From a personal assessment by this author, unreliable responses from some interviewees, especially from the *kaya* Fungo community, cannot be dismissed. This was particularly so for the responses to the 'source' of the building poles. The company of a *kaya* guard during the interviews and the prevailing uncertainties of the legality in the collection of building poles from the *kaya*, might have created a suspicious atmosphere among some community members, resulting to distrust. Fear of being arrested and convicted as 'culprits' for collecting poles from the *kaya* might have led to the interviewees supplying incorrect information, intentionally avoiding the identification of the *kaya* as the source of 'their' building poles.

Good quality building poles, were identified as becoming scarce with time, and more expensive to purchase (interviewee 2008), thus it was not surprising that 'poor' quality species were used to supplement, and sometimes to replace the 'best' but rarer species. The community members of both *kayas* attributed the problems of poor housing facilities to the lack of good quality building poles i.e. the 'best' species for building poles. Some community members complained of not being able to get the 'best' poles for building because they are not allowed to collect from the *kayas* any more (Nyamweru 1997). The results in this study showed that, although a wide range of species are used for building poles, much effort was put into using the 'best' species available. Few species (five out of 48 in *kaya* Mtswakara, and six out of 55 in *kaya* Fungo) were the most common used (in ≥50% homesteads), and these were the species specified as the 'best' for building poles (Tables 6.2; 6.10). This shows that for building poles there was a strong trend for the selection of a few species, which in turn may suffer an over-exploitation if the extraction rates exceed the regeneration abilities of these species. In *kaya* Fungo, an exception in this argument was *Croton talaeporos*, which was identified as a least preferred species, yet it was extensively used. This indicates that although species selection and utilisation was primarily based on preference, inclusion of less or even the least preferred species occurred, especially with the *kaya* Fungo community. This could be interpreted to mean that in addition to preference, easy availability of the plant species was equally important in the species utilisation. The most preferred species were likely to have been utilised extensively and became locally rare with time; the communities were, therefore, forced to resort to the less preferred species, which were relatively common.

There was a strong relationship between the species collected and their source. Community members from different distance categories collected some species exclusively from the kaya. For *kaya* Mtswakara community, these included *Cynometra suaheliensis, Craibia brevicaudata, Manilkara sulcata, Diospyros consolatae* and *Scorodophloeus fischeri*, which are all evergreen dry forest species (Beentje, 1994) and were recorded in the *Scorodophloeus* and in the *Hugonia* dense forests communities in this study. *Diospyros consolatae* was recorded in the *Brachystegia* woodland community. While for the *kaya* Fungo community, the species that was collected mainly from the *kaya* was *Croton pseudopulchellus*, a common understorey species of drier lowland forests or woodlands (Beentje 1994), and was recorded in the *Uvariodendron* dense forest community in this study. All these species, in their respective *kaya* areas, were described by the users as 'best'. The exclusive collection of these species from the *kayas* is an indication that, in the surrounding farmland and bushland areas they were either unavailable or available in relatively low densities. Around *kaya* Mtswakara, apart from the *kaya*, these species could also be collected from Mwache Forest Reserve, at a monthly fee of Kenya shillings (Ksh.) 400.00 for a permit. Due to low economic status of most families, collection from the *kaya* was preferred to the Mwache Forest Reserve.

Terminalia spinosa, a wooded grassland species (Beentje 1994), recorded in the wooded grassland *Acacia* community (in *kaya* Mtswakara), was collected substantially collected from the *kaya* only by gatherers in the 'near' homesteads (Table 6.4), but with increasing distance from the *kaya* it was collected mostly from the 'bushland' (Table 6.6). This pattern was also observed for the *Grewia plagiophylla*, *Canthium mombazense* and *Combretum illairii*, all being bushland species (Beentje 1994). In this study *Grewia plagiophylla* was recorded in the *Acacia* community; *Canthium mombazense* was recorded in both *Hugonia* dense forest community and in the *Brachystegia* woodland community, while *Combretum illairii* was recorded in the *Scorodophloeus* and *Hugonia* dense forest communities.

The limited but significant collection from the 'bushland' around *kaya* Mtswakara and the very extensive dependence on the 'bushland' around *kaya* Fungo, indicate that in the 'bushland' there were considerable populations of the species utilised for building poles. However, although there is no information available on the 'stocks' of these utilised species in the 'bushland', it was unlikely that the community needs could be satisfied by collection from the 'bushland' exclusive of the '*kaya*'. Although the 'bushland' was the principal source of building poles to the *kaya* Fungo community, the 'major' species used for building poles were recorded in the *kaya*, and collection from the *kaya* was substantiated by the signs of pole collection of these species which were noted during the fieldwork of this study. The importance of the *kayas* as sources of building poles was therefore established, although some community members, including some *kaya* custodians (elders or guards) were not willing to strongly admit it.

To the *kaya* Fungo community, the people's private farmlands were considerably important sources of building poles. There was a spectrum of responses in the arrangements involved in collection of poles from a neighbour's farm. Most interviewees explained that the pole collection from a neighbour's farm was free only if the poles were for domestic use. But collection of poles for sale had different arrangements, which included payment of charges for collection. However, in some cases, payments for pole collection from other people's farms were made even for collections meant for domestic use (interviewee 2018).

Acquisition of poles from the *kaya* has been identified to benefit those who can pay the elders a stipulated 'token' (*kadzama*) (interviewee 1037). Although the idea of 'token' payment for collection of building poles has been in existence since the early history of the *kayas* (interviewees1003; and 2027), it has been described as 'unwanted' and free collection is desired (Nyamweru 1997). This could be an indication that currently most of the *Midzichenda* consider the *kayas* primarily as resource-bases for plant resources and only secondarily as holy places of worship that should not be destroyed through excessive tree cutting. The existing restrictions on plant resource extraction, although not well received by some community members, has been appreciated by others as it conserves much of what remains of the *kayas*. In the absence of timber extraction control strategies the *kayas* would have been cleared of many of the tree species, especially the multipurpose species that are also used for building (interviewee 2048). Examples given of multipurpose species included *Dalbergia melanoxylon*, which in addition to its local demand for house building, is also used extensively in carving such that the species has become rare in Kenya (Beentje 1994). Despite its high quality wood, in *kaya* Mtswakara, this species was used in fewer homesteads compared to some less preferred species like *Grewia plagiophylla*, *Canthium mombazense*, and *Combretum illairii* (Table 6.2). In *kaya* Fungo *Dalbergia melanoxylon* was used in fewer homesteads than the less preferred species *Croton talaeporos*, *Acacia robusta*, *Thespesia danis* and *Combretum illairii*.

The observed extensive extraction of *Combretum schumannii* from *kaya* Fungo (Plate 4.3), a preferred species for building and for making beehives, is a good example of what happens to a preferred species if the timber collection restrictions are relaxed. In *kaya* Fungo most of the mature trees of *Combretum schumannii* would appear to be sprouts of a collected mother plant. If the physiology of *Combretum schumannii* did not allow for the extensive coppicing, the species would be locally rare or even extinct in *kaya* Fungo. This might be the explanation for some other species in the *kayas*, e.g. *Milicia excelsa* (Fig. 4.4), which during this survey it was only noted as dead stumps and there was no standing tree noted. This was despite the explanation by the guards that in *kaya* Fungo the species was common in the past. The rarity of preferred species in the *kayas* and surrounding areas has been described as a recent phenomenon (interviewee 2007). Causes of the decline can be associated with the ongoing clearing of forests and burning for farmlands (interviewee 2048) and charcoal making. The ongoing trade in plant resources has also contributed considerably to the scarcity of some species (interviewee 2053).

The fact that farmland contributed very little to the building pole resources in both *kaya* areas meant that in the past decades there has been no effort to plant trees for building poles and that could have been used in the recent past. This could be attributed to community satisfaction in the sufficient supply of the resource in the *kayas* and the 'bushland'. However, this satisfaction most likely was not maintained, and sources other than the *kaya* and the 'bushland' are now resorted to (i.e. the markets and private farmlands), and these sources are likely to become even more important in future (interviewee 1006). Despite the common low contribution from farmlands in both *kaya* areas, comparatively more collection from the farmlands was made by the *kaya* Fungo community than by the *kaya* Mtswakara community. Based on historical information and the housing conditions, scarcity of building poles in the *kaya* Fungo area seemed to have been more acute and possibly has been experienced for a much longer period, than in the *kaya* Mtswakara area. The *kaya* Fungo community, therefore, might have started taking precautions with regards to future needs by planting and caring for wild plant species on their farms at a relatively earlier period. Hence, the relatively higher collection of building poles from the farmlands among *kaya* Fungo community than the *kaya* Mtswakara community. It was clear that the necessity to take precautions for shortage of supply of building poles and other woody products in the farmlands and bushland were yet to be appreciated by most of the *kaya* Mtswakara community members.

Amongst the community members of both *kayas*, there was a local informal trade in building poles as indicated by the considerable acquisition from the 'near' markets. Specific members of the communities were known, and were also noted during the fieldwork of this study, to make frequent and bulk pole collections, which were more than the normal demand for a single homestead. These gatherers, as reported by other community members, sold their collections mostly locally (in the villages) but also in 'distant' urban places. Thus in addition to meeting local demand in building poles, the *kayas* and the 'bushland' were also likely to be sources of building poles for demands in urban areas, which are supplied through informal, and often secretive, trade. This was established through the guards in both *kayas*, and some elders who complained of 'foul play' by some community members who sought for permission to collect poles for domestic use but who were found to have eventually sold the poles they had collected.

The internal local trade in building poles was more prominent among the *kaya* Mtswakara community, than the *kaya* Fungo community. Although purchase of the materials would be governed by the economic status of the individuals, in *kaya* Mtswakara it seemed that the purchase of building poles was partly influenced by distance from the *kaya*. In the 'near' homesteads purchase was not important, but in the 'middle-distance' and 'far' homesteads, purchase was of considerable importance, and utilisation of 'alternative' species was also higher. In contrast, in *kaya* Fungo, local purchase of building poles was relatively low. It was not clear whether this difference was due to discrepancy in the economic status between the two community groups, or due to the fact that for the *kaya* Fungo community most pole collections were made from the 'bushland' and not the *kaya*. Despite the low trade in building poles at village level, , extraction and selling of the building poles at the 'distant' urban market centres (i.e. Kaloleni and Mariakani, about 20 Km away) was acknowledged and described as the main source of income to some members of the *kaya* Fungo community.

In both *kayas* the adult male were the main pole collectors, with a minimal participation of male children (Tables 6.2; 6.10). The art of pole collection seemingly requires skills in selection of the right species, size and form, in addition to facing the risks such as snakebites and thorn pricks in the forests or the bushland. In company of the adults, the children might be receiving informal training in the collection practices as well as the necessary protection against the risks during the collection sessions. Although it could not be immediately established in this study, among some of the community members there might have been intentional discourage of unaccompanied children from making collections of building poles in the *kaya* forests or 'bushland'.

Conclusion

The results in this section reflect that the *kaya* as a source of building pole is more important for the community living in the immediate vicinity of *kaya* Mtswakara than for *kaya* Fungo, but both communities share the collection of some of the 'best' species for building poles from the *kaya*. Most of the 'best' species are rare outside the *kayas* and continue to become rarer, while the demand for building poles is likely to increase with time, especially when some people opt to trade in the building poles as their main source of income. Therefore, the *kayas*, which are already facing a substantial threat from plant resource extraction, will not be able to meet the demands of the local community in building poles. There is need, therefore, to discourage pole collection for selling and that other options such as wild plant cultivation, the introduction of alternative building materials e.g. mud-bricks, and the introduction of income generating activities be strongly encouraged.

Plate 6.1: Grasshouse, the traditional dwelling of the Midzichenda (Photo taken in June 1999)

Plate 6.2: Earth-walled, angular-framed house-type, thatched with roofing shingles (Photo taken in June 1999)

Plate 6.3: Earth-walled, angular-framed house-type, strengthened by partially cementing the walls (Photo taken in June 1999)

Plate 6.4: Damaged grasshouse near *kaya* Fungo after the unusual heavy rains in the 1997-1998 short rain season. (Photo taken in April 1999).

6.3 PLANTS USED FOR FIREWOOD

6.3.1 Materials and methods

In the *Midzichenda* culture, the female members of the community are responsible of firewood collection. The issues related to collection and utilisation of firewood, therefore, were investigated by interviewing the women, using a structured questionnaire (Fig. 6.7).

The Questionnaire

The questionnaire used (Fig. 6.7) was similar in structure and content to that used for the interviews concerning building poles (Fig. 6.1). Based on similar procedures and definitions as in the building poles, female members of the community were interviewed on the preference levels, sources and collector of plant species used for firewood in each homestead. The active female members of the community who participated in firewood collection were favoured for interviewees. The homesteads were identified using serial numbers (3000 + the count number of the homestead for *kaya* Mtswakara community; 4000 + count number of the homestead for *kaya* Fungo community) which were in the sequence of the date when the interviews were conducted. The communities were classified into different economic classes based on the house types, material possessions and financial earnings as previously described (Fig. 6.2).

Female field assistants (Nzara Kambe in *kaya* Mtswakara area, and Irene Changawa in *kaya* Fungo area) conducted most of the interviews on the acquisition and utilisation of firewood. It was felt that, being female and natives of their respective areas, these assistants were in a better position to consult with other women and collect accurate information. These interviewing sessions did not involve the company of *kaya* guards as this was also judged to be important in obtaining accurate and meaningful data.

Fig. 6.7: Structured questionnaire used for collecting information on acquisition and utilisation of firewood around the *kayas* Mtswakara and Fungo

Questionnaire for Home visits

INTRODUCTORY STATEMENT

I am (name of interviewer), researching on the domestic utilization of wild plant resources. I am interested in finding out some details regarding firewood/building poles. Please help me to understand your acquisition and utilisation of the resource.

DESCRIPTION OF THE HOMESTEAD:

Homestead No.	Number of houses	Estimate population	Village	Nearest Kaya

WEALTH INDICATORS:

House type(s): (a) Block & Iron sheet. (b) Block & Shingles. (c) Mud & Iron sheet. (d) Mud & Shingles (e) Gras

Is any family member employed (earning average subsistence salary > Ksh. 800.00) (Yes) (No)

Does the family own: (a) Vehicle (b) Bicycle (c) TV (d) Radio (e) Livestock (e) Poultry

MAIN INTERVIEWEE:

Name: ....

Age: [Very old] [Old] [Mid age][Young]

Gender: [Male] [Female]

Employed: [Yes] [No]

Religion: [Islam] [Christian] [Traditional] [Others]

Relation to Kaya elder/guard: [Yes] [No]

Other people present during the interview:

Name	Age	Gender	Religion	Relation to interviewee

DETAILS OF SPECIES USED

Plant resource investigated: FIREWOOD

1. **What is the name of the plant?** .... (Don't know)

(Identification by the interviewer) ....

2. **Preference level:** (Best) (Good) (Least) (No answer)

3. (a) **Source:** (a) Bought (i) Local (ii) Far (b) Collected (i) Kaya (ii) Private farmland (iii) Bushland

3. (b) **If collected, who was the collector?** (i) Child (ii) Adult (iii) Adult and child

1. **What is the name of the plant?** .... (Don't know)

(Identification by the interviewer) ....

2. **Preference level**: (Best) (Good) (Least) (No answer)

3. (a) **Source:** (a) Bought (i) Local (ii) Far (b) Collected (i) Kaya (ii) Private farmland (iii) Bushland

3. (b) **If collected, who was the collector?** (i) Child (ii) Adult (iii) Adult and child

UTILISATION RATE AND ALTERNATIVE FUEL

1. **Rate of utilization**: Number of head-loads[2] per week (...............)

2. **Alternative fuel** : (Charcoal) (Kerosene) (Gas) (Electrical) (None)

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[2] Head-load refers to the unit load collected and carried (on head) from the collection areas, which varies in weight (10 – 30kg) depending on the person carrying the load.

6.3.2 RESULTS: Plant species used for firewood around *kaya* Mtswakara

Interviewees

The same villages visited for information on building poles were re-visited for interviews on the acquisition and utilisation of firewood. However, the selection of homesteads and sequence of interviews were independent of those for building poles. A total of 117 questionnaires were administered, 40 in the 'near', 38 in the 'middle-distance' and 39 in the 'far' homesteads. Among the interviewees, 60 were middle-aged (15 – 35 years), 50 were old (36-50 years) and 7 were very old (>50 years). 112 of the interviewee were female and five were male. Out of the 117 interviewees, 5.1% were 'poor', 82.1% were 'middle-class', and 12.8% were 'rich'. Only 3.4% of the interviewees were employed, earning a wage in addition to their farming activities. The interviewees included 71.8% Muslims, 21.4% Christians, and 6.8% who practised their traditional faith. The homesteads in which interviews were conducted had a population size range of 3 – 42, with a mean of 11.6 people per homestead.

The population differences between communities in different distance categories were statistically (Kruskal-Wallis test) not significant, but the variation in firewood utilisation rate (head-loads per week) (Table 6.13) were statistically significant (at $p<0.05$). The firewood utilisation rate was statistically lower (Mann-Whitney test) in the 'near' and 'middle-distance' homesteads compared to 'far' homesteads, but not the difference was not significant between 'near' and 'middle-distance' homesteads. This meant that in the 'near' and in the 'middle-distance' homesteads the firewood utilisation rates (firewood head-loads in a given time) were lower than in the 'far' homesteads. However, the amount of wood in a 'head-load' by weight or by volume was not standard and from the author's observations, in the 'far' homesteads the 'head-load' was sometimes defined to included a smaller 'hand-load' (as the two types of '-loads' share the same local term, *hiha*). Therefore, the variation in the rate of firewood utilisation (head-loads per week) between homesteads at different distances from the *kaya*, might not be based on wood weight or volume, but most likely on the imprecise nature of load size and the definition of 'head-load'.

Table 6.13: Population and amount of firewood used in different distances from *kaya* Mtswakara.

Distance category	Population per homestead	Range of head-loads per week	Head-loads per week
Near (n=40)	11.7	2 – 5	2.9
Middle-distance (n=38)	11.1	2 – 5	3
Far (n=39)	12	2 - 5	3.7

Plant species used, resource-bases and collectors

A total of 38 plant species were used for firewood, of which 11 were major species (used for firewood in 10% or more homesteads) (Table 6.14). The major species included: dense forest species *Craibia brevicaudata* and *Cynometra suaheliensis*; forest/bushland species *Combretum illairii* and *Lamprothamnus zanguebaricus*; wooded grassland species *Acacia mellifera* and *Grewia plagiophylla*; woodland species *Diospyros bussei*; bushland species *Thespesia danis*; and cultivated crops *Anacardium occidentale* (cashew tree), *Coconus mucifera* (coconut palm trees) and *Mangifera indica* (mango tree). Of the major species only two species (the dense forest species *Craibia brevicaudata* and *Cynometra suaheliensis*) were identified as 'best' for firewood, while the rest were either 'good' or 'poor'. Some species that were identified as 'best', e.g. *Julbernardia magnistipulata*, *Brachystegia spiciformis* and *Terminalia spinosa* were minor species (used for firewood in less than 10% homesteads). The measure of utilisation therefore did not necessarily reflect the quality of the species; in fact most of the major species for firewood were not the 'best' species. In addition to quality, the species utilisation for firewood would seem to be influenced by other factors, of which the most likely were the availability and specific customary beliefs.

Table 6.14: Percentage of homesteads (117) in which each of the identified species was used as firewood around *kaya* Mtswakara, and the species preference level (as a percentage of the utilised amount of the species)

Species	Percentage of homestead in which species is Utilised	Best	Good	Poor
Combretum illairii	32	12.5	87.5	0
Grewia plagiophylla	30	16.7	83.3	0
Anacardia occidentale	27	0	7.4	95.6
Coconus nucifera	27	0	22.2	77.8
Craibia brevicaudata	24	100	0	0
Cynometra suaheliensis	23	100	0	0
Thespesia danis	19	0	89.5	10.5
Lamprothamnus zanguebaricus	14	21.4	71.4	7.2
Diospyros bussei	14	14.3	85.7	0
Acacia mellifera	12	25	75	0
Mangifera indica	12	0	50	50
Julbernardia magnistipulata	9	100	0	0
Flueggea virosa	7	0	85.7	14.3
Terminalia spinosa	6	50	50	0
Mugundi	6	0	100	0
Brachystegia spiciformis	5	100	0	0
Albizia anthelmintica	5	0	100	0
Acacia zanzibarica	4	0	100	0
Tamarindus indica	3	0	0	100
Haplocoelum inoploeum	2	100	0	0
Garcinia livingstonei	2	50	50	0
Psidium guajava	2	0	100	0
Charika	2	50	50	0
Ziziphus pubescens	1	100	0	0
Manilkara sulcata	1	100	0	0
Dalbergia melanoxylon	1	100	0	0
Scorodophloeus fischeri	1	100	0	0
Dalbergia boehmii	1	100	0	0
Vitex payos	1	0	0	100
Diospyros consolatae	1	0	0	100
Thevetia peruviana	1	0	0	100
Cassia singueana	1	0	100	0
Ricinus communis	1	0	0	100
Citrus limoni	1	0	0	100
Lannea schweifurthii	1	0	100	0
Lecaniodiscuss fraxinifolius	1	0	100	0
Chinyerere	1	100	0	0
Mkotera-mundu	1	100	0	0

Generally the 'bushland' was the main source of firewood to the community around *kaya* Mtswakara, and 'private farmland' was of second importance (Fig. 6.8). The *kaya* contributed for wood slightly less than that collected from the 'private farmland', and purchased wood contributed for the smallest amount of the firewood used. All purchased wood for fire was 'bought near'.

Based on the data for the major species, the sources of firewood were species specific. The *kaya* was the main source of the 'best' firewood dense forest species *Craibia brevicaudata* and *Cynometra spp*; the 'bushland' was the main source of 'good' firewood species *Grewia plagiophylla, Thespesia danis, Lamprothamnus zanguebaricus, Diospyros bussei,* and *Acacia mellifera*. The 'private farmland' was the main source of the 'poor' firewood cultivated species *Anacardia occidentale, Coconus nucifera* and *Mangifera indica*. In general, female adult together with children (girls) were the main collectors of the firewood. However, collection from the *kaya* was mainly associated with adult collectors. The species 'bought near' corresponded with the species that were collected from the *kaya* and the 'bushland', which meant that some collectors were probably seller-gatherers, trading on the firewood at village level.

Relationship between use and source of firewood to distance from the kaya

The collection of the major species in different distance categories showed that as distance from the *kaya* increased the importance of the *kaya* as a source of firewood reduced, while the 'bushland' became the principal source (Fig. 6.9). In the 'near' homesteads the *kaya*, the 'bushland' and the 'private farmland' each contributed about similar amounts of firewood. Although the *kaya* and 'private farmland' remained important sources of firewood in the 'middle-distance', the 'bushland' became the most important source of firewood. The 'bushland' was also the principal source of firewood in the 'far' homesteads, where the *kaya* had little significance as a source of firewood.

Fig. 6.8: Sources of firewood for communities living around *kaya* Mtswakara

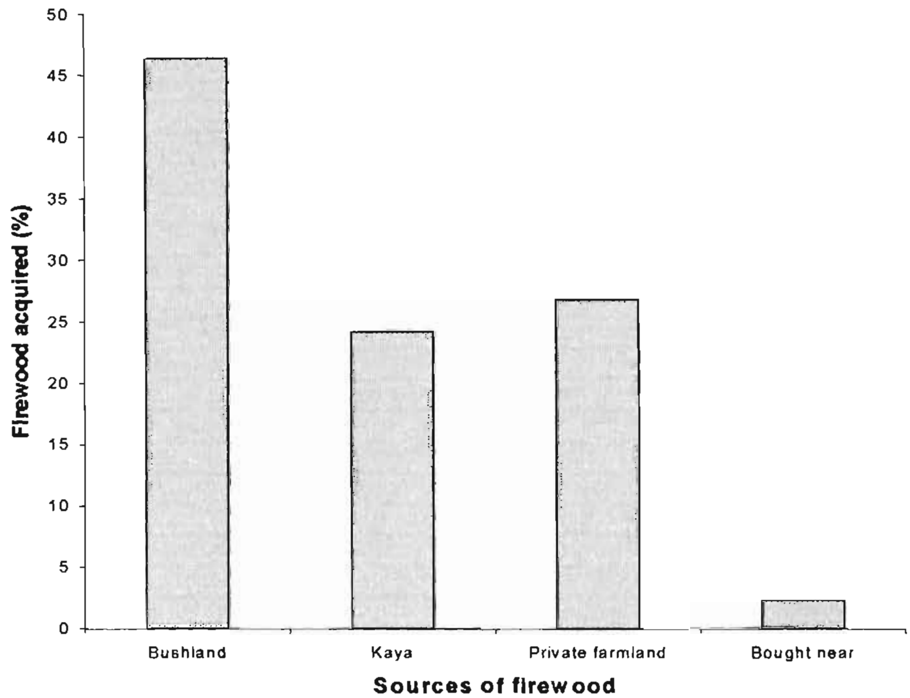
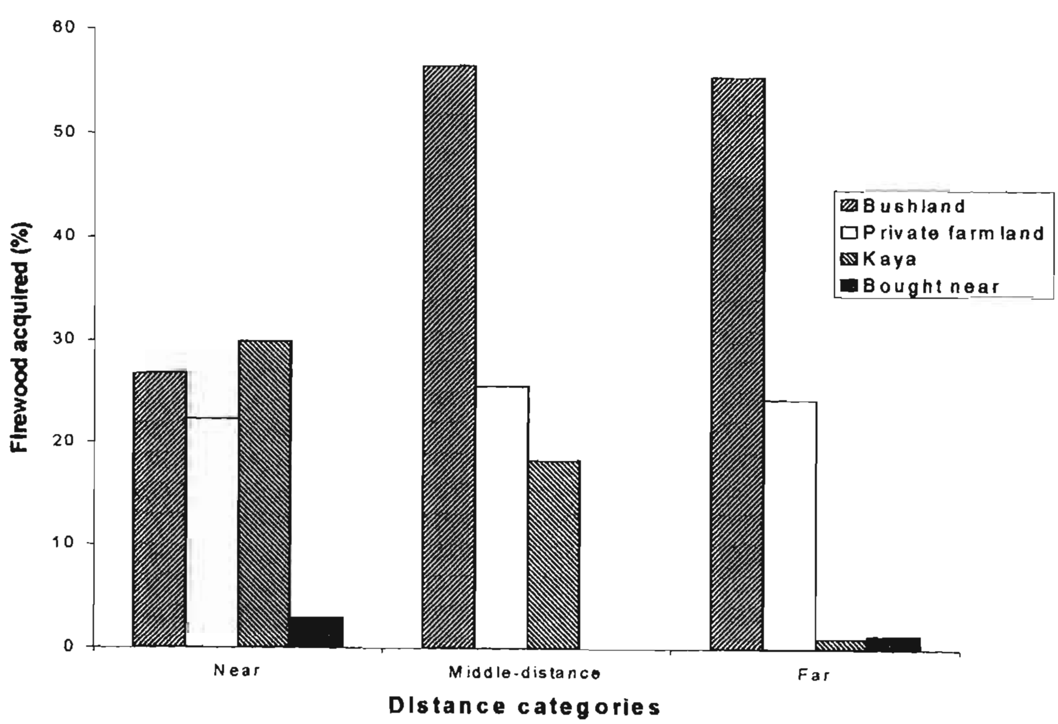


Fig.6.9: Percentages of firewood acquired from different sources in different distance categories around *kaya* Mtswakara



Although the *kaya*, the 'private farmland' and the 'bushland' each contributed considerable amounts of firewood in the 'near' and 'middle-distance' homesteads, the main species collected from these sources were different. Dense forest species were collected from the *kaya*, wooded grassland and bushland species were collected from the 'bushland', and cultivated crop species were collected from 'private farmland'. Thus the utilisation of the dense forest species *Cynometra spp.* and *Craibia brevicaudata* decreased with increasing distance from the *kaya*, while the utilisation of the shrubland (except for *Lamprothamnus zanguebaricus* and *Acacia mellifera*) and the cultivated crop species (except for *Coconus nucifera*) increased with increasing distance from the *kaya* (Table 6.15). The decreasing utilisation of dense forest species in the 'middle-distance' and 'far' homesteads was most likely due to the 'distance' factor i.e. from the *kaya*, and the unavailability of these species outside the *kaya* forest. Unlike for the building poles, firewood collection, which was done on average after every third day, did not always involve long distance (>5km) walks in search for firewood. The long distance,combined with the restrictions in firewood collection from the *kaya*, probably strongly discourage the 'far' distance communities from frequent visits to the *kaya* for firewood collection.

The increasing utilisation of low preference firewood species (bushland species, wooded grassland species, and cultivated crop species (Table 6.14), with increasing distance from the *kaya*, was most likely due to the unavailability of the better alternative ('best') species. The utilisation of both *Lamprothamnus zanguebaricus* and *Acacia mellifera* seemed to be inconsistent, most likely due to differences in the species population densities. Cultivated crop species *Coconus nucifera* was utilised in about similar amounts, possible because of the relatively strong fire that this species can give compared to the other cultivated species.

Table 6.15: Utilisation (%) of the major species used for firewood in different distance categories around *kaya* Mtswakara

Species	Utilisation in 'near' homesteads (n=40)	Utilisation in 'middle-distance' homesteads (n=38)	Utilisation in 'far' homesteads (n=39)
Cynometra suaheliensis	42.5	15.8	0
Craibia brevicaudata	40	21.1	0
Coconus nucifera	25	23.7	20.5
Anacardia occidentale	20	21.1	28.2
Grewia plagiophylla	12.5	26.3	38.5
Combretum illairii	10	28.9	43.6
Lamprothamnus zanguebaricus	10	18.4	7.7
Acacia mellifera	10	2.6	17.9
Thespesia danis	7.5	18.4	23.1
Diospyros bussei	0	13.2	23.1
Mangifera indica	0	13.2	17.9

In different distance categories, the species utilisation was generally low; even the most utilised species were recorded in about 40% homesteads or less. This shows that: either there were no specially target species used for firewood, instead there was a wide range of species used of which each was used infrequently; or that the 'best' species which would have been used more exclusively than the other species were rare or inaccessible. From this author's personal observations, the latter assumption was more likely than the former.

Use of alternative fuel

In the entire area around *kaya* Mtswakara, among the visited homesteads (n=117), only 8.5% families used an alternative fuel for firewood. In the near homesteads 10% of the interviewed population used kerosene as an alternative fuel, there were no records of use of alternative fuel in the 'middle-distance', and in the 'far' homesteads 15.4% used kerosene as an alternative fuel. Since there was no simple pattern reflecting use of alternative fuel in relation to distance from the *kaya*, it was presumed that the use of alternative fuel was probably determined by the economic status of the families. Thus based on the data that was collected concerning the economic status, 33.3% of the 'rich' (n=15) and 5.2% of the 'middle-class' (n=96) used kerosene as an alternative fuel, while among the 'poor' (n=6) there were no records of alternative fuel used. The assumption that the use of alternative fuel was mainly determined by the economic status of the families could be true, however, the 'poor' economic class sample size was small. However, it was clear that most of the community members (>90%) in the entire area exclusively relied on firewood and, therefore, that fuel type remains the most important, and the demands are likely to increase in future.

6.3.3 RESULTS: Plant species used for firewood around *kaya* Fungo

Interviewees

In *kaya* Fungo polygamy was very common and each of the co-wives in a single home made separate arrangements for firewood and its utilisation, with each wife attending only to the needs of her "house". In such situations where firewood acquisition and utilisation were not shared, each 'house' was considered as an independent 'homestead'. A total of 100 questionnaires were administered, 37 in the 'near' homesteads, 35 in the 'middle-distance' and 28 in the 'far' homesteads. Among the interviewees, four were young (<15 years old), 39 were mid-aged (15 – 30 years), 48 were old (30-50) and 9 were very old (>50 years). The interviewees included 96 female and four male members of the community. Out of the interviewees, 11% were 'poor', 69% were 'middle-class' and 20% were 'rich'. The interviewees included 23% Muslims, 55% Christians and 22% who maintained their traditional faith. The interviewed homesteads had a population size range of 3 – 30, with a mean of 10.3 people per homestead.

Amount of wood used in relation to distance from the kaya

There were differences in both the population size and the number of head-loads used per week by each homestead in the different distance categories (Table 6.16). However, both the population size and the number of head-loads used per week were not statistically significantly different (at $p<0.05$) between the distance categories.

Table 6.16: Population and amount of firewood used in different distances from *kaya* Fungo

Distance category	Population mean	Range of Head-load/week	Mean head-load/week
Near	9.4	2 – 7	4.6
Distant	10.5	3 – 7	5.2
Far	11.3	2 - 7	4.8

Plant species used, their source and collectors

A total of 53 species were used for firewood (Table 6.17), and 14 were major species (used in 10% homesteads or more). Out of the14 major species only three species, *Acacia robusta, Acacia reficiens* and *Grewia plagiophylla* were identified as 'best' firewood species, while the rest were identified as 'good' or 'poor'. The 'poor' firewood species that were utilised extensively included *Lantana camara, Croton talaeporos, Grewia forbesii,* and '*Mkulu-kwanya*'. Although *Dalbergia melanoxylon* was identified as one of the 'best' species for firewood, it was a minor species in terms of utilisation. Similar to the situation in *kaya* Mtswakara, therefore, the measure of the utilisation of a species did not reflect its strict popularity in the sense of quality; in contrast most of used species were not the preferred ('best') species for firewood.

Generally the bushland was the principal source of firewood for the communities around *kaya* Fungo, and the 'private farmland' was the second important source (Fig. 6.10). The *kaya* was not an important source of the firewood, and none of the major species were collected significantly from the *kaya*. In *kaya* Fungo area there was no wood locally i.e. 'bought near', that was used as firewood. However, it was reported and also observed during the fieldwork of this study that firewood collection from *kaya* Fungo for selling in the urban areas was common.

Table 6.17: Plant species utilised (%) for firewood, and their preference levels (as a percentage of the utilisation) in homesteads around *kaya* Fungo

Species	Percentage of homesteads in which species was utilised	Best	Good	Poor
Acacia robusta	78	56	22	0
Thespesia danis	61	18	43	0
Grewia plagiophylla	55	37	18	0
Lantana camara	55	0	18	37
Croton talaeporos	42	0	8	34
Lamprothamnus zanguebaricus	24	11	13	0
Hoslundia opposita	22	4	12	6
Euclea natalensis	22	2	19	1
Acacia reficiens	20	15	5	0
Combretum illairii	20	9	11	0
Grewia forbesii	19	0	6	13
Mukulu-kwanya	13	0	3	9
Terminalia spinosa	11	8	3	0
Acacia zanzibarica	11	5	6	0
Allophylus rubifolius	10	4	5	1
Premna chrysoclada	9	0	7	2
Flueggea virosa	8	0	5	3
Diospyros bussei	6	1	4	1
Albizia anthelmintica	6	0	0	6
Vitex payos	6	0	1	5
Commiphora africana	6	0	0	6
Dichrostachys cinerea	6	0	2	4
Brachystegia spiciformis	6	0	5	1
Anacardia occidentale	5	0	0	5
Dalbergia melanoxylon	4	4	0	0
Bridelia carthartcia	4	0	4	0
Scutia myrtina	3	1	2	0
Acacia mellifera	3	0	3	0
Catunaregam nilotica	3	0	1	2
Vernonia sp.	3	0	0	3
Harrisonia abyssinica	3	0	3	0
Craibia brevicaudata	2	2	0	0
Croton pseudopulchellus	2	2	0	0
Combretum schumannii	2	1	1	0
Thevetia peruviana	2	1	1	0
Haplocoelum inoploeum	2	0	2	0
Strychnos madagascariensis	2	0	0	2
Lannea schweifurthii	2	0	0	2
Ormocarpum kirkii	2	0	1	1
Ximenia americana	2	0	1	1
Manilkara mochisa	1	1	0	0
Manilkara sulcata	1	1	0	0
Garcinia livingstonei	1	1	0	0
Commiphora edulis	1	0	0	1
Diospyros squarrosa	1	0	1	0
Erythrina sacluexii	1	0	0	1
Piliostigma thoningii	1	0	1	0
Cussonia zimmermanii	1	0	0	1
Maytenus sp.	1	1	0	0
Tabernaemontana elegans	1	0	0	1
Munyeekapuru	1	0	0	1
Mthakuma	1	0	1	0
Mtsungwi	1	0	0	1

Fig. 6.10: Sources of firewood for communities living around *kaya* Fungo

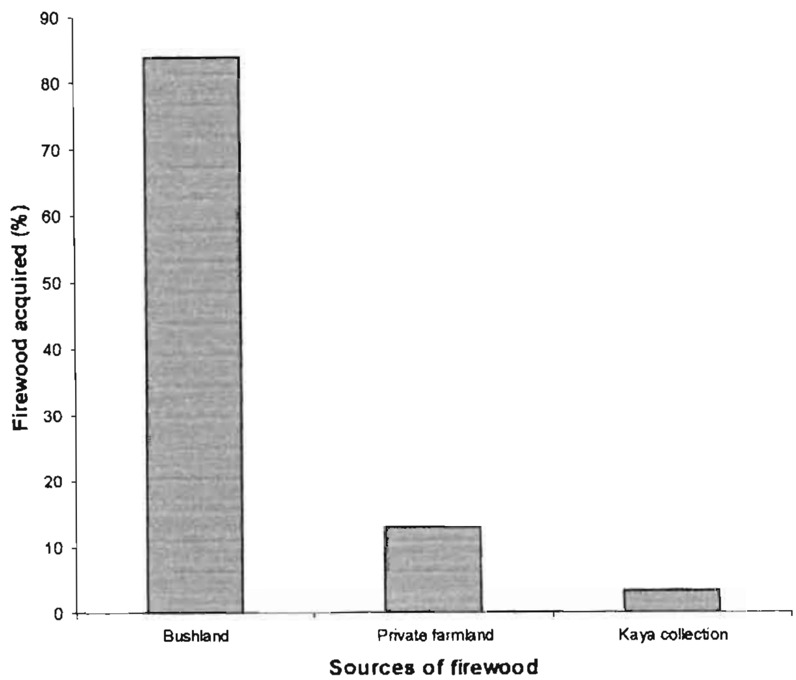
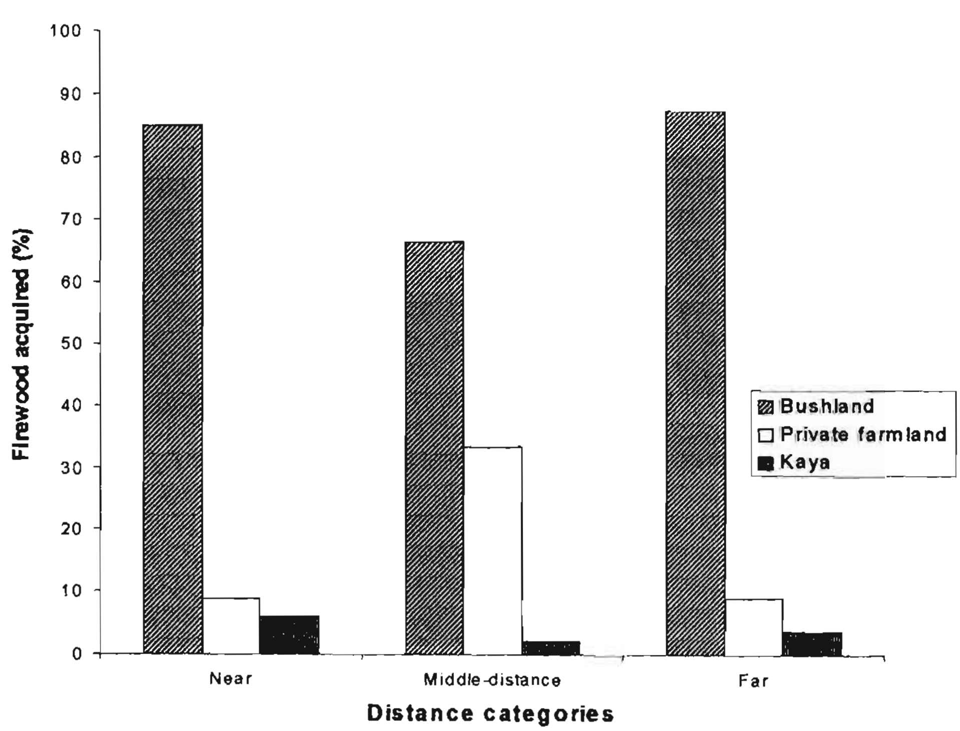


Fig. 6.11: Percentages of firewood from different sources in the different distance categories around *kaya* Fungo



Firewood acquisition and use in relation to distance from the kaya

In all distances the 'bushland' remained the principal source of firewood around *kaya* Fungo, and 'private farmland' was the second important source (Fig. 6.11). In the 'middle-distance' the 'private farmland' was relatively a more important source of firewood than in 'near' and 'far' homesteads, while collection from the 'bushland' was notable lower; an observation that could not be immediately explained. Most of the major species were, in all distance categories, collected from the bushland, except for *Acacia zanzibarica*, which in the 'near' homesteads was collected mostly from the *kaya*; and *Grewia plagiophylla* and *Grewia forbesii* which in the 'far' homesteads were considerably collected from the 'private farmland'.

Of the major species, *Acacia robusta*, *Thespesia danis* and *Lantana camara* were utilised significantly (>40%) in all distance categories; while *Grewia plagiophylla* was significantly utilised only in 'near' and 'far' homesteads; and *Croton talaeporos* and *Combretum illairii* were utilised significantly only in 'near' homesteads (Table 6.18). All the other species were used in less than 40% homesteads in all distance categories. It was surprising that *Combretum illairii* and *Terminalia spinosa*, which are usually common in the bushland/wooded grassland areas, were not used in the 'middle-distance'. In *kaya* Fungo, therefore, in all three distance categories *Acacia robusta*, *Thespesia danis* and *Lantana camara* were possible the target species for firewood. The extensive use of these species can be defined on the basis of both quality (*Acacia robusta* and *Grewia plagiophylla*) and availability (*Lantana camara*). The variation in utilisation levels of the other species for firewood in different distance categories was also likely to be due to differences in distribution/densities of those species in the different localities, i.e. relative availability. In *kaya* Fungo, species utilisation for firewood on basis of wood quality seemed to be secondary to availability. It is not clear, but interesting, what impacts the utilisation of these species for firewood has on the wild population with reference to future requirements of the communities.

Use of alternative fuel

In the entire community of *kaya* Fungo only 8.7% used an alternative fuel for firewood. There was a general increase in the use of alternative fuel with increase in distance from the *kaya*. In the 'near' homesteads there were no records of use of alternative fuel, while 8.6% 'middle-distance' and 17.9% 'far' homesteads used kerosene as an alternative. Apart from kerosene, there was no other alternative fuel used in the area surrounding *kaya* Fungo. However, since the *kaya* was not an important source of firewood the pattern in the use of alternative fuel with reference to the distance from the *kaya* is not easily explained. An alternative factor determining use of alternative fuel was the economic status of the families. On the basis of economic status 15% of the 'rich' community, 7.1% of the 'middle-class' community, and none among the 'poor' community, used kerosene for fuel. It is likely therefore, that the economic status more than the distance from the *kaya*, was important in influencing the use of alternative fuel. Because the community was generally poor, there was a high demand for wood in the area. This high demand is likely to increase further with time.

Table 6.18: Utilisation (%) of the major species for firewood in different distances around *kaya* Fungo

Species	**Utilisation (%) in 'near' homesteads (n=37)**	**Utilisation (%) in 'middle-distance' homesteads (n=35)**	**Utilisation (%) in 'far' homesteads (n=27)**
Acacia robusta	91.9	65.7	75
Thespesia danis	64.9	45.7	71.4
Croton talaeporos	62.2	22.9	35.7
Grewia plagiophylla	56.8	37.1	71.4
Combretum illairii	51.4	0	3.6
Lantana camara	48.6	65.7	50
Lamprothamnus zanguebaricus	32.4	17.1	21.4
Hoslundia opposita	32.4	2.9	17.9
Acacia reficiens	29.7	17.1	10.7
Euclea natalensis	16.6	25.7	25
Terminalia spinosa	16.2	0	17.8
Acacia zanzibarica	16.2	5.7	10.7
'Mukulu-kwanya'	10.8	14.3	14.3
Grewia forbesii	8.1	34.3	14.3
Allophylus rubifolius	8.1	8.5	14.3

6.3.4 DISCUSSION: Firewood demand and supply

The most used cooker by the *Midzichenda* community was the traditional three stone cooking hearth (Nyamweru, 1997) which is used with firewood. In this study it was established that around both *kayas* Mtswakara and Fungo available firewood was becoming rare and more difficult to obtain with time, a fact that the local community have also noted (Nyamweru 1997). To collect firewood requires that one walks longer distances and spends more time searching than it used to be in the past (interviewee 4067). The only source of abundant 'best' firewood species is the *kaya* forest, but free collection from the *kaya* is not allowed (interviewee 4023). Thus most community members opt to use even 'poor' wood which was equally not easy to obtain (interviewees 3016, and 4065). Around both *kayas* most of the major species used for firewood were mostly not the 'best' species. The best explanation for this observation is that species utilisation, which under normal circumstances would be determined mainly by the quality of the wood, is now to a large extent dependant on availability due to the scarcity of the resource. Availability in this context would refer to all the aspects involved, including free access. Although in the *kaya* forests, species recognised as 'best' for firewood were recorded, traditionally, the plant resource collection was restricted and controlled.

The decrease in firewood supply was likely to have resulted from increased demand due to population growth, expansion of cropland, and the restriction on firewood collection from the *kaya* (Nyamweru 1997). The 'best' species for firewood are likely to have been cleared in the process of making cropland areas and/or over-exploited in the areas outside the *kaya*. As a result the 'poor' species became relatively common in the freely accessible areas, such as the 'bushland', which was the principal source of firewood for communities in both *kayas*. The unavailability of 'best' species for firewood has forced the *Midzichenda* to drop their cultural practise of cooking using traditional clay pots (*nyungu*), which require stronger fire (obtained from 'best' species), and resorted to the metallic cooking pot (*sufuria*) which heats relatively faster even with fire from 'poor' quality wood (interviewees 3004, 4054). Also another change in tradition due to acute shortage of firewood was the use of species that are culturally prohibited (Table 6.19), particularly around *kaya* Fungo, where one of the previously culturally prohibited species (*Grewia forbesii*) was a major species used for firewood.

Table 6.19: Plant species culturally not used for firewood, and their present-use status around *kayas* Mtswakara and Fungo

Species	Used in Mtswakara	Used in Fungo
Grewia forbesii (Mbavu-ng'ombe)	No	Yes
Dichrostachys cinerea (Mkingiri)	No	Yes
Afzelia quanzensis (Mwamba)	No	No
Euphobia nyikae (Chaa-Komba)	No	No
Vernonia hildebrandtii (Mlaza-koma)	No	No
Canthium kilifiensis (Mtsamula-ndolwa)	No	No
Vangueria infausta (Muviru)	No	No

The main difference between firewood acquisition between Mtswakara and Fungo was the considerable reliance of the *kaya* for firewood in *kaya* Mtswakara area (Fig. 6.8), from which 'best' firewood species were collected (Table 6.14). The exclusive collection of 'best' firewood species from the *kaya* in Mtswakara can be attributed to vegetation transformation through clearing and farming, which has resulted in the 'bushland' and 'farmland' habitats that are either not suitable for these species or just lack these species. In contrast, in Fungo, the *kaya* was not an important source of firewood (Fig. 6.10), and the dense forest species considered 'best' for firewood were not commonly utilised (Table 6.17). Although it could not be confirmed in this study, the considerable exploitation of the *kaya* for firewood in Mtswakara compared to Fungo was likely to be due to the relatively lower respect for the customary laws and *kaya* culture in Mtswakara compared to Fungo. More socio-cultural work would be useful to test this assumption.

In *kaya* Fungo area, local trade in firewood at village level was not common. However, there were strong signs of informal trade in firewood and charcoal, which members of the local community 'exported' to the urban centres of Mariakani and Kaloleni, for selling. During the fieldwork for this study women carrying head-loads of firewood and walking about 20km to the urban centres where they sold their collection were encountered. Charcoal making activities in the neighbourhood of *kaya* Fungo were noted, which included observations of heaps of collected wood organised for charcoal making (Plates 6.5) as well as charcoal burning in progress (Plate 6.6). Commercial activities in firewood and charcoal were confirmed with the *kaya* guards, *kaya* elders and community members. According to one community member (interviewee 4058) who makes charcoal for sale, these activities were an important source of income to him and many others in the area.

In *kaya* Mtswakara area, local trade in firewood at village level was relatively important (Table 6.14). In addition, based on information from community members, some businessmen from urban centres were interested in trade in firewood from the *kaya* and its environs, but were obstructed by the traditional restrictions of the *kaya* elders. Hence there was a likelihood of the *kaya* being utilised as a firewood source for both the neighbouring villages and the urban centres. It would be interesting to establish the details and extent of the existing informal trade in firewood and other plant resources at village levels and its relation to the supplies in the urban centres. Although this trade was hidden and undertaken with secretive procedures due to the prohibition orders, its impact might be enormous and threaten the conservation of the *kaya*.

Firewood collection from 'private farmland' was only significant around *kaya* Fungo. However, around both *kayas*, the utilisation of cultivated wild plant species was commanded by the male members of the community, whose main interests and priorities were not firewood. Wood of wild plant species used for fuel was collected from the 'private farmland' only as the remains after the collection of poles or from materials left after pruning the plants (interviewee 4089). There were no plant species that were grown specifically to meet the demands of firewood. Therefore, the 'private farmland' was not a source of firewood *per se*, rather firewood was a subordinate resource to other intended resources derived from the domesticated plant species e.g. shade, poles, medicines and grave markers. This was also true for the cultivated crop species *Coconus nucifera*, *Anacardia occidentale* and *Mangifera indica*. Around *kaya* Fungo the cultivated crop species were not important for firewood because in that area those species were not grow due to the unfavourable conditions (Boxem et al. 1987).

Arrangements of collection of firewood from neighbour's farmland areas were complex. In some cases, access to wood in other people's farmland was free (interviewee 4083), but in some situations one has to seek permission and collection is not guaranteed (interviewees 3055, 4054). It is likely, therefore, that with time the 'bushland' which mainly constitutes other people's farmland areas will not be as freely accessible for firewood as is today. In that situation, firewood collection from the *kayas* (which are communally owned) might lead to conflicts between conservation and resource demand.

In addition to cooking, the *Midzichenda* use firewood to dry and preserve harvested corn in the granary, in a process that a strong fire is maintained day and night, for 2–3 months. In the corn drying process significantly more firewood is used than in cooking. In this study, the available data does not include the corn drying process, because the data collection time did not coincide with corn drying period. However, firewood utilisation in corn drying is an important issue to investigate. Also lack of house-heating facilities in the rural areas has led to the use firewood to warm the houses during the cold weather (May – August). The local smiths, whom rely on firewood for iron smelting to produce domestic tools, also use considerable amounts of firewood. All these other uses of firewood need to be considered to establish the gross annual cycle demand of firewood by the local communities.

The use of alternative fuel, mainly kerosene, around both *kayas* was not significant, and was mainly related to the economic status of the families. This meant that firewood remained the most important fuel for the communities living around the *kayas*. While with time the demand for wood for fuel is likely to increase due to the expected population increase, the availability of wood, particularly the 'best' firewood species, is likely to reduce even further.

Under the traditional control procedures, firewood collection from the *kaya* has been regulated by the prohibition of collection of green wood. However, probably due to the acute firewood shortage, some local community members alleged that the restriction on firewood collection was implemented by the conservation activities of CFCU (Nyamweru 1997). To effect good conservation efforts and foster a good relation with the local communities, this misconception requires correcting, probably through the ongoing environmental education programmes. Along with these programmes, the increasing demands for firewood by the local communities need to be addressed. As wood-supplies in the 'bushland' areas get used up, it is unlikely that the traditional laws or modern conservation values will be convincing to the local communities and sufficient to stop the collection of firewood from the *kaya*. The cultural value of the *kaya*, in times of critical resource need, might be considered secondary to its value as a resource-base. To alleviate these pressures, there is need to increase the firewood supply in the 'private farmland', possible by intensifying the ongoing forestry programmes of the CFCU. Fast growing exotic species might be ideal for solving the existing firewood problems. An alternative solution is the provision of fuel-efficient stoves (Nyamweru 1997). However, it should be known that the latter solution might not be feasible. The conservative families might not easily accept adoption of a new cooking style (interviewee 3004). Therefore a preliminary survey would be necessary to determine acceptance levels in target communities. The introduction of these stoves could be done through collaboration of an energy-related Non-Governmental Organisations (Nyamweru 1997), and/or by assigning experts in that field to provide in-house training of the community members.

Plate 6.5: A heap of wood organised for charcoal making near *kaya* Fungo. (Photo taken in May 1999)

Plate 6.6: Low scale charcoal making activities taking place near *kaya* Fungo (Photo taken in June 1999).

6.4 HARVESTABLE BUILDING POLES AND FIREWOOD IN *KAYAS*

6.4.1 Introduction and methods

To provide an estimate of the resource base, and the potential supply of building poles and firewood, a sampling strategy which was both efficient (person-hours) and effective was devised. Harvestable building poles and deadwood for fuel in the *kayas* Mtswakara and Fungo were investigated in 'belt transects' established in different physiognomic vegetation segments. Three transects were established in each of the physiognomically different vegetation segment in each *kaya*. The areas in which transects were established were subjectively selected. Large sample areas provide a greater probability of encountering different patches or "clumps" of individuals (Gauch 1982), while small sample areas may fall entirely in specific patches (Peters 1996) hence measurements concerning specific plant species could be an overestimation or an underestimation. In this study the belt-transects used measured 0.2 ha (20 X 100m). To establish details of the distribution patterns in each transect, data from each transect was collected in separate ten blocks of 0.02 ha (10 X 20m) which were linearly contiguous along the transect. In company of respondents (Mwatela Chuphi for Mtswakara and Kavila Mtaveta for Fungo), walks were made through each of the blocks in each transect, and harvestable building poles were identified, counted and the basal diameter (BD) measured to determine the size-specific density estimates of the poles.

The amount of dry wood harvestable for firewood in each block (10 X 20m) of the belt transect was determined and estimated in 'head-load' (20-25kg) units through visual observation and assessment.

6.4.2 RESULTS: Harvestable building poles in *kaya* Mtswakara

Building pole sub-types

The building poles utilised by the *Midzichenda* are of three sub-types, differentiated on the basis of the sizes used. These are 'standing-poles', 'rafter-poles' and 'wither-poles'. Each of these pole sub-types has a specific function in the house construction, which determines their measurements. The different sizes of these pole sub-types were measured in this study, and their estimated measures and functions are given below.

- Standing-poles (*viguzo*) form the basic structure of the house and are the poles most exposed to destruction by termites. The standing poles are the most important in determining house-life, as they determine the stability and durability of the walls of the house. Species selection for qualities such as termite resistance and durability is likely to be very important for standing poles. The standing poles had a basal diameter (BD) measure that ranged from 5 to 10 cm. The relatively thicker standing poles (>9cm BD) are usually used for building grasshouses, while the relatively thinner standing poles (5-9cm BD) are used for building the angular-structured earth-walled houses.
- Rafter-poles (*pau*) are smaller in size compared to standing-poles, and used for holding the roofing materials which are either roofing-shingles or grass. Rafter-poles measure from 3 to 5 cm BD.
- Wither-poles (*fiho*) are the thinnest, measuring from 1.5 to 4 cm BD. The thicker wither-poles (2.5-3 cm BD) are used as stabilisers (*tsambo*) tied mid-way along the standing poles, while the relatively thinner wither poles are tied across the standing poles in pairs (one on the inside and another on the outside). Pairs of wither-poles are tied on standing poles from a low point (about three inches from the ground) to the highest part of the standing poles. In grasshouses the wither-poles are tied singularly (not in pairs) but are much closer (7 –14 cm apart) compared to the wither-pole pairs in mud-walled houses (tied 15 – 25 cm apart).

The highest number of species that can be used for building poles in general was recorded in *Julbernardia* vegetation (*Hugonia* community) and the least in *Cynometra* vegetation (*Scorodophloeus* community) (Table 6.20). In each vegetation type the number of species used for standing-poles was the least. Although not sampled, building poles were generally absent in the *Acacia* wooded grassland community which mostly comprised vegetation patches that measured less than 100m stretches.

Table 6.20: Number of species used for building poles in different vegetation types in *kaya* Mtswakara

Physiognomic Vegetation segment	Community type	No. of species used for all pole sub-types	No. of species used for wither-poles	No. of species used for rafter-poles	No. of species used for standing-poles
Julbernardia vegetation	*Hugonia* community	39	33	28	14
Brachystegia vegetation	*Brachystegia* community	31	20	23	16
Cynometra vegetation	*Scorodophloeus* community	29	25	23	17

Although in the *Hugonia* community the total number of species used for building poles was the highest, this contrasted with the density of harvestable poles in that vegetation type where it had about a third of the densities available in the *Scorodophloeus* community (Table 6.21). The *Brachystegia* community had the lowest number of harvestable poles recorded for the three community types (Table 6.21).

Table 6.21: Number of harvestable poles (n ha^{-1}) in the different vegetation types in *kaya* Mtswakara

Physiognomic Vegetation segment	Community type	Wither-poles density (n/ha)	Rafter-poles density (n/ha)	Standing-poles density (n/ha)
Cynometra vegetation	*Scorodophloeus* community	3324	2212	1025
Julbernardia vegetation	*Hugonia* community	1252	789	255
Brachystegia vegetation	*Brachystegia* community	800	722	424

Harvestable poles in Scorodophloeus community

A total of 25 species used for wither-poles were recorded in *Scorodophloeus* community, but over 78% of the harvestable wither-poles were of only five species, namely *Scorodophloeus fischeri, Craibia brevicaudata, Croton pseudopulchellus Asteranthe asterias* and *Cynometra webberi* (Table 6.22). Harvestable wither-poles of the remaining species were in lower densities, each contributing less than 3% of the total harvestable wither-poles.

Table 6.22: Occurrence frequency of species used for wither-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each of species in *Scorodophloeus* community in *kaya* Mtswakara

Species	Occurrence frequency in (10x20m) blocks (n=30)	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ=1883)
Scorodophloeus fischeri	28	465	24.7
Craibia brevicaudata	26	406	21.6
Croton pseudopulchellus	20	286	15.2
Asteranthe asterias	15	185	9.8
Cynometra webberi	12	129	6.9
Cynometra suaheliensis	10	53	2.8
Thespesia danis	5	49	2.6
Combretum schumannii	4	49	2.6
Manilkara sulcata	4	47	2.5
Grewia plagiophylla	4	37	2.0
Nectropetalum kaessnerii	4	33	1.8
Ochna thomasiana	4	27	1.4
Hunteria zeylanica	4	23	1.2
Diospyros consolatae	3	17	0.9
Canthium mombazense	2	16	0.8
Coffea sessiliflora	2	10	0.5
Ozoroa insignis	1	10	0.5
Maytenus sp.	1	9	0.5
Milletia usaramensis	1	8	0.4
Ophrypetalum odoratum	1	5	0.3
Caesalpinia insolita	1	4	0.2
Cola minor	1	4	0.2
Markhamia zanzibarica	1	4	0.2
Rinorea illicifolia	1	4	0.2
Pycnocoma littoralis	1	3	0.2

A total of 23 species used for rafter-poles were recorded in *Scorodophloeus* community, but only six species constituted of over 80% of the harvestable poles recorded in that vegetation type (Table 6.23). These species were *Scorodophloeus fischeri, Craibia brevicaudata, Croton pseudopulchellus, Asteranthe asterias, Cynometra suaheliensis* and *Cynometra webberi*. Harvestable rafter-poles of the remaining species recorded were in lower densities, each contributing less than 3% of the total harvestable rafter-poles.

Table 6.23: Occurrence frequency of species used for rafter-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Scorodophloeus* community in *kaya* Mtswakara

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type (Σ=1319)**
Scorodophloeus fischeri	23	281	21.3
Craibia brevicaudata	23	239	18.1
Croton pseudopulchellus	20	194	14.7
Asteranthe asterias	18	148	11.2
Cynometra suaheliensis	16	134	10.2
Cynometra webberi	15	116	8.8
Combretum schumannii	4	40	3.0
Nectropetalum kaessnerae	6	37	2.8
Manilkara sulcata	5	21	1.6
Grewia plagiophylla	5	18	1.4
Thespesia danis	2	13	1.0
Hunteria zeylanica	3	12	0.9
Markhamia zanzibarica	3	11	0.8
Canthium mombazense	2	10	0.8
Ochna thomasiana	2	8	0.6
Uvariodendron kirkii	1	8	0.6
Ophrypetalum odoratum	1	7	0.5
Haplocoelum inoploeum	2	6	0.5
Rinorea illicifolia	1	4	0.3
Coffea sessiliflora	1	4	0.3
Caesalpinia insolita	1	3	0.2
Acalypha neptunica	1	3	0.2
Julbernardia magnistipulata	1	2	0.2

A total of 17 species used for standing-poles were recorded in *Cynometra* community, however, only six species constituted of about 95% of the total harvestable poles (Table 6.24). These species are *Scorodophloeus fischeri, Craibia brevicaudata, Croton pseudopulchellus, Cynometra suaheliensis, Cynometra webberi* and *Manilkara sulcata*. Harvestable poles of the remaining species were in lower densities, each contributing less than 4% of the total harvestable poles.

Table 6.24: Occurrence frequency of species used for standing-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Scorodophloeus* community in *kaya* Mtswakara

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ=543)
Scorodophloeus fischeri	20	154	28.4
Craibia brevicaudata	21	126	23.2
Croton pseudopulchellus	14	76	14.0
Cynometra suaheliensis	10	72	13.3
Cynometra webberi	11	50	9.2
Manilkara sulcata	9	40	7.4
Asteranthe asterias	3	21	3.9
Ochna thomasiana	4	18	3.3
Combretum schumannii	3	16	2.9
Haplocoelum inoploeum	3	14	2.6
Grewia plagiophylla	2	8	1.5
Markhamia zanzibarica	2	6	1.1
Pycnocoma littoralis	2	4	0.7
Diospyros consolatae	1	4	0.7
Nectropetalum kaessnerii	1	3	0.6
Thespesia danis	1	2	0.4
Acalypha sp.	1	1	0.2

In general, six species *Scorodophloeus fischeri, Craibia brevicaudata, Croton pseudopulchellus, Asteranthe asterias, Cynometra suaheliensis* and *Cynometra webberi* were the most important species for harvestable poles of all the three pole sub-types in the *Scorodophloeus* community. *Scorodophloeus fischeri* and *Craibia brevicaudata* were particularly important, each contributed about 20% of the total harvestable poles of each pole sub-type recorded. Also the distribution patterns of harvestable poles of *Scorodophloeus fischeri* and *Craibia brevicaudata* were consistently abundant in all transects, while the distribution patterns of harvestable poles of the other important species (*Croton pseudopulchellus, Asteranthe asterias, Cynometra suaheliensis* and *Cynometra webberi*) were either in clumps or rare in the transects.

Harvestable building poles in Hugonia community

A total of 33 species used for wither-poles were recorded in the *Hugonia* community, of which seven species *Canthium mombazense, Diospyros consolatae, Croton pseudopulchellus, Manilkara sansibarensis, Asteranthe asterias, Ochna thomasiana* and *Ophrypetalum odoratum* constituted of about 64.1% of the total harvestable poles (Table 6.25). Harvestable poles of the remaining species used for wither poles were in lower densities, each contributing less than 4% of the total wither-poles recorded in *Hugonia* community.

A total of 28 species used for rafter poles were recorded in the *Hugonia* community, but about 64% of the harvestable rafter-poles recorded were of seven species, *Diospyros consolatae, Manilkara sansibarensis, Canthium mombazense, Ophrypetalum odoratum, Croton pseudopulchellus, Ochna thomasiana* and *Asteranthe asterias*. Harvestable poles of the remaining species were recorded in lower densities, each contributing less than 5% of the total rafter-poles recorded.

A total of 14 species used for standing-poles were recorded in the *Hugonia* community. Seven of these species contributed about 79% of the total harvestable standing-poles (Table 6.27). These species were *Diospyros consolatae Manilkara sansibarica, Croton pseudopulchellus, Ophrypetalum odoratum, Pycnocoma littoralis, Asteranthe asterias* and *Diospyros natalensis*. Harvestable standing-poles of the remaining species occurred in lower densities, each contributing less than 5% of the total harvestable poles recorded in that community.

Table 6.25: Occurrence frequency of species used for wither-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Hugonia* community in *kaya* Mtswakara

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ=753)
Canthium mombazense	17	132	17.5
Diospyros consolatae	21	76	10.1
Croton pseudopulchellus	15	64	8.5
Manilkara sansibarensis	19	60	8.0
Asteranthe asterias	17	57	7.6
Ochna thomasiana	14	47	6.2
Ophrypetalum odoratum	9	47	6.2
Heinsia crinita	12	29	3.9
Hunteria zeylanica	7	23	3.1
Polysphaeria parvifolia	6	22	2.9
Monodora grandidiera	9	19	2.5
Allophylus rubifolius	7	18	2.4
Pancovia golungensis	7	18	2.4
Lamprothamnus zanguebaricus	6	17	2.3
Pycnocoma littoralis	4	17	2.3
Haplocoelum inoploeum	5	12	1.6
Psydrax faulknerae	4	11	1.5
Diospyros natalensis	1	11	1.5
Coffea sessiliflora	3	10	1.3
Buxus obtusifolia	3	8	1.1
Markhamia zanzibarica	3	8	1.1
Manilkara sulcata	2	7	0.9
Toddaliopsis kirkii	4	6	0.8
Carissa tetramera	2	5	0.7
Ochna mossambicensis	2	5	0.7
Cassia sp.	1	5	0.7
Craibia brevicaudata	1	5	0.7
Ozoroa insignis	1	4	0.5
Milletia usaramensis	1	3	0.4
Cynometra suaheliensis	1	2	0.3
Deinbolia borbonica	1	2	0.3
Julbernardia magnistipulata	1	2	0.3
Vitex mombassae	1	1	0.1

Table 6.26: Occurrence frequency of species used for rafter-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Hugonia* community in *kaya* Mtswakara

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type (Σ=475)**
Diospyros consolatae	21	58	12.2
Manilkara sansibarensis	15	58	12.2
Canthium mombazense	15	46	9.7
Ophrypetalum odoratum	14	35	7.4
Grewia plagiophylla	12	31	6.5
Croton pseudopulchellus	8	27	5.7
Monodora grandidiera	13	26	5.5
Hunteria zeylanica	10	24	5.1
Asteranthe asterias	8	24	5.1
Pycnocoma littoralis	14	23	4.8
Cynometra suaheliensis	1	20	4.2
Ochna thomasiana	11	18	3.8
Polysphaeria parvifolia	4	12	2.5
Diospyros natalensis	4	12	2.5
Suregada zanzibariensis	7	11	2.3
Markhamia zanzibarica	3	10	2.1
Buxus obtusifolia	5	7	1.5
Craibia brevicaudata	2	6	1.3
Heinsia crinita	4	5	1.1
Lamprothamnus zanguebaricus	4	5	1.1
Haplocoelum inoploeum	2	4	0.8
Manilkara sulcata	2	4	0.8
Maytenus mossambicensis	2	3	0.6
Toddaliopsis kirkii	2	2	0.4
Cynometra webberi	1	1	0.2
Carissa tetramera	1	1	0.2
Cassia sp.	1	1	0.2
Ozoroa obovata	1	1	0.2

Table 6.27: Occurrence frequency of species used for standing-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Hugonia* community in *kaya* Mtswakara

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ=153)
Diospyros consolatae	13	28	18.3
Manilkara sansibarensis	9	22	14.4
Ophrypetalum odoratum	13	19	12.4
Pycnocoma littoralis	12	19	12.4
Croton pseudopulchellus	6	14	9.2
Asteranthe asterias	6	10	6.5
Diospyros natalensis	6	8	5.2
Lamprothamnus zanguebaricus	5	7	4.6
Cynometra webberi	4	7	4.6
Craibia brevicaudata	4	6	3.9
Markhamia zanzibarica	4	5	3.3
Cynometra suahelliensis	3	5	3.3
Haplocoelum inoploeum	1	2	1.3
Canthium mombazense	1	1	0.7

In *Hugonia* community, therefore, the most important species for all pole sub-types were *Croton pseudopulchellus, Manilkara sansibarensis, Asteranthe asterias, Ophrypetalum odoratum* and *Diospyros consolatae*. For the relatively thinner poles (wither- and rafter-poles) *Ochna thomasiana* and *Canthium mombazense* were also important. The important species in *Hugonia* community, however, showed clumped distribution patterns in the transects, and thus being relatively abundant or otherwise generally rare and occasionally absent from some blocks. Overall this meant that the *Hugonia* community was generally poor in harvestable poles.

Building poles in Brachystegia Community

A total of 20 species used for wither-poles were recorded in the *Brachystegia* community. Among these species, eight species contributed over 70% of the total harvestable wither-poles recorded in that community (Table 6.28). These species were *Canthium mombazense, Grewia plagiophylla, Diospyros consolatae, Psydrax faulknerae, Croton pseudopulchellus, Vittelariopsis kirkii, Combretum illairii* and *Lamprothamnus zanguebaricus*. Harvestable wither-poles of the remaining species were recorded in lower densities, each contributing less than 5% of the wither-poles recorded in that community.

Table 6.28: Occurrence frequency of species used for wither-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Brachystegia* community in *kaya* Mtswakara

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type (Σ=480)**
Canthium mombazense	15	61	12.7
Grewia plagiophylla	12	52	10.8
Diospyros consolatae	14	49	10.2
Psydrax faulknerae	14	42	8.8
Croton pseudopulchellus	10	36	7.5
Vittelariopsis kirkii	4	36	7.5
Combretum illairii	8	31	6.5
Lamprothamnus zanguebaricus	9	30	6.3
Thespesia danis	9	22	4.6
Manilkara sansibarica	6	20	4.2
Allophylus pervillei	6	18	3.8
Garcinia livingstonei	4	18	3.8
Ochna thomasiana	6	13	2.7
Bridelia cathartica	4	12	2.5
Heinsia crinita	4	10	2.1
Haplocoelum inoploeum	4	9	1.9
Carissa tetramera	1	7	1.5
Tricalysia ovalifolia	3	6	1.3
Psydrax polhillii	2	5	1.0
Manilkara sulcata	2	3	0.6

In the *Brachystegia* community a total 23 species used for rafter-poles were recorded. Only one species, *Diospyros consolatae,* contributed more than 10% of the harvestable rafter-poles recorded. However, out of the 23 species, ten species contributed for over 70% of the total harvestable rafter-poles in that community (Table 6.29). The ten species are *Diospyros consolatae, Manilkara sansibarensis, Vittelariopsis kirkii, Combretum illairii, Thespesia danis, Canthium mombazense, Croton pseudopulchellus, Ochna mossambicensis, Garcinia livingstonei* and *Asteranthe asterias*. Harvestable rafter-poles of the rest of species were in lower densities, each contributing less than 5% of the total harvestable rafter-poles in that community.

Table 6.29: Occurrence frequency of species used for rafter-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Brachystegia* community in *kaya* Mtswakara

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ=427)
Diospyros consolatae	12	51	11.9
Manilkara sansibarensis	13	42	9.8
Vittelariopsis kirkii	4	34	8.0
Combretum illairii	11	32	7.5
Thespesia danis	11	31	7.3
Canthium mombazense	9	27	6.3
Croton pseudopulchellus	9	25	5.9
Ochna mossambicensis	7	24	5.6
Garcinia livingstonei	9	23	5.4
Asteranthe asterias	8	22	5.2
Lamprothamnus zanguebaricus	9	20	4.7
Ochna thomasiana	7	19	4.4
Allophylus pervillei	3	13	3.0
Uapaca nitida	5	12	2.8
Psydrax faulknerae	6	10	2.3
Haplocoelum foliolosum	3	9	2.1
Cynometra suaheliensis	2	8	1.9
Milletia usaramensis	1	8	1.9
Haplocoelum inoploeum	4	7	1.6
Heinsia crinita	2	4	0.9
Diospyros natalensis	2	3	0.7
Psydrax polhilii	1	2	0.5
Manilkara sulcata	1	1	0.2

In the *Brachystegia* community, a total of 16 species used for standing-poles were recorded, of which eight species *Manilkara sansibarensis, Thespesia danis, Garcinia livingstonei, Ochna mossambicensis, Ochna thomasiana, Cynometra suaheliensis, Diospyros consolatae* and *Uapaca nitida*, contributed over 75% of the total harvestable standing-poles recorded in *Brachystegia* community (Table 6.30). Harvestable standing-poles of the rest of the species were in lower densities, each contributing less than 5% of the total harvestable poles.

Table 6.30: Occurrence frequency of species used for standing-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6ha) of each species in *Brachystegia* community in *kaya* Mtswakara

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type; (Σ=254)**
Manilkara sansibarensis	13	39	15.4
Thespesia danis	11	36	14.2
Garcinia livingstonei	9	23	9.1
Ochna mossambicensis	8	23	9.1
Ochna thomasiana	8	20	7.9
Cynometra suaheliensis	5	19	7.5
Diospyros consolatae	9	18	7.1
Uapaca nitida	6	14	5.5
Croton pseudopulchellus	4	12	4.7
Sideroxylon inerme	4	9	3.5
Vittelariopsis kirkii	3	9	3.5
Catunaregam nilotica	3	8	3.1
Haplocoelum inoploeum	3	7	2.8
Allophylus pervillei	3	7	2.8
Diospyros natalensis	3	5	2.0
Toddaliopsis kirkii	2	5	2.0

The most important species for harvestable poles in the *Brachystegia* woodland community therefore are *Manilkara sansibarensis, Thespesia danis, Garcinia livingstonei, Ochna mossambicensis, Ochna thomasiana, Cynometra suaheliensis, Diospyros consolatae, Uapaca nitida, Vittelariopsis kirkii, Combretum illairii, Canthium mombazense, Croton pseudopulchellus, Asteranthe asterias, Grewia plagiophylla, Psydrax faulknerae* and *Lamprothamnus zanguebaricus*. Thus the number of species important for building poles in the

Brachystegia community is higher when compared to the other vegetation types. This was probably in part due to the harvestable poles of most of these species being commonly found in "clumps" and thus often locally rare. *Cynometra suaheliensis* and *Cynometra webberi* were recorded only on the termite mounds; *Thespesia danis* and *Uapaca nitida* were also rare and clumped; *Manilkara sansibarensis* was rare and with a disjunct distribution; while *Diospyros consolatae* was common but strongly clumped. All the other species were rare, and absent in some transects. This meant that in the *Brachystegia* community pole distribution was generally inconsistent, and the community type was poor in harvestable building poles.

6.4.3 RESULTS: Harvestable building poles in *kaya* Fungo

The highest number of species used for building poles in general was in the dense forest area (*Uvariodendron senso stricto* sub-community), and the least was in *Brachystegia* woodland (*Brachystegia* community) (Table 6.31). The number of species used for specific pole sub-types within each vegetation type did not differ substantially. The high number of species used for pole sub-types in *Uvariodendron senso stricto* sub-community (dense forest vegetation) corresponded with high number of harvestable poles (n ha^{-1}) of the different pole sub-types (Table 6.32). There was a higher supply of poles used for the different pole sub-types in the *Acacia* community, which had about one-third less species used than the *Uvariodendron senso stricto* sub-community. The lowest number of species used for building poles in the *Brachystegia* community corresponded with the lowest densities of harvestable poles of all the sub-types in that vegetation (Table 6.32).

Dense forest vegetation (Uvariodendron senso stricto sub-community)

Although a total of 20 species used for wither-poles were recorded in the *Uvariodendron senso stricto* sub-community (Table 6.33), seven of these species constituted 82.8% of the harvestable wither-poles in that vegetation type. These species were *Craibia brevicaudata, Combretum schumannii, Croton pseudopulchellus, Coffea sessiliflora, Eugenea capensis, Uvariodendron kirkii* and *Grewia plagiophylla*. The first three of these species contributing 59% of all the harvestable wither-poles. The poles of the other species were recorded in lower densities, each contributing less than 5% of the total harvestable wither-poles in that vegetation type.

Table 6. 31: Number of species used for building poles in different vegetation types in *kaya* Fungo

Physiognomic Vegetation type	Community type	No. of species used for all pole sub-types	No. of species used for wither-poles	No. of species used for rafter-poles	No. of species used for standing-poles
Dense forest vegetation	*Uvariodendron senso stricto* sub-community (*Uvariodendron* community)	30	21	23	21
Julbernardia vegetation	*Hunteria* stage (*Uvariodendron* community)	23	16	21	16
Acacia scrub-land vegetation	*Acacia reficiens* sub-community (*Acacia* community)	21	20	18	16
Brachystegia vegetation	*Brachystegia* community	20	13	14	15

Table 6. 32: Number of harvestable poles (n ha^{-1}) in different vegetation types in *kaya* Fungo

Physiognomic Vegetation type	Community type	No. of wither poles (n ha^{-1})	No. of rafter poles (n ha^{-1})	No. of standing poles (n ha^{-1})
Dense forest vegetation	*Uvariodendron senso stricto* sub-community (*Uvariodendron* community)	1110	1410	1174
Julbernardia vegetation	*Hunteria zeylanica* stage (*Uvariodendron* community)	810	757	680
Acacia scrub-land vegetation	*Acacia reficiens* sub-community (*Acacia* community)	950	1659	1252
Brachystegia vegetation	*Brachystegia* community	459	377	294

Table 6.33: Occurrence frequency of species used for wither-poles in (20 x 100m) blocks (n=30) of three transects, and number of poles in (0.6ha) of each species in *Uvariodendron senso stricto* sub-community in *kaya* Fungo

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type (Σ= 666)**
Craibia brevicaudata	25	182	27.3
Combretum schumannii	18	125	18.8
Croton pseudopulchellus	18	86	12.9
Coffea sessiliflora	15	46	6.9
Eugenea capensis	11	39	5.9
Uvariodendron kirkii	11	38	5.7
Grewia plagiophylla	6	35	5.3
Cola minor	12	28	4.2
Thespesia danis	4	14	2.1
Haplocoelum inoploeum	5	13	2.0
Lecaniodiscus fraxinifolius	4	12	1.8
Ochna thomasiana	5	11	1.7
Asteranthe asterias	2	8	1.2
Lamprothamnus zanguebaricus	3	7	1.1
Acalypha neptunica	3	6	0.9
Euclea natalensis	2	5	0.8
Ochna mossambicensis	2	4	0.6
Grewia truncata	1	3	0.5
Hunteria zeylanica	2	2	0.3
Manilkara sulcata	2	2	0.3

In the *Uvariodendron senso stricto* sub-community 22 species used for rafter-poles were recorded (Table 6.34). However, five of these species constituted 72.4% of the harvestable rafter-poles in that vegetation type. These species are *Craibia brevicaudata, Croton pseudopulchellus, Combretum schumannii, Cola minor* and *Uvariodendron kirkii*. Harvestable poles of the other species were recorded in lower densities, each contributed less than 5% of the total harvestable rafter-poles in the vegetation type.

Table 6.34: Occurrence frequency of species used for rafter-poles in (10 x 20m) blocks (n=30) in three transects and the number of harvestable poles (in 0.6ha) of each species in *Uvariodendron senso stricto* sub-community in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ= 836)
Craibia brevicaudata	29	292	34.9
Croton pseudopulchellus	22	160	19.1
Combretum schumannii	16	62	7.4
Cola minor	16	47	5.6
Uvariodendron kirkii	16	45	5.4
Grewia plagiophylla	8	38	4.5
Manilkara sulcata	13	37	4.4
Eugenea capensis	11	35	4.2
Ochna thomasiana	14	33	3.9
Thespesia danis	7	20	2.4
Haplocoelum inoploeum	10	17	2.0
Dombeya taylorii	6	11	1.3
Diospyros loureriana	4	6	0.7
Diospyros natalensis	2	6	0.7
Euclea natalensis	2	6	0.7
Lamprothamnus zanguebaricus	3	5	0.6
Hunteria zeylanica	2	5	0.6
Suregada zanzibariensis	3	4	0.5
Toddaliopsis kirkii	2	3	0.4
Coffea sessiliflora	2	2	0.2
Deinbolia borbonica	1	1	0.1
Grewia truncata	1	1	0.1

In the *Uvariodendron senso stricto sub-community*, although a total of 20 species were identified to be used for standing-poles (Table 6.35), five of these species constituted 75.6% of the harvestable standing-poles available in that vegetation type. These species were *Craibia brevicaudata, Combretum schumannii, Cola minor, Croton pseudopulchellus* and *Grewia plagiophylla*. Harvestable standing-poles of the other species were recorded in lower densities, each contributing less than 5% of the total harvestable poles in the vegetation type.

Table 6.35: Occurrence frequency of species used for standing-poles in (10 x 20m) blocks (n=30) in three transects and the number of harvestable poles (in 0.6ha) of each species in *Uvariodendron senso stricto* sub-community in *kaya* Fungo

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type (Σ=702)**
Craibia brevicaudata	26	253	36.0
Combretum schumannii	22	89	12.7
Cola minor	19	79	11.3
Croton pseudopulchellus	20	65	9.3
Grewia plagiophylla	10	44	6.3
Manilkara sulcata	16	34	4.8
Uvariodendron kirkii	12	29	4.1
Haplocoelum inoploeum	10	26	3.7
Ochna thomasiana	9	22	3.1
Thespesia danis	7	18	2.6
Euclea natalensis	4	11	1.6
Diospyros natalensis	6	8	1.1
Lamprothamnus zanguebaricus	3	5	0.7
Lecaniodiscus fraxinifolius	3	4	0.6
Hunteria zeylanica	2	4	0.6
Manilkara sulcata	2	4	0.6
Grewia densa	2	3	0.4
Haplocoelum foliolosum	2	2	0.3
Diospyros bussei	1	2	0.3
Eugenia capensis	1	2	0.3

The most important species for building poles in the dense forest *Uvariodendron senso stricto* sub-community therefore were *Craibia brevicaudata, Combretum schumannii, Croton pseudopulchellus, Uvariodendron kirkii* and *Grewia plagiophylla*. However, only harvestable poles of *Craibia brevicaudata, Combretum schumannii* and *Croton pseudopulchellus* were common throughout the vegetation type. While harvestable poles of *Craibia brevicaudata* were evenly distributed and commonly in high densities, harvestable poles of *Combretum schumannii* and *Croton pseudopulchellus* were mostly found in clumps and thus generally only in low densities.

Dense forest vegetation (Hunteria zeylanica stage)

A total of 16 species used for wither-poles were recorded in the *Hunteria zeylanica* stage (Table 6.36). Nine of these species constituted about 77% of the harvestable wither-poles recorded in the vegetation type. These species were *Ochna thomasiana, Combretum schumannii, Manilkara sansibarensis, Ophrypetalum odoratum, Craibia brevicaudata, Hunteria zeylanica, Croton pseudopulchellus* and *Heinsia crinita*. Harvestable wither-poles of the other species were recorded in low levels, each contributing less than 5% of the total harvestable wither-poles recorded in that vegetation type.

Table 6.36: Occurrence frequency of species used for wither-poles in (10 x 20m) blocks (n=30) of three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Hunteria zeylanica* stage in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ= 486)
Ochna thomasiana	19	58	11.9
Combretum schumannii	15	58	11.9
Manilkara sansibarensis	18	44	9.1
Ophrypetalum odoratum	18	42	8.6
Craibia brevicaudata	11	40	8.2
Hunteria zeylanica	14	37	7.6
Croton pseudopulchellus	11	33	6.8
Julbernardia magnistipulata	17	31	6.4
Heinsia crinita	12	31	6.4
Coffea sessiliflora	11	24	4.9
Haplocoelum inoploeum	8	18	3.7
Toddaliopsis kirkii	8	17	3.5
Cola minor	7	17	3.5
Suregada zanzibariensis	6	16	3.3
Uvariodendron kirkii	7	14	2.9
Oxyanthus sp.	3	6	1.2

A total of 21 species used for rafter-poles were recorded in *Hunteria zeylanica* stage, of which nine species contributed 75% of the harvestable rafter-poles in that vegetation type (Table 6.37). These species were *Ochna thomasiana*, *Combretum schumannii*, *Croton pseudopulchellus*, *Ophrypetalum odoratum*, *Craibia brevicaudata*, *Manilkara sansibarensis*, *Heinsia crinita*, *Julbernardia magnistipulata* and *Hunteria zeylanica*. Harvestable poles of the other species were in lower densities, each contributing less than 5% of the total harvestable rafter-poles recorded in that vegetation type.

Table 6.37: Occurrence frequency of species used for rafter-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Hunteria zeylanica* stage in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ= 454)
Ochna thomasiana	13	55	12.1
Combretum schumannii	15	48	10.6
Croton pseudopulchellus	14	43	9.5
Ophrypetalum odoratum	16	42	9.3
Craibia brevicaudata	9	33	7.3
Manilkara sansibarensis	17	32	7.0
Heinsia crinita	15	32	7.0
Julbernardia magnistipulata	12	29	6.4
Hunteria zeylanica	14	25	5.5
Suregada zanzibariensis	11	19	4.2
Monodora grandidiera	9	18	4.0
Haplocoelum inoploeum	8	14	3.1
Cola minor	5	12	2.6
Acalypha neptunica	5	10	2.2
Pteleopsis tetraptera	5	10	2.2
Eugenea capensis	4	9	2.0
Manilkara sulcata	5	7	1.5
Ochna mossambicensis	4	7	1.5
Toddaliopsis kirkii	4	6	1.3
Uvariodendron kirkii	2	2	0.4
Hymnea verucosa	1	1	0.2

In the *Hunteria zeylanica* stage, a total of 16 species identified to be used for standing-poles, of which eight species constituted of 82.5% of the harvestable poles (Table 6.38). These species were *Craibia brevicaudata, Combretum schumannii, Ochna thomasiana, Ophrypetalum odoratum, Julbernardia magnistipulata, Hunteria zeylanica, Manilkara sansibarensis* and *Cola minor*. Harvestable poles of the other species were recorded in lower densities, each contributing less than 5% of the total number of harvestable poles recorded in the vegetation type.

Table 6.38: Occurrence frequency of species used for standing-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Hunteria zeylanica* stage in *kaya* Fungo

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type (Σ=408)**
Craibia brevicaudata	14	55	13.5
Combretum schumannii	17	52	12.7
Ochna thomasiana	17	49	12.0
Ophrypetalum odoratum	18	45	11.0
Julbernardia magnistipulata	15	43	10.5
Hunteria zeylanica	12	37	9.1
Manilkara sansibarensis	16	33	8.1
Cola minor	9	23	5.6
Coffea sessiliflora	8	18	4.4
Suregada zanzibariensis	8	16	3.9
Haplocoelum inoploeum	6	12	2.9
Ochna mossambicensis	5	7	1.7
Heinsia crinita	5	7	1.7
Uvariodendron kirkii	2	6	1.5
Toddaliopsis kirkii	3	4	1.0
Hymnea verucosa	1	1	0.2

The important plant species for building poles in the *Hunteria zeylanica* stage therefore, were *Craibia brevicaudata, Combretum schumannii, Croton pseudopulchellus, Ochna thomasiana, Ophrypetalum odoratum* and *Manilkara sansibarensis*. However, only harvestable poles of *Ophrypetalum odoratum, Manilkara sansibarensis, Combretum schumannii* and *Ochna thomasiana* were consistently common throughout the vegetation type, although, like all the other species, were found in relatively low densities.

Acacia scrub-land vegetation (Acacia reficiens sub-community)

A total of 16 species used for wither-poles were recorded in *Acacia* vegetation, of which seven species accounted for 86.2% of the harvestable wither-poles in that vegetation type (Table 6.39). These species were *Lamprothamnus zanguebaricus, Grewia plagiophylla, Grewia densa, Acacia reficiens, Thespesia danis, Terminalia spinosa* and *Acacia robusta*. Harvestable wither-poles of the other species were in lower densities, each contributing less than 4% of the total wither-poles recorded in that vegetation type.

Table 6.39: Occurrence frequency of species used for wither-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Acacia reficiens* sub-community, in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ= 572)
Lamprothamnus zanguebaricus	14	108	18.9
Grewia plagiophylla	14	106	18.5
Grewia densa	14	99	17.3
Acacia reficiens	10	60	10.5
Thespesia danis	7	45	7.9
Terminalia spinosa	10	44	7.7
Acacia robusta	7	31	5.4
Euclea racemosa	5	22	3.8
Combretum illairii	4	20	3.5
Rhus natalensis	4	13	2.3
Dalbergia melanoxylon	4	8	1.4
Allophylus rubifolius	5	7	1.2
Manilkara mochisa	1	4	0.7
Scutia myrtina	2	3	0.5
Catunaregam nilotica	1	1	0.2
Diospyros bussei	1	1	0.2

A total of 18 species were used for rafter-poles in the *Acacia reficiens* sub-community (Table 6.40). Out of which five species constituted 81% of the harvestable rafter-poles recorded in the vegetation type. These species were *Acacia reficiens, Grewia plagiophylla, Terminalia spinosa, Grewia densa* and *Lamprothamnus zanguebaricus*, with *Acacia reficiens* clearly the most important with it alone contributing 43.7%. Harvestable rafter-poles of the other species were recorded in lower densities, each contributing less than 5% of the total harvestable-rafter poles recorded in that vegetation type.

Table 6.40: Occurrence frequency of species used for rafter-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Acacia reficiens* sub-community in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ=1005)
Acacia reficiens	29	439	43.7
Grewia plagiophylla	19	130	12.9
Terminalia spinosa	18	96	9.6
Grewia densa	13	88	8.8
Lamprothamnus zanguebaricus	13	57	5.7
Acacia robusta	11	42	4.2
Thespesia danis	6	32	3.2
Euclea racemosa	7	26	2.6
Combretum illairii	3	22	2.2
Dalbergia melanoxylon	6	17	1.7
Allophyllus rubifolius	5	11	1.1
Catunaregam nilotica	4	11	1.1
Scurtia myrtina	4	10	1.0
Manilkara mochisa	5	7	0.7
Rhus natalensis	3	6	0.6
Zanthoxylum chalybeum	2	6	0.6
Diospyros bussei	3	4	0.4
Ximenia americana	1	1	0.1

In the *Acacia reficiens* sub-community, a total of 19 species used for standing-poles were recorded, of which six species constituted 77% (Table 6.41). These species were *Acacia reficiens, Acacia robusta, Terminalia spinosa, Grewia plagiophylla, Thespesia danis* and *Grewia densa*. Harvestable standing-poles of the other species were recorded in low densities, each contributing less than 5% of the total standing-poles recorded in that vegetation type.

Table 6.41: Occurrence frequency of species used for standing-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Acacia reficiens* sub-community, in *kaya* Fungo

Species	**Occurrence frequency in (10x20m) blocks**	**No. of poles (in 0.6 ha)**	**Representation (%) in vegetation type (Σ= 745)**
Acacia reficiens	26	205	27.5
Acacia robusta	25	140	18.8
Terminalia spinosa	19	71	9.5
Grewia plagiophylla	16	71	9.5
Thespesia danis	9	48	6.4
Grewia densa	12	40	5.4
Croton talaeporos	9	33	4.4
Lamprothamnus zanguebaricus	9	23	3.1
Dalbergia melanoxylon	7	22	3.0
Euclea racemosa	5	22	3.0
Allophylus rubifolius	6	16	2.1
Catunaregam nilotica	6	15	2.0
Ormocarpum kirkii	3	12	1.6
Scurtia myrtina	4	7	0.9
Rhus natalensis	2	7	0.9
Sideroxylon inerme	4	6	0.8
Diospyros bussei	2	5	0.7
Toddaliopsis sp.	1	1	0.1
Zanthoxylum chalybeum	1	1	0.1

In general, the important species for building poles in the scrub-land *Acacia reficiens* sub-community were *Grewia plagiophylla, Grewia densa, Acacia reficiens Acacia robusta* and *Terminalia spinosa*. Although harvestable poles of these 'important' species were uniformly distributed in the vegetation type, their pole densities were generally low except for *Grewia plagiophylla* and *Acacia reficiens*.

Woodland vegetation (Brachystegia community)

A total of 15 species used for wither-poles were recorded in the *Brachystegia* community, of which seven species accounted for 79% of the total harvestable wither-poles (Table 6.42). These species were *Grewia plagiophylla, Psydrax faulknerae, Canthium mombazense, Lamprothamnus zanguebaricus, Vitex mombassae, Acalypha neptunica* and *Bridelia cathartica*. *Psydrax faulknerae* and *Grewia plagiophylla* were the most important, each contributing about 20% of the harvestable wither-poles. Harvestable wither-poles of the other species were recorded in lower densities, each contributing less than 5% of the total harvestable wither-poles recorded in that vegetation.

Table 6.42: Occurrence frequency of species used for wither-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Brachystegia* community in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (0.6 ha)	Representation (%) in vegetation type (Σ= 275)
Grewia plagiophylla	13	56	20.4
Psydrax faulknerae	12	54	19.6
Canthium mombazense	11	32	11.6
Lamprothamnus zanguebaricus	6	24	8.7
Vitex mombassae	7	22	8.0
Acalypha neptunica	7	16	5.8
Bridelia cathartica	3	14	5.1
Heinsia crinita	4	12	4.4
Ochna thomasiana	5	10	3.6
Psydrax polhilii	4	10	3.6
Ximenia americana	2	6	2.2
Lecaniodiscus fraxinifolius	1	6	2.2
Asteranthe asterias	2	5	1.8
Acacia robusta	1	5	1.8
Monodora grandidiera	1	3	1.1

A total of 14 species used for rafter-poles were recorded in the *Brachystegia* community, of which eight species accounted for 82.7% of the total harvestable rafter-poles recorded in that vegetation type. (Table 6.43). These species are *Psydrax faulknerae, Grewia plagiophylla, Ochna thomasiana, Lamprothamnus zanguebaricus, Manilkara sansibarensis, Canthium mombazense, Ximenia americana* and *Vitex mombassae*, with one of them (*Psydrax faulknerae*) contributing 22.6% of the harvestable poles. Harvestable rafter-poles of the other species were recorded in lower densities, each contributing less than 5% of the total harvestable rafter-poles.

Table 6.43: Occurrence frequency of species used for rafter-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Brachystegia* community in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type (Σ= 226)
Psydrax faulknerae	14	51	22.6
Grewia plagiophylla	9	38	16.8
Ochna thomasiana	9	24	10.6
Lamprothamnus zanguebaricus	5	19	8.4
Manilkara sansibarensis	5	15	6.6
Canthium mombazense	4	15	6.6
Ximenia americana	5	13	5.8
Vitex mombassae	5	12	5.3
Suregada zanzibariensis	4	10	4.4
Croton talaeporos	3	10	4.4
Lecaniodiscus fraxinifolius	1	8	3.5
Asteranthe asterias	2	7	3.1
Acacia robusta	3	3	1.3
Garcinia livingstonei	1	1	0.4

A total of 13 species used for standing-poles were recorded in the *Brachystegia* community, of which ten species accounted for 88.7% of the harvestable standing-poles recorded in that vegetation type (Table 6.44). These species were *Grewia plagiophylla, Ochna thomasiana, Manilkara sansibarensis, Terminalia spinosa, Vitex mombassae, Ximenia americana, Garcinia livingstonei, Croton talaeporos, Acacia robusta* and *Suregada sansibarensis.*

Harvestable standing-poles of the other species were recorded in lower densities, each contributing less than 5% of the total harvestable standing-poles recorded in the *Brachystegia* community.

Table 6.44: Occurrence frequency of species used for standing-poles in (10 x 20m) blocks (n=30) in three transects, and the number of harvestable poles (in 0.6 ha) of each species in *Brachystegia* community in *kaya* Fungo

Species	Occurrence frequency in (10x20m) blocks	No. of poles (in 0.6 ha)	Representation (%) in vegetation type; (Σ= 177)
Grewia plagiophylla	7	21	11.9
Ochna thomasiana	8	20	11.3
Manilkara sansibarensis	9	19	10.7
Terminalia spinosa	8	19	10.7
Vitex mombassae	11	17	9.6
Ximenia americana	5	16	9.0
Garcinia livingstonei	5	15	8.5
Croton talaeporos	4	12	6.8
Acacia robusta	4	9	5.1
Suregada sansibarica	3	9	5.1
Monodora grandidiera	4	7	4.0
Lamprothamnus zanguebaricus	2	7	4.0
Lecaniodiscus fraxinifolius	2	6	3.4

Overall, the most important species for building poles in the *Brachystegia* woodland community were *Grewia plagiophylla, Ochna thomasiana* and *Vitex mombassae*. *Manilkara sansibarensis, Terminalia spinosa, Ximenia americana* and *Garcinia livingstonei* were only important for the relatively thicker pole sub-types, while *Psydrax faulknerae, Lamprothamnus zanguebaricus* and *Canthium mombazense* were important for the thinner pole sub-types. Poles of *Grewia plagiophylla* and *Vitex mombassae*, were generally rare but consistently recorded in all trannsects, and occassionally clumped in some blocks. Poles of the other species were inconsistently distributed in the transects, sometimes completely absent. Clearly, therefore, the *Brachystegia* vegetation type was not an important source of poles.

6.4.4 Collectable Firewood in *kayas* Mtswakara and Fungo

In Mtswakara deadwood as a potential firewood resource was only recorded in one of the three transects of *Scorodophloeus* community. The deadwood was of *Manilkara sulcata* and *Cussonia zimmermannii*. Other resource users (possible building pole collectors) had collected the *Manilkara sulcata* and some remains of the collected wood, about two head-loads, were left. The *Cussonia zimmermannii*, which was felled during the collection of the *Manilkara sulcata*, was identified as not an important species for firewood. Only in the first transect of the *Hugonia* community was deadwood noted, which was about one head-load. Again the deadwood appeared to be 'leftovers' from the collection of branches of *Julbernardia magnistipulata*. The *Julbernardia magnistipulata* branches were felled by local smiths who used the wood for hoe-handles. There were no deadwood recorded in the transects of the *Brachystegia* community. Firewood collectors in Mtswakara commonly visit areas that other resource users (particularly of poles and hand-hoe handles) had made a collection. The firewood collectors then collect the remains of the wood, an observation made even in areas outside the sampled transects this study.

In Fungo, generally there were no dead wood recorded in the transects of all the vegetation types.

6.4.5 DISCUSSION: Harvestable plant resources in the *kayas*

Pole collection and species selection

The pole collectors considered three aspects during pole selection. These are species type (durable and culturally acceptable species), form (straightness) and size (dependent on the pole type required). However, a collector was in most cases was forced to compromise between these aspects because the three do not always occur in one specific pole. Culturally the species type and pole size were the most important aspects, and form was secondary (Chuphi pers. comm.).

Despite being potentially compromised during pole collection, 'a straight form' is very important in house construction. However, the local communities had devised a way of straightening the bowed poles by making partial cuts on the inner part of bent place(s) and force the pole to remain straight using a piece of wood that is inserted at the cut place(s). Thus, some poles are harvestable although the form was not right (Mtaveta pers. comm.).

Important vegetation types and tree species for building poles

In both *kayas*, the relatively dense forest area carried the highest densities of harvestable poles. These vegetation types (*Scorodophloeus* community in Mtswakara; and *Uvariodendron senso stricto* sub-community in Fungo), rich in building poles, were not common in areas outside the *kayas*. In addition, there were signs that the areas occupied by these vegetation types were shrinking while other vegetation types were increasing. In this study it was noted that the *Scorodophloeus* dense forest community in *kaya* Mtswakara was being replaced by the *Acacia* wooded grassland community, which is not an important source of building poles. The *Uvariodendron* dense forest community in Fungo seemed to be being replaced by the *Acacia robusta* community which again had a low pole density.

The most important species for building poles in *kaya* Mtswakara i.e. *Scorodophloeus fischeri* and *Craibia brevicaudata*, were recorded in the *Scorodophloeus* community and were either rare or absent in the other vegetation types of the *kaya*, and were absent in the farmland areas outside the *kaya*. Mature *Scorodophloeus fischeri* (Caesalpinaceae) and *Craibia brevicaudata* (Papilionaceae) were noted to grow with many saplings, which suggested a high recruitment ability of these species from their seeds. However, despite their recruitment potentials, the growth rates and their wood maturity period (i.e. to an acceptable quality) is not clearly known. Compared to exotic species such as *Casuarina equisitifolia*, these species are slow growers (Luke pers. comm.). The most common harvestable size of these species was the wither-pole sub-type (2-4cm BD), and the least common harvestable size was the standing-pole sub-type (5-10cm BD). Absence of data on previous densities of the harvestable poles made it difficult to comment on the temporal patterns of the availability of poles. However, according to the respondent, the densities were reducing with time, mainly because of frequent pole collection by some community members who then sold their collections. In addition to its use for building poles, *Craibia brevicaudata* is also a major species used for firewood in (Section 6.3) and for medicinal purposes (Chapter Five), while *Scorodophloeus fischeri* is important for making local furniture e.g. a traditional bed (Chapter Five).

Other species with considerable harvestable poles in *kaya* Mtswakara were *Croton pseudopulchellus* and *Asteranthe asterias*, particularly for the thinner pole sub-types (wither- and rafter-poles). *Croton pseudopulchellus* (Euphorbiaceae) and *Asteranthe asterias* (Annonaceae) are shrubs or small tree species (Beentje 1994) found in the dense forest vegetation type and mostly recorded in the shrub layer, but their population recruitment rates are not known. However, it is likely that the two species reached maturity or usable sizes after a longer period than exotic species like *Casuarina equisitifolia*. In addition to the building use, dry sticks of *Croton pseudopulchellus* are used by the *Midzichenda* to add flavour in milk, and roots are used for medicinal purposes (Chapter Five). *Asteranthe asterias* is used for building by other Kenyan communities (Beentje 1994), and among the *Midzichenda*, the leaves and roots of the species are used for medicinal purposes (Chapter Five).

In *kaya* Fungo, the important species for building poles were *Craibia brevicaudata* and *Combretum schumannii*, recorded in the *Uvariodendron* community (Chapter Two), and were rare in the other vegetation types and absent outside the *kaya* forest. In addition to building, *Combretum schumannii* was also a major species used for firewood in Fungo (Section 6.3), hollow stems of the species were used for making traditional beehives, and roots are used for medicinal purposes (Chapter Five). The species is becoming generally rare due to overexploitation (Beentje 1994), and in Fungo most of the individual trees were sprouts of a harvested mother tree. However, different species used for building poles had considerable high pole densities in the different vegetation types in *kaya* Fungo (Table 6.45), with poles of some species being not recorded in other vegetation types despite the high density occurrences in specific vegetation types. Poles of *Croton pseudopulchellus* and *Uvariodendron kirkii* were common in *Uvariodendron senso stricto* dense forest sub-community; and poles of *Ophrypetalum odoratum* and *Manilkara sansibarensis* were mainly in the *Hunteria* dense forest stage. Poles of *Grewia densa, Acacia reficiens, Acacia robusta* and *Terminalia spinosa* were mainly in the *Acacia robusta* community; and poles of *Vitex mombassae, Ximenia americana* and *Terminalia spinosa* were mainly in the *Brachystegia* woodland community. Only harvestable poles of *Grewia plagiophylla* were common in all the vegetation types, except for *Hunteria* dense forest stage.

Table 6.45: Species recorded with considerable importance as building poles in different vegetation types in *kaya* Fungo

Vegetation type	Species recorded
Uvariodendron senso stricto sub-community	*Craibia brevicaudata, Combretum schumannii, Croton pseudopulchellus, Uvariodendron kirkii, Grewia plagiophylla* and *Ochna thomasiana*
Hunteria stage	*Craibia brevicaudata, Combretum schumannii, Ochna thomasiana, Ophrypetalum odoratum* and *Manilkara sansibarensis*
Acacia reficiens sub-community	*Grewia plagiophylla, Grewia densa, Acacia reficiens* and *Acacia robusta*
Brachystegia community	*Grewia plagiophylla, Ochna thomasiana, Vitex mombassae, Ximenia americana* and *Terminalia spinosa*

The growth rates of the species with consideable pole densities were not known, but compared to exotic species e.g. the *Casuarina equisitifolia*, are likely to be slow growers. In terms of sizes, the highest densities were of the wither-poles (2-4 cm BD) and the least were of standing-poles (9-12cm BD). However, in *kaya* Fungo, like in *kaya* Mtswakara, there were no data on previous densities of the harvestable poles of different size classes. According to the respondent, Mr. Mtaveta, the current harvestable pole densities have reduced significantly compared to the past. However, the respondent identified the decrease in the dense forest habitat area as being the main cause of the scarcity of poles of popular species rather than resulting from wood/pole collection *per se*. However, the observation made in this study of the extensive collection of *Combretum schumannii* suggested strongly that pole/wood collection had significant contribution to the scarcity of poles of the popular species.

Species used and available poles in the two kayas

The number of species used for building poles in different vegetation types in *kaya* Mtswakara (39 – 29 species) was higher than that in *kaya* Fungo (30 – 20 species). Also the sum of densities of all pole sub-types (n ha^{-1}) in each vegetation type was higher in *kaya* Mtswakara than that in *kaya* Fungo (Table 6.46). The dense forest area in *kaya* Mtswakara had about twice the number of harvestable poles than in the comparative dense forest area in *kaya* Fungo. This meant that *kaya* Mtswakara was certainly richer in harvestable poles than *kaya* Fungo.

Some of the species recorded with the highest densities in the two *kayas* were also the major species used for building poles in the homesteads around the *kayas*. Tables 6.47, and 6.48 give the details of the major species for building in the homesteads around the *kayas* and the species with high pole densities in *kayas* Mtswakara and Fungo.

Table 6.46: Harvestable poles in different vegetation types in *kayas* Mtswakara and Fungo

Vegetation types	Building poles (n ha^{-1}) in Mtswakara	Building poles (n ha^{-1}) in Fungo
Scorodophloeus community (**Mtswakara**) versus *Uvariodendron senso stricto* sub-community (**Fungo**)	6561	3694
Hugonia community (**Mtswakara**) versus *Hunteria zeylanica* stage (**Fungo**)	2296	2247
Brachystegia community (**Mtswakara v. Fungo**)	1946	1130

Table 6.47: Comparison between the major species used for building poles in homesteads neighbouring *kaya* Mtswakara and the species with high pole densities (80 poles ha^{-1}) in the *kaya* forest

Major species for building that also had high pole densities	Major species for building that had low pole densities	Species with high pole densities but were not major species for building
Cynometra suaheliensis	*Terminalia spinosa*	*Asteranthe asterias*
Scorodophloeus fischeri	*Manilkara sulcata*	*Cynometra webberi*
Grewia plagiophylla	*Combretum schumannii*	*Thespesia danis*
Diospyros consolatae	*Dalbergia melanoxylon*	*Ochna thomasiana*
Croton pseudopulchellus	*Combretum illairii*	*Manilkara sansibarensis*
Canthium mombazense		
Craibia brevicaudata		

Table 6.48: Comparison between the major species used for building poles in the homesteads neighbouring *kaya* Fungo and the species with high pole densities (80 poles ha^{-1}) in the *kaya* forest

Major species for building that also had high pole densities	Major species for building that had low pole densities	Species with high pole densities but were not major species for building
Grewia plagiophylla	*Thespesia danis*	*Craibia brevicaudata*
Acacia robusta	*Croton talaeporos*	*Combretum schumannii*
Terminalia spinosa	*Combretum illairii*	*Ochna thomasiana*
Acacia reficiens	*Dombeya taylorii*	*Cola minor*
Croton pseudopulchellus	*Dalbergia melanoxylon*	*Grewia densa*
	Diospyros bussei	*Lamprothamnus zanguebaricus*

It is difficult to explain the results given in Tables 6.47 and 6.48. It may be that the major species for building and that had high pole densities were relatively fast growing species. However, the high pole densities could also be attributed to the control of plant resource extraction from the *kayas*. Despite the high pole densities of some of these species in demand, the domestic need for building poles expressed by the local communities in both *kayas*, compounded with the pole trade activities, could be of conservation significance in the absence of plant resource extraction controls. Certainly, free pole collection is likely to be a threat to these species.

The major species that had low pole densities were possible the species that were common in the shrubland areas outside the *kayas*. However, *Manilkara sulcata* (Table 6.47) a dry evergreen forest species (Beentje 1994), *Combretum schumannii* and *Dombeya taylorii* (Table 6.48) which were recorded in dense forest vegetation in this study (Chapter Two), and were less common in the shrub-land, were an exception. Whether the low pole densities for *Manilkara sulcata*, *Combretum schumannii* and *Dombeya taylorii* in the *kayas* were as a result of the pole collectionactivities in the past, it could not be established, but it also could not be discounted. Some species in this group (Tables 6.47; 6.48) were known to occur frequently in the bush-land (Beentje 1994), and in this study were also recorded in wooded grassland or shrub-land vegetation types. It is likely therefore that pole gatherers prioritised and mostly collected from the *kaya* the species that were not available outside the *kaya*.

The species with high pole density but were not major species for building (Table 6.47; 6.48) could have been assumed to be the species of low preference in building. However, this was not the case for *Craibia brevicaudata*, *Combretum schumannii* and *Cola minor*, which were known to be excellent sources of building poles (Mtaveta pers. comm.) in *kaya* Fungo. The high pole densities of these species in the *kaya* could be attributed to the existing control of plant resource collection. In *kaya* Mtswakara, *Cynometra webberi* was also known to be a good source of building poles (Chuphi pers. comm.), however, during the interviews (Section 6.3) it was not easy to distinguish between *Cynometra suaheliensis* and *Cynometra webberi*, both commonly identified as 'Mfunda' (Chapter Five). It could be, therefore, that *Cynometra webberi* was also a major species for building poles but was missed in the recording process.

6.5 TREE DOMESTICATION, TRADE AND CONTROL OF PLANT RESOURCE EXTRACTION

6.5.1 Tree domestication around the *kayas*

Introduction and Methods

Domestication of plant species, other than food crops, was investigated during the visits to the homesteads simultaneously as the family members were interviewed on the utilisation of building poles or firewood. The investigation was conducted through observations and discussion with the farmers. The plant species domesticated were listed and their uses inquired from the farmers. During the discussion the names of the plant species were recorded in the vernacular of the farmer, and then matched with respective scientific names in the ethnobotanical inventory given in this thesis in Chapter Five.

Results and Discussion

Around Mtswakara a total of 12 tree species (Table 6.1) were domesticated in 29% homesteads (n=100). The domesticated species included those planted by the farmers and others that had grown naturally but were deliberately retained on the farm. The planted species were mainly exotic species, and the species retained after they grew naturally were indigenous species. The only exception was the indigenous species *Milicia excelsa* which was planted in one homestead. The planted species were generally confined to immediately around the homesteads, where the seedlings could be protected and cared for, while most of the indigenous species were found on the cultivated farmland amidst cultivated crops.

Although generally tree domestication around *kaya* Mtswakara was low (in >30% of the visited homesteads), relatively exotic species were more popular than the indigenous species. This was probably due to the fast growth rate of the exotic species compared to the indigenous species. A shrub species, *Thevetia peruviana* of the family Apocynaceae, which is poisonous (Luke pers. comm.) was the most common. This species was mainly grown as an ornamental and for shade, and to a lesser extent for building poles. The neem tree, *Azadirachta indica*, was also common and popular for its medicinal values. The species is believed to treat some forty diseases, thus it was mainly domesticated for its medicinal importance. *Milicia excelsa*, although a good quality timber species (Beentje 1994) was the least domesticated species.

Table 6.49: Domesticated plant species and their uses around *kaya* Mtswakara.

Species	Homesteads recorded (%)	Uses
Thevetia peruviana	20	Ornamental, building , and shade
Azadirachta indica	18	Medicinal and shade
Casuarina equisitifolia	10	Building poles
Terminalia spinosa	8	Building poles and fire-wood
Dalbergia melanoxylon	7	Building poles and firewood
Diospyros squarrosa	7	Farm-shade, building poles and firewood
Ziziphus mucronata.	5	Shade, building poles and firewood
Tectona grandis	4	Shade and building poles
Cassia siamea	3	Shade and building
Acacia mellifera	3	Firewood
Eucalyptus sp.	2	Shade, building , firewood
Milicia excelsa	1	Shade and timber

Compared to *kaya* Mtswakara area, around *kaya* Fungo tree domestication was a more common practice both in terms of the percentage of homesteads in which domestication was carried out and number of species type domesticated. In the villages surrounding *kaya* Fungo, 28 species (Table 6.2) were domesticated in 68% homesteads (n=97). Similar to the situation around *kaya* Mtswakara, all the exotic species were planted near the homesteads, while all the indigenous species, except for *Afzelia quanzensis*, were deliberately retained on the farmlands where they grew naturally. In the farmlands surrounding *kaya* Fungo, although exotic species *Thevetia peruviana* and *Lucina lucosifolia* were common, the indigenous species *Terminalia spinosa* and *Grewia plagiophylla* were the most commonly domesticated species. Both *Terminalia spinosa* and *Grewia plagiophylla* have symbolic uses to the Giriama, but whether their popularity in domestication was derived from the symbolic values over the other uses was not established.

Table 6.50: Domesticated plant species and their uses around *kaya* Fungo

Species	Homesteads recorded (%)	Uses
Terminalia spinosa	35.1	Building, firewood and for symbolic use (*vigango*)
Grewia plagiophylla	26.8	Building, firewood, shade and for symbolic use (*koma*)
Thevetia peruviana	19.6	Ornamental, building and firewood
Lucina lucosifolia	12.4	Shade, building and firewood
Combretum illairii	8.2	Building and firewood
Azadirachta indica	7.2	Medicinal, shade and building
Cassia sp.	7.2	Shade, building and firewood
Lannea schweinfurthii	7.2	Shade, medicinal and firewood
Casuarina equisitifolia	6.2	Building
Croton talaeporos	6.2	Building, firewood and shade
Melia sp.	6.2	Shade, building and firewood
Tamarindus indica	4.1	Spice fruits, shade and building
Albizia anthelmintica	3.1	Shade, soft-timber and firewood
Diospyros squarrosa	3.1	Building, firewood, shade
Manilkara mochisa	3.1	Shade, medicinal and firewood
Zanthoxylum chalybeum	3.1	Building, shade and medicinal
Delonix sp.	2.1	Shade, building and firewood
Lecaniodiscus fraxinifolius	2.1	Building, shade and firewood
Tectona grandis	2.1	Shade, timber and firewood
Adenia gummifera	1.0	Medicinal
Acacia robusta	1.0	Building and firewood
Acacia mellifera	1.0	Building and firewood
Afzelia quanzensis	1.0	Shade and timber
Dalbergia melanoxylon	1.0	Building and firewood
Ficus sp.	1.0	Shade
Sclerocarya birrea	1.0	Timber, shade and fruits for food
Terminalia cattapa	1.0	Shade and edible fruits

In both *kaya* areas some community members expressed interest in some plant species for domestication. The species that most people expressed interest in were exotic species *Casuarina equisitifolia, Lucina lucosifolia* and *Tectona grandis*.

The observation of more homesteads participating in tree domestication and more species domesticated around *kaya* Fungo than around *kaya* Mtswakara concur with earlier observations (section 6.1 and 6.2) where the *kaya* Fungo community acquired more poles and firewood from private farmland than the *kaya* Mtswakara community. It is likely that an experience of acute shortage for plant resources had been felt much earlier in *kaya* Fungo area, which has resulted in precautions and great effort to counter shortages. It is also likely that the restriction and control in plant resource extraction from *kaya* Fungo were considerable effective, and the community members have had to plan for alternative options.

In the historical development of farming, especially during land clearing and preparation the trees were felled and stumped to make way for the cultivated crops (Kajambo pers. comm.). Farmers usually believe that crops are less productive under shady conditions. This farming practice contributed considerable to the loss of timber tree species in particular and indigenous vegetation in general (Robertson & Luke 1993). It is likely that following difficulties in acquiring plant resources for various domestic uses, a greater tolerance to retaining useful species occurred, which resulted in the presence of selected tree species kept in the cultivated fields. This indicates that the farmers recognised the incentive of protecting trees, and that the utilised species in communal land and forested areas were becoming scarce and difficult to collect. However, there was little evidence of the planting of indigenous tree species that had ethnobotanical value in both *kaya* areas.

Tree domestication and cultivation is important in the conservation of the genetic pool of the species utilised which are likely to be threatened with increased demand (Clarke 1994) as well as in reducing pressure on already substantially disturbed indigenous vegetation sources such as the *kayas*. However, although the vast bulk of agricultural work among the *Midzichenda* is done by women (Hawthorne et al. 1981), in this study it was noted that all the plant species domestication were primarily intended for uses other than firewood (Sidi Chondo pers. comm.). Since by cultural tradition firewood collection is a woman's responsibility, utilisation of the domesticated tree species primarily for other uses was understood to result from the customary male-dominance, which reign strongly in *Midzichenda* homesteads. Surprisingly, most of the female members of the community did not complain on that unfavourable arrangement, on the contrary, they accepted it. This suggests that firewood collection from the private farmland does not feature in either the current or future tree domestication efforts.

Conclusion

The need to improve and broaden the tree domestication practice among the community members in both *kayas* is clear, and in particular with more emphasis required in *kaya* Mtswakara area. In addressing the tree domestication issue, it might be important to recognise limiting factors to tree domestication as identified by the community members. In this study some of the problems highlighted by the farmers were:

i) *Harsh environmental conditions*: This was a common problem in both *kaya* areas, but more so around *kaya* Fungo. Some farmers lost tree seedlings, which they had obtained with difficulty, in the prolonged drought conditions, resulting in discouraged farmers in tree domestication.

ii) *Land tenure*: The land occupied by the communities surrounding both *kayas* had not been adjudicated and therefore the farmers were, legally speaking, squatters. Although the communities had been settled in these areas for centuries, as their history indicate (Spear 1978), the land that they live and farm on is regarded as Government land under the custody of Local Government. Government authorities have powers to allocate the land to any Kenyan, and not necessarily those settled in the area. These land tenure arrangements give the farmers little incentive to engage in long-term vegetation management practices. On the contrary, some farmers get engaged in short-term vegetation exploitation e.g. timber trade, which only enhance forest degradation, reduction in tree cover, and soil degradation (Afikorah-Danquah 1997).

iii) Livestock that belong to other members of the community sometimes grazed on planted tree seedlings. This is because among the local communities there were no defined grazing lands, thus livestock owners graze freely across the area, except for crop fields.

Grazing in the fields that are free of crops sometimes led to the loss of seedlings, which discouraged the farmers from further attempts in tree domestication.

iv) Most farmers showed interest in tree domestication, but they lacked the means to obtain seedlings of these species of their interests (i.e. the exotic species), which were said to be available at the local administration or forest Department offices, but were for sale. Due to the poverty, most farmers complained that their wish to practice tree domestication was obstructed by the inability to meet the costs. Although provision of free or subsidised tree seedlings might not create a commitment among some farmers, it might motivate some and encourage tree domestication activities.

v) Some farmers complained that the tree seedlings frequently died but did not understanding the cause of death. This seemed to be lack of technical skills and an understanding of the tree planting and management procedures. Although the farmers are supposed to receive technical assistance from the local forestry offices, this appeared to be more in theory than in practise. Provision of technical information on tree mangement might be necessary to improve the success of the tree domestication practise.

6.5.2 Trade in building poles and firewood in the local markets

Introduction and Methods

Trade in building poles and firewood resources of forest plant species were investigated through visits to local urban markets neighbouring the *kaya* forests. The markets included Mazeras, Kaloleni and Kokotoni. Informal interviews were conducted with the persons selling the building poles and firewood in these markets. The interviews were focused to identification of the plant species sold, sources of those species, common customers, and existing demand of those resources. Through observation, the amounts of firewood and building poles stocked by the sellers were estimated. Visits were also made to larger urban markets (Mombasa-Mackinon and Kilifi town) to list other potential forest plant products that were commercialised.

Results and Discussion

Firewood

A trading centre at Kokotoni, along the Mombasa-Nairobi road, constituted of stalls of firewood and building poles. The firewood stall was stocked with assorted indigenous plant species, of which only *Acacia zanzibarica* could be correctly identified. The firewood was sold in bundles of two pieces (a big one "5ft" and a small one "1.5ft") at Ksh. 10.00, and the main customers were mainly local businesses-women involved in cooking foodstuffs, e.g. fried fish, and bums, for sell. Relatively, a small population of the community bought firewood for domestic uses. The wood sold was purchased from farmers in the rural villages, Bamba in Giriama. Stocks of firewood were usually replenished after the available wood had all been sold off. According to the stall attendant, a lorry load of wood (4 tonnes) was sold in about two weeks. At the time of visit, there was about half a lorry load (2 tonnes) in the stall.

Two more firewood stalls were found at Kaloleni, a trading centre off the main Mombasa-Nairobi road. Both stalls belonged to Giriama women. In one stall the sold wood comprised of assorted plant species that included *Cynometra* spp. and *Brachylaena huillensis*. In the second stall the species stocked were assorted but comprised mostly *Brachylaena huillensis*, and other species were *Cynometra* spp., *Grewia plagiophylla* and *Premna chrysoclada*. In both stalls *Brachylaena huillensis* was identified to be the most preferred and the fastest selling species, and therefore the stall owners preferred to always include this species in their stock. However, there was a ban on the collection of this species from the wild, and therefore it was difficult to get large mounts of that species. At one stall the wood was sold in bundles of two pieces (one long and one short) at Ksh.10.00 per bundle, similar to the observation made at Kokotoni. In the second stall the wood was sold in single sticks, a long one (about 5ft) at Ksh. 10.00 and a short one (about 1.5ft) at Ksh. 5.00.

Similar to Kokotoni, the main customers for firewood were the local business-women involved in cooking foodstuffs for sell in the streets, and low demand of firewood for domestic uses. In addition, the owner of the second stall (Dama) also supplied firewood to local institutions such as schools and hospitals. Both traders estimated that they sold at a rate of a lorry load (4 tonnes) per month, and firewood supplies to institutions were made following an order. Some of the wood was supplied by agents at a cost of between Ksh. 4,000.00 - 5,000.00, per lorry load, and the agents were known to get the wood from Bamba (Giriama). As an alternative source of supply, the sellers bought wood from the farmers (in Giriama), and hire transport to carry the wood to Kaloleni. In the two stalls, at the time of visit the available firewood stock was about two lorry loads (8 tonnes) in the first stall, and one and a half lorry load (6 tonnes) in the second stall. Although Mazeras, a town along the main Mombasa-Nairobi road, was a very busy trading centre, there was no firewood sold. This was possibly due to the presence of large stocks of charcoal being sold, an alternative cheap fuel, at the roadside.

An alternative source of firewood for the communities living near *kayas* Mtswakara and Fungo was the Mwache Forest Reserve. Firewood collection from the Forest Reserve was done on payment (Ksh. 20.00 for a day, or Ksh 45.00 for a month). Bulk firewood collection for sale was allowed after paying a collection fee (between Ksh 400.00 – 1000.00). Firewood collection from the Forest Reserve was done on weekdays, and only dead wood was collected (Umazi & Mramba pers. comm.). Most women, whom were unemployed, tended to collect more than their domestic need to sell to neighbours and friends. Excess collections from Mwache Forest Reserve were made possible by the availability of transport (lorries) for a fee. The firewood sold to neighbours costed much less (six pieces of wood at Ksh. 20.00) than the prices in the local markets.

Building Poles

At Kokotoni there were two stalls in which building poles were sold. However, at the time of visit, both stalls had pole stocks which were exclusively of Mangrove and Sisal poles. The price for the Mangrove poles was Ksh 70.00 per pole, and Ksh 20.00 per Sisal pole. The stalls were occasionally stocked with indigenous species, but this was rare due to difficult in getting consistent supplies. However, a market for the indigenous species poles was known to exist.

At Kaloleni building poles were sold in two stalls. One of the stalls, owned by an Asian lady, was stocked with Mangrove and sisal poles, and poles of assorted indigenous forest plant species. The Mangrove poles were sold at Ksh. 90.00 – 100.00 per pole, and sisal poles were

Ksh. 20.00 per pole. The other forest species included *Acacia reficiens* sold at Ksh. 70.00 – 80.00 per pole. The remaining indigenous species (unidentified) were of poor form (not straight) and were sold at Ksh. 60.00 – 70.00 per pole. Although the poles sold were exclusively of standing-poles, wither-poles (*fito*) and rafter-poles (*pau*) of indigenous forest species could be supplied when ordered. Mangrove and Sisal poles were supplied to these traders by some agents in major urban centres like Mombasa, while the indigenous forest species were supplied by other agents whom made collections from Bamba (in Giriama). At the time of the visits for this research the available poles in the stall included *Acacia spp.* 150 poles, *Mangrove poles* - 300, Sisal poles - 200, other poles (assorted indigenous forest species) 250 poles (on estimations). In the second stall, owned by an Asian man, only sisal and Mangrove poles were sold. Prices for the poles were the same as those in the first stall. Despite the diverse trade activities to be found in Mazeras, there were no building poles sold.

Poles from indigenous forest plant species sold in the markets were generally in very low quantities. The availability of Mangrove poles, collected legally through certification of the Forest Department, and the availability of Sisal poles, collected from large sisal plantations, significantly reduced the demand for building poles, especially in the urban markets. However, the presence of poles of the forest species suggested existence of a potential market. The relatively low price for poles of the forest species is an indication that the gatherers in the rural villages made very low profits out of the trade. These prices were mostly a reflection of the degree of desperateness of the gatherer, which the urban market sellers exploited and the poles were bought at below the genuine economic value.

In addition to the firewood and poles sold in the markets, a 'house to house' trade was being conducted by gatherer-sellers, which was common along the Kilifi-Kaloleni road (Plate 6.6). These gatherer-sellers, mostly female members of the community, travelled over 15 km from the collection areas to the urban areas where they conduct their selling. This was possibly prompted by the fact that customers in the urban areas are often willing to pay more than the ones in villages (Godoy & Bawa 1993). In the rural areas the gatherer-sellers sold the poles at Ksh 20.00 per pole, (and Ksh.1.00 per rafter- or wither-pole) i.e. very low prices. In the urban areas the prices increased but were mainly dependent on the bargaining powers of the customer.

In addition to firewood and building poles, in the visited town/city markets (Mombasa and Kilifi), other forest products were also recorded. These included fruits of *Ancylobotrys petersiana, Saba comorensis, Landolphia kirkii, Tamarindus indica, and Dialium orientale*. The main customers of these fruits were identified to be the Asian community and children of other ethnic groups living in these town/city centres. The fruits were supplied to sellers by gatherers whom made collections from the rural villages, including the *kayas* forests. However, some sellers were also gatherers. In the markets there were also assorted items woven from *Hyphaene compressa*, which included mats, baskets, sieves, and hats. Farm implements made of wooden handles such as hand-hoe, axes and machetes were also being sold. Toothbrush sticks, and plants parts of medicinal values were also sold.

Conclusion

The results in this study show that to a certain extent some members of the rural communities living near the *kayas* expend considerable effort to derive a low income from the selling of the wild plant products. Although historically, the extraction of plants and animals by the local communities from the *kaya* has been going on for a considerably long time, the issue of selling these forest products is relatively new (Kajambo pers. comm.). Plant resource extraction is a viable activity when serving the needs of a small local population (Homma 1992), and although around both *kayas* the population sizes were considerably low, the sharing of these resources with the urban markets, increases the dependant population to an apparent unsustainable level. Observations made in the market centres might not reflect the complete picture of the trade in firewood and building poles, because of the presence of women hawkers who sell their collection in 'house-to-house' visits and/or sell to their visiting neighbours from their own houses. In this study the latter two informal and less conspicuous modes of trade were not exhaustively investigated. Therefore, details of the economic contribution of the forest products to the rural community remains to be fully investigated.

Although the *kayas* were not identified as major sources of these plant resources, there was a higher likelihood that some of the plant resources were collected from the *kayas* neighbouring the urban centres.

Plate 6.7: 'House to house' informal trade in firewood, building poles and sawn timber plunks, carried out by the local women. These women were walking along the Kilifi-Kaloleni road. (Photo taken in June 1999).

6.5.3 Traditional control in plant resource extraction

Introduction and Methods

Kaya elders were consulted for information on the existing traditional management systems, particularly in the control of plant resource extraction from the *kaya* forests. The elders were also involved in discussions of the management practises that were in position in the early history of the *kaya* forests. The community guards, responsible of the daily surveillance in the forests, were also interviewed on their participation as well as problems they encountered while executing their duties in the *kaya* management system and resource extraction controls.

Results and Discussion

Kaya Mtswakara

The *kaya* elders consulted for information on plant resource extraction and control for *kaya* Mtswakara were Hamisi Mwero Yawa, Mganga Chiberya and Chuphi Mwayaya. The community *kaya* guards consulted included Mwatela Chuphi and Nyae Mrisa. Additional information on traditional *kaya* management was acquired from a prominent elder, Chirapho Maganga Mgandi, before he died.

In the early history of the *kaya*, building poles were collected from the *kaya* on permission from the elders, an arrangement that did not involve any payment. Firewood collection was mainly done on the shrub-land areas outside the *kaya* and this could be on any day of the week. Only in times of need would there be firewood collections from the *kaya* forest area and these were only allowed on *Jumwa* (the fourth day of the traditional four-day calendar). Collection of both building poles and firewood was prohibited in sacred sites within the *kaya*. Defaulters were subjected to traditional fines, of magnitudes that reflected the seriousness of their offence. The traditional fine included giving an animal (sheep or bull), a black chicken, three pieces of cloth (red, white and black), about a kilogram (2 *pishi*) of *Ricinus communis* seeds and *kadzama* (a local palm brew, *mnazi*) to the council of elders. These items were used and consumed in the *kaya* in a ceremony meant to appease the spirits following the offence.

About two decades ago, the *kaya* elders from the three major Duruma *kayas* (Mtswakara, Gandini and Chonyi) reviewed the management protocols and plant resource extraction control and procedures for the three *kayas* (Mwayaya pers. comm.). Following the acute shortage of firewood in the areas outside the *kaya*, the elders decided that firewood could be collected regularly from the *kaya*, i.e. every *Jumwa*. However, only dead wood was to be collected, and therefore during the firewood collection cutting tools should not be used. There was no restriction on the size or number of head-loads each collector was allowed in every collection session. Firewood collection from sacred sites was still prohibited.

Some of the information from the *kaya* elders was not consistent with that from the *kaya* guards. The guards explained that due to acute shortage of firewood in and outside the *kaya*, coupled with bulky firewood collection for commercial purposes by some community members, collection of firewood from the *kaya* had been suspended. According to the guards, community members who wished to collect firewood had to seek permission from the *kaya* elders, and collection could only be made on a *Jumwa*. From observation, the firewood collectors visited the *kaya* for firewood collection every *Jumwa*, and while some collectors sought permission from the elders before collection, others did not.

Bulk firewood was usually required during communal ceremonies such as funerals and weddings. Collections for large amounts of firewood required during these ceremonies were also made from the *kaya*. The host families sought permission from the *kaya* elders, and the arrangement involved payment of a monetary token (*kadzama*) of Ksh. 200.00. The collectors, period of collection and site for collections were identified by the *kaya* elders, and this information was given to the *kaya* guards whom were supposed to supervise the collection.

Collection of building poles from *kaya* Mtswakara was allowed only after receiving permission from the *kaya* elders. The elders assessed the authenticity of the need before making a decision. Prospective pole collectors were supposed to pay a monetary *kadzama* to the elders, which varied depending on the amount of poles required. For a collection of poles enough to build a two-roomed house, the *kadzama* was Ksh. 200.00, and was Ksh. 400.00. for a four-roomed house. Permission for pole collection was then granted, and the collection was expected to end after a week. The guards accompanied the collector and supervised the collection to ensure that: no collections were made from sacred sites; no excess collections were made; and no collection was made after the permitted period. For both firewood and building poles, collection for commercial interests was not allowed.

Defaulters were subjected to a traditional fine of a magnitude that reflects the extent of the violation. Firewood collectors who carry/use cutting-tools were fined Ksh. 100.00. Pole collectors who did so without permission or firewood collectors on days other than *Jumwa* had to pay to the elders a sheep, a black chicken, about 1kg (2 *pishi*) of Ricinus *communis* seeds, three pieces of black cloth, and a monetary *kadzama* of Ksh. 400.00. The items were used in a cleansing ceremony to appease the spirits, and the foods were eaten during the ceremony. The money collected was shared only among the *kaya* elders. There were conflicting statements among the respondents on the circumstance of the money collected from prospective pole/firewood collectors and defaulters. Some said that the money was saved and used for cultural activities and functions, but the majority of the elders confirmed that the money was shared between the *kaya* elders and used for personal needs.

With regard to plant resource extraction and control, the *kaya* Mtswakara elders complained on the lack of enough support from some local provincial administration offices. On the other hand the *kaya* guards blamed the *kaya* elders on the inability to stop defiance in the plant resource extraction. The guards were not happy that they did not benefit from the collected monetary tokens and fines. According to the guards there were disagreement between different faction groups of *kaya* elders, which created an atmosphere of enmity and organised defiance in the extraction of plant resources, to challenge some of the reigning *kaya* elders.

Collection of building poles from the neighbouring Mwache Forest Reserve for a fee was thought by some to encourage illegal pole collection from the *kaya*, as the collectors used the permits from the Forest Reserve to defend themselves against conviction when found in the *kaya* with the poles. This was mainly because the footpath to and from the Forest Reserve crosses through the *kaya*. The hunting and trapping of small mammals and birds, which were accepted by the traditional forest management, also contributed to illegal pole collection. The hunters entered into the *kaya* forest without arousing any suspicion from the guards or elders, but then in some cases the hunters changed their mission from hunting to the collection of building poles. Unresolved disputes on *kaya* encroachment has encouraged more defaulters who expressed dissatisfaction with the *kaya* elders for prohibiting pole collection (for commercial purposes) but being unable to end the encroachment for farming.

The council of elders for *kaya* Mtswakara included two contrasting types: one group was of young and educated men, with political aspirations and administrative power on one side; and the other was of old men who demanded respect on basis of their age and traditional wisdom. The two groups seem to be involved in a struggle for power, which intensified after the death of a prominent and respected spiritual leader, Chirapho Mgandi Mganga (Mrisa pers. comm.). Members of the community affiliated themselves to the faction groups on the basis of family relationships or expected material gains. This resulted in disagreements rooted from previous unsettled defaults (*kaya* encroachment) and monetary expenditure. The disputes rooted to expenditure of monetary fees and fines were because some elders did not benefit (Chiberya pers. comm.). In comparison with the historical management practices, 'money' in the *kaya* set up was a new issue (Chuphi pers. comm.), probably introduced because of the increasing financial requirements in running the *kaya* activities. However, due to the lack of a proper code of guidance, the money is shared between elders for personal usage, as a result beneficiaries and non-beneficiaries disagree, hence the intense internal wrangles. Some elders, including the spiritual leader, complained of being excluded in the dividend. From a different perspective, a local administrator in an effort to solve the dispute, suggested that the payments of the monetary fines and fees demanded by *kaya* elders should be made in the local administration office, which would then decide on the best expenditure of the collection.

Although CFCU has in the near past played a role in quelling the feuds among faction groups, including that in which new *kaya* elders were appointed, the expenditure of the fees and fines still requires to be carefully addressed. The expenditure of collected funds needs to meet the satisfaction of the community members to avoid conflicts in *kaya* conservation. If there is no immediate solution the *kaya* elders could be advised to employ the historical traditional fee and fine, which did not include money.

Kaya Fungo

Information on *kaya* management and resource extraction control for *kaya* Fungo was sought from *kaya* elders Ishmail Katana Kajambo and Tayari Mwaringa, and from *kaya* community guards Kazungu Pius Torophe, Kazungu Mwaringa and Kahindi Katana. Additional information was recorded from some community members during the survey on collection and utilisation of building poles and firewood.

According to all the respondents, in the early history of *kaya* Fungo firewood collection was made outside the *kaya*, in the shrub-land areas neighbouring the villages. This was because of the strong fear of the calamities believed to befall on anyone who faulted the customary laws. However, due to relative scarcity, pole collections have been made from the *kaya* forest area, except from sacred sites. The prospective pole collector visited the elders who lived inside the *kaya* to seek permission. During the visit a token (*kadzama*) in the form of local palm beer (*mnazi*) was given to the elders whom discussed the issue as they drunk. When satisfied with the request, the elders identified a specific collection site, and instruct the collector to present the load of poles collected to the elders, so as to confirm that no excess poles were collected. In those historical times there were no *kaya* guards, therefore, the elders were responsible of surveillance and monitoring as well.

A defaulter was subjected to a traditional fine that included a goat, and *kadzama* (local palm brew). If the defaulter was not able to pay, he would be held captive in the *kaya* until his family/clan paid the fine. The food and drink were shared among all the community members present during the occasion. A cleansing ceremony was said to be necessary only if a collection was made from a sacred site.

Information on the existing traditional management system was characterised by inconsistency among respondents. The prevalent information among the community members and a *kaya* elder was that, at the time of the interview for this research, collection of all types of plant resources from the *kaya* had been banned. The ban was due to severe degradation of vegetation in the *kaya* following the introduction of commercially-oriented collections of firewood and building poles, and collection of wood for charcoal making. The ban was intended to give the degraded vegetation time to recover. According to the *kaya* elder, the domestic needs of the *kaya* Fungo community for plant resources were to be met by collection from the shrub-land (*fehemani*). This explanation conforms to the results in Sections 6.1 and 6.2, where building poles and firewood were collected in relatively low amounts from the *kaya*. However, according to another *kaya* elder and two *kaya* guards, only pole collection from the *kaya* had been banned, but deadwood collection for fuel was allowed in all days of the week, but no collections were allowed at the sacred sites. This was explained to be due to the shortage of firewood in the surrounding bush-land, which did not meet the demands of the local community. Firewood collectors were noted in the *kaya* during the fieldwork of this study. Exact current situation was made more complicated when the third guard explained that firewood collection was allowed every *Jumwa*, and pole collection could be made with permission from the *kaya* elders. However, there was no evidence in recent times of people who had been granted permission to collect building poles from the *kaya*.

The *kaya* elders were organising a meeting (for mid June 1999) to discuss and review the protocols in plant resource collection, so as to address the community's outcry on domestic needs especially for building poles and firewood, which were said to be scarce in the bush-land areas outside the *kaya*. The elders were aware that there were genuine demands for domestic uses but that these merged with some commercial interests of some community members, which they need to scrutinise and discourage.

In the existing traditional management system, defaulters were summoned before the *kaya* elders and were fined or acquitted depending on the magnitude of the misconduct. The traditional fine included a goat, *kadzama* (local beer) and money. The money was used for buying food. Eating and drinking was done in the *kaya*, shared between community members present. However, cases of people being arrested and fined were few, despite the frequent observations of signs of plant resource collections especially building poles, which the guards identified as being illegal. The *kaya* guards complained that *kaya* elders sometimes did not take legal action against defaulters, particularly those closely related to them. Also the guards complained of the strategies used by illegal pole collectors, who use a hand saw for cutting the poles to minimise the noise.

The guards, mostly relying on the sound from cutting to identify a collection incident, thus fail to make arrests in the dense forest where visibility is poor.

The existing traditional administration in *kaya* Fungo, like that in *kaya* Mtswakara, was subjected to conflicts between groups within the community, especially with regard to appointments of spiritual leaders. Traditionally, a spiritual leader is replaced after his death by a fully initiated community member of a different clan from that of the former spiritual leader (Torophe pers. comm.). However, the past three spiritual leaders have all been from one clan, the *Milulu*. Although this is said to be due to the lack of a fully initiated and traditionally qualified candidate in the other clans (Jembe pers. comm.) some members of the community were not happy with this trend. In addition this was preceded by unceremonious eviction of a previous spiritual leader (Simba Wanje). According to Nyamweru (1997), some community members only knew the elders of *kaya* Fungo from the power struggle that was going on. The inconsistency in information regarding plant resource collection in *kaya* Fungo reflects the absence of a common management protocol, and lack of effective communication between the traditional *kaya* managers and the rest of the community.

Although *kaya* Fungo elders had also introduced money as part of the traditional fine, the introduction was not criticised to a similar level as was in *kaya* Mtswakara. Possible this was because the money collected was used for communal expenditure and not for the benefit of a few elders.

Conclusions

The historical conception of the *kayas* as 'holy shrines' and employment of traditional governance, including mechanisms for dealing with exploitation of natural resources from the *kaya* is still in existence. However, the historical successful forest resource extraction control that used to be exercised by the *kaya* elders in the past (Spear 1978), when traditional functions and orders were respected without questioning (Mgandi pers. comm.) has not remained the same. In the past the *kaya* elders were recognised in a social structure, charged with respected and accepted roles, including law enforcement (Kajambo pers. comm.). Today, although the elders are supposed to undertake the same roles and have the same traditional responsibilities, they are not receiving the same level of respect as was the case in the past. In recent times there are few young people who are interested in the cultural initiations, in contrast to the old days when many of the youth aspired to become *kaya* elders (Hawthorne et al. 1981), even though only the few who could pay for the rituals were initiated (New 1873). It was during these initiations that cultural knowledge and the ritual activities of the tribe were passed on (Hawthorne et al. 1981), a knowledge that acted as the main 'social security' of the *kaya* elders, and which enhanced fear among the community members of the traditional spiritual powers and traditions. However, social-political changes create new demands and interests (FTPP 1999), and with time the traditional knowledge has been replaced by western education, the spiritual fear has been replaced with new religious faiths, and the traditional local rule by the Central Government System (Azevedo, 1993). Hence the increased disregard for the traditional values and the decline in respect for the elders (Robertson & Luke 1993). The traditional management system for the *kayas* has as a result weakened.

In addition, the recent modifications of traditional protocols to include money in the traditional 'token' and 'fines' has ignited internal feuds, and resulted in divisions among the community members. Thus inter-clan wrangles and differences in interests have led to various types of power struggle. As a result the traditional *kaya* management systems weaken further, in a context of internal conflicts. The *kaya* elders, therefore, are incapable of successfully managing the *kaya* forests and controlling the plant resource extraction independently. There is an urgent need for an external support.

CHAPTER SEVEN
CONCLUSIONS AND RECOMENDATIONS

7.1 INTRODUCTION

This study addressed a number of major issues concerning the *kaya* forests, the vegetation types and their relationships to possible determining ecological factors, the utilisation of forest resources by local communities, and the traditional management strategies in *kaya* conservation. A harmonious relationship between these components is important for the future conservation and management objectives of the *kaya* forests. Effective management is the immediate challenge to the managers of protected forest areas in the face of the prevailing socio-economical and political changes, some of which are perceived to be against the conservation priorities.

In this final chapter the major conclusions made in previous chapters are summarised and discussed from the perspective of conservation of *kaya* forests. Discussion of the assumptions and limitations of this study are considered, where appropriate, because of their significance to the conclusions made. Based on the major conclusions, management recommendations for the *kaya* forests are also presented.

7.2 VEGETATION AND SOILS

Vegetation survey and classification is always a compromise between the objectives of the study, the methodology and the time and resources available for this study. In this study phytosociological methods (Braun-Blanquet 1932; 1964) based on subjective sampling determined through a preliminary survey of physiognomically recognised vegetation types were used. Although there were few exceptions, most of the sample plots established in similar physiognomic vegetation types determined *a priori* were, in the resultant TWINSPAN classification analysis, grouped into similar vegetation units. Clearly, physiognomic vegetation descriptions were a useful first level of classification, despite the limitation of universal usage (Goodman 1990). There is a wide disagreement concerning the characters of physiognomic vegetation to be used, and the extent to which physiognomy should be combined with floristic composition and environment determinants (White 1983).

Subjective sampling was employed in this study. The preference for subjective sampling was based on assumption that vegetation segments, which differed physiognomically, were potential representatives of different community types. Application of random sampling was likely to miss some vegetation segments, and the classification of the vegetation types would relatively be less comprehensive, especially when the vegetation in the *kaya* forests was perceived to be both heterogeneous and disturbed.

The TWINSPAN classification denoted that *kayas* Mtswakara and Fungo have vegetation types definable by their plant species compositions. In *kaya* Mtswakara, four plant communities (*Scorodophloeus, Hugonia, Brachystegia* and *Acacia* communities) were recognised, and the vegetation was classified up to sub-community level. In *kaya* Fungo (and Mirihi-ya-kirao), three communities (*Uvariodendron, Acacia* and *Brachystegia* communities) were recognised, and the vegetation was classified up to seral stage level. The indicator species for the vegetation types were not necessarily the upperstorey dominant tree species, which were used to describe the physiognomic vegetation segments in the preliminary survey of this study, and which are commonly used to identify vegetation types (Schmidt 1991). In this study undestorey plant species were also important as indicator species of vegetation types. Climber species (*Hugonia castaneifolia*) and shrub species (*Psydrax faulknerae* and *Rytigynia celastroides*) were diagnostic species for different vegetation types in *kaya* Mtswakara. While in *kaya* Fungo, climber species (*Salacia sp.*), shrub species (*Dalbergia melanoxylon, Uvariodendron kirkii, Grandidiera boivinii*), and herbaceous species (*Chloris roxburghiana*) were diagnostic species for different vegetation types. The difference between some vegetation types (e.g. the *Ochna-Pancovia* and *Dobera loranthifolia* sub-communities in *Hugonia* community in *kaya* Mtswakara; and *Uvariodendron* and *Acacia* communities in *kaya* Fungo) were obvious even prior the TWINSPAN classification (Mueller-Dombois & Ellenberg 1974). However, for other vegetation types (e.g. *Ricinodendron* and *Commiphora-Asplenium* sub-communities in *kaya* Mtswakara; *Grandidiera* and *Uvariodendron senso stricto* sub-communities, and the three sub-stages in *Salacia* stage in *kaya* Fungo), the differences were not self-evident prior the TWINSPAN classification. The TWINSPAN analysis therefore, helped to understand phytosociological details beyond the physiognomic recognisable differences of the vegetation types. However, in *kaya* Fungo there was a vegetation type that remained undetermined, possible due to the low representation (four relevés) of the vegetation type. It would be important that more data targeted at this particular vegetation is collected so that the vegetation type can be identified. In addition, the knowledge of the forest ecology remains incomplete without the understanding of the lower plant species (the mosses and lichens) and the animal species in these forests, which were not included in this study.

Soil variation was an important factor in determining and being determined by, the vegetation dynamics in the *kaya* forests i.e. at that level of scale. The major soil division in both *kayas* was based on the base status of the soils, where the relatively nutrient rich soils were separated from the relatively nutrient poor soils. The nutrient content variation between soil types in both *kayas*, were corresponded and could be summarised using the physical characteristics, particularly the texture and colour (Tables 3.14; 3.15). This is probably because the colour of soils is determined by the nature of texture of the soil material, and the colours in the upper horizons are related to the chemical properties of the soils, particularly the organic carbon content, and Ca and Na levels (Fitzpatrick 1980). Generally high content of organic matter result in dark colours, but in presence of large amounts of Ca and Na dark colours will form even with small amounts of organic matter (Fitzpatrick 1980). The darker colours in the dense forest areas of both *kayas* therefore, were likely to be a result of both high organic matter content (Tables 4.2; 4.5) and high Ca levels (Tables 4.3; 4.6). In Fungo, low contents of iron in the luvisols and/or planosols (Fitzpatrick 1980), most likely due to movement down the profile, might be responsible of the grey colour of the sandy-loams. On contrast, the bright colours, particularly in the sandy soils of the *Brachystegia* woodland communities in both *kayas*, were likely to be due to both low levels of organic matter content (Tables 4.2; 4.5) and low Ca levels (Tables 4.3; 4.6).

Comparing the ranges and the means of soil nutrient concentrations and soil acidity (Tables 4.3; 4.6) the soils in the Mtswakara and Fungo were considerable different. The *kaya*

Mtswakara soils were relatively nutrient richer, with higher clay and carbon contents, and lower soil acidity than the *kaya* Fungo soils. In *kaya* Mtswakara the soils were also considerable more varied (pale-black and white sands, pale black and black sandy-loams) compared to *kaya* Fungo (pale-grey, pale-black and black sandy-loams), where white sands were exclusively found at *Mirihi-ya-kirao* forest patch. Soil genesis is influenced by parent material, climate, organisms, topography and time (Fitzpatrick 1980; Goodman 1990). Although each of these factors is important, locally one factor may exert a particularly strong influence (Fitzpatrick 1980). The variation in soil types between *kayas* Mtswakara and Fungo is likely to be a due to the differences in topography (Fitpatrick 1980; Goodman 1990) and their position from the shoreline (White 1983). Compared to *kaya* Fungo, *kaya* Mtswakara is closer to the shoreline which meant that the soils in *kaya* Mtswakara are younger (White 1983). In addition being on hilly terrain, the soils were continually rejuvenated such that at the elevated localities, as surface erosion removes the topsoil, the parent material enters the bottom of the rooting zone, where it weathers and releases nutrients (Whitmore 1989), and the low-lying localities are continually rejuvenated by deposition process. Also, in *kaya* Mtswakara the presence of termites, whose activities increase enrich the soils with nutrients (particularly Ca) and increase soil permeability (Burnham 1989), increased the variability in soil types in *kaya* Mtswakara, as well as the differences in soil types between *kayas* Mtswakara and Fungo.

The soils in *kaya* Fungo, being far from the shoreline, are likely to be relatively older (White 1983). And being on a flat featureless area, there were no erosional and depositional processes. The process likely to influence the soil properties in *kaya* Fungo include loss of minerals to underground soils through leaching, and mineral rejuvenating through organic matter decomposition. Over time, therefore, the soils are likely to have become relatively stable, with relatively less variation. Compared to *kaya* Mtswakara, in *kaya* Fungo the decomposition of organic matter was probably a significant mineral rejuvenating process of the soils, in which minerals are recycled between the soil and the vegetation with limited extraneous transfers (Burnham 1989), in an otherwise very infertile soils (Boxem et al 1987). Removal of the vegetation in *kaya* Fungo therefore, is likely to impair the ability of the forest to trap and cycle nutrients, and also to regenerate its canopy (Whitmore 1989). This would mean that the dense forest vegetation in *kaya* Fungo (*Uvariodendron* community) is more fragile to anthropogenically-induced disturbance, because the impacts are significantly effected to both the vegetation as well as the soil properties.

Despite the identified variation in soils within and between the *kayas* Mtswakara and Fungo in this study, it will be important that future studies consider soil profile analysis which might depict more differences in the soil types particularly in the different vegetation types identified in these *kayas*.

The soil variations in both *kayas* were to some extent related to the vegetation type, particularly the *Brachystegia* community, which was associated with the nutrient poor white sandy soils. The soils, primarily, distinguished the *Brachystegia* woodland community from the remaining vegetation types. However, the other vegetation types were not exhaustively separated along the soil gradients. The occurrence of *Acacia* community in both *kayas* was due to anthropogenic influence, namely slashing, burning, grazing and pole cutting.

Specific species (*Cynometra suaheliensis, Cynometra webberi, Ricinodendron heudelotii, Pancovia golungensis, Pycnocoma littoralis, Pandanus rabaiensis, Buxus obtusifolia, Cordia monoica* and *Dorstenia hildebrandtii*) were noted to be strongly associated with undulating terrain, recorded only in *kaya* Mtswakara; while other species (*Afzelia quanzensis, Tabernaemontana elegans, Dombeya taylorii, Excoecaria madagascariensis, Loeseneriella africana* and *Laportea lanceolata*) were more associated with the flat terrain, recorded only in *kaya* Fungo (Table 2.14). Whether the different topography, more than the soil properties, were the primary determinants of the distribution of these species in the two *kayas*, or if other historical factors were also important in the distribution, it was not immediately established.

7.3 CONSERVATION OF THE *KAYAS*

The word '*conservation*' covers a wide range of concepts, with protection of plant and animal species from any form of exploitation at one end of the spectrum to sustained utilisation while maintaining or even improving the quality of the environment at the other end (Tivy & O'Hare

1981). The latter perspective is a more popular modern conservation philosophy. The main question in conservation is how to utilise the environment and maintain particular selected values – be they ecological, biological, economic or aesthetic. The ultimate goal of conservation and management should be to maintain or even restore a functional and self-sustaining community of species where biological (including genetic) diversity is maintained through natural processes and/or managed intervention.

7.3.1 Conservation values of the *kayas*

Biological values

Different authors (Dale 1939; Moomaw 1960; Hawthorne *et al.* 1981; Hawthorne 1993; Schmidt 1991; Robertson & Luke 1993; Burgess *et al.* 1998) have detailed the general biological importance of the Kenya coastal forests, which are a representative of the endangered eastern coastal forest mosaic (Robertson & Luke 1993; Burgess 1998). Some of the plant species recorded in the Kenya coastal forests are of particular scientific interest and concern. These include species threatened in different ways and which are endangered (Table 7.1). Most of these species have a very narrow distribution, and destruction of their habitat localities could lead to ultimate extinction in the wild. *Cynometra greenwayi*, for example, has only been recorded in *kaya* Waa (a forest patch measuring about 70 ha), and in Watamu, North Coast of Kenya (Luke pers. comm.). *Keetia lukei* has only been recorded in Gongoni Forest Reserve, *kaya* Muhaka and *kaya* Jibana. And *Gigasiphon macrosiphon* has only been recorded in Mrima Forest Reserve, Marenje Forest Reserve, Gongoni Forest Reserve, *kaya* Muhaka, and Rondo Plateau in Tanzania.

Since the inception of the CFCU, intensive botanical inventories led to the publication of new species from the *kayas*, e.g. *Keetia lukei* (*kayas* Muhaka and Jibana) and *Ceoropegia konasita* (*kaya* Mudzi-Muvya). Several other plant species collected from the *kayas* are potential new species records to science, e.g. a *Cynometra* sp. from *kaya* Jibana (Luke pers. comm.). Yet the botanical inventories for the *kayas* are to date not exhaustive, thus possibilities of new records of plant species at the national and global levels are very probably.

Table 7.1: Kenya coastal forest species with different threats and conservation status levels (adapted from: Luke *et al.* (1996))

Species	Family	Threats	Status	IUCN threat category
Ancistrocladus robertsoniorum	Ancistrocladaceae	Habitat destruction	Endangered	B1 & 2c
Bauhinia mombassae	Caesalpiniaceae	Habitat destruction	Endangered	B1 & 2c
Cephalosphaera usambarensis	Myristicaceae	Habitat destruction	Critically endangered	B1 & 2e
Cynometra greenwayi	Caesalpiniaceae	Habitat destruction	Critically endangered	B1 & 2b,c, e
Diospyros shimbaensis	Ebenaceae	Habitat destruction	Endangered	B1 & 2c
Euphorbia tanaensis	Euphorbiaceae	Habitat destruction	Critically endangered	B1 & 2c; D
Euphorbia taruensis	Euphorbiaceae	Habitat destruction	Critically endangered	B1 & 2a, b, c, d
Ficus faulkneriana	Moraceae	Habitat destruction	Critically endangered	C2 a; D
Gigasiphon macrosiphon	Caesalpiniaceae	Habitat destruction	Endangered	B1 & 2a, b, c, d, e
Keetia lukei	Rubiaceae	Habitat destruction	Critically endangered	B1 & 2a, b, c, d, e
Oxyanthus pyriformis ssp. *longitubus*	Rubiaceae	Habitat destruction	Endangered	B1 & 2c
Phyllanthus sacleuxii	Euphorbiaceae	Habitat destruction	Critically endangered	B1 & 2a, b, c, d; A 1c
Synsepalum subverticillata	Sapotaceae	Habitat destruction	Endangered	B1 & 2c
Ziziphus robertsoniana	Rhamnaceae	Habitat destruction	Endangered	B1 & 2a, b, c, d, e

Although none of the above species (Table 7.1) has been recorded in the two *kayas* investigated in this study, *kayas* Mtswakara and Fungo showed a rich biological diversity with a total of 424 and 345 plant taxa respectively. Complete plant lists of the taxa recorded in Mtswakara and in Fungo are given in Appendix VII and VIII respectively. Out of these taxa, 30 in *kaya* Mtswakara (Table 7.2), and 24 in *kaya* Fungo (Table 7.3) have significant levels of rarity (Robertson & Luke 1993).

Table 7.2: Species with different rarity levels recorded in *kaya* Mtswakara

Species	Family	Rarity level
Actiniopteris radiata	Actinopteridaceae	Rare in the Kenya Coast
Uvaria faulknerae	Annonaceae	Rare in a world sense
Chlorophytum holstii	Asphodelaceae	Rare in Kenya
Cryptolepis sinensis ssp. *africana*	Asclepiadaceae	Rare in Kenya
Huernia archeri	Asclepiadaceae	Rare in a world sense
Combretum butyrosum	Combretaceae	Rare in Kenya
Bidens taylorii	Compositae	Rare in Kenya
Ipomoea shupangensis	Convolvulaceae	Rare in Kenya
Cyperus alternifolius ssp. *flabelliformis*	Cyperaceae	Rare in the Kenya Coast
Cyperus kaessneri	Cyperaceae	Rare in the Kenya Coast
Sansevieria robusta	Dracaenaceae	Rare in the Kenya Coast
Jatropha hildebrandtii var. *hildebrandtii*	Euphorbiaceae	Rare in Kenya
Ricinodendron heudelotii ssp. *africanum*	Euphorbiaceae	Rare in Kenya
Uapaca nitida	Euphorbiaceae	Rare in Kenya
Acacia etbaica ssp platycarpa	Mimosaceae	Rare in the Kenya Coast
Pseudoprosopis euryphylla ssp. *puguensis*	Mimosaceae	Rare in Kenya
Angraecum cultriforme	Orchidaceae	Rare in Kenya
Bonatea rabaiensis	Orchidaceae	Rare in Kenya
Crotalaria goodiiformis	Papilionaceae	Rare in the Kenya Coast
Crotalaria polysperma	Papilionaceae	Rare in the Kenya Coast
Adenia lindiensis	Passifloraceae	Rare in Kenya
Polygala petitiana	Polygalaceae	Rare in the Kenya Coast
Talinum caffrum	Portulacaceae	Rare in the Kenya Coast
Canthium glaucum	Rubiaceae	Rare in Kenya
Pavetta linearifolia	Rubiaceae	Rare in Kenya
Psychotria punctata	Rubiaceae	Rare in the Kenya Coast
Psydrax recurvifolia	Rubiaceae	Rare in Kenya
Haplocoelum foliolosum	Sapindaceae	Rare in the Kenya Coast
Cissus phymatocarpa	Vitaceae	Rare in a world sense
Cyphostemma buchananii	Vitaceae	Rare in the Kenya Coast

Table 7.3: Species with different rarity levels recorded in *kaya* Fungo

Species	Family	Rarity level
Psilotrichum cyathuloides	Amaranthaceae	Rare in Kenya
Ceropegia nilotica	Asclepiadaceae	Rare in Kenya
Tylophora stenoloba	Asclepiadaceae	Rare in Kenya
Commiphora campestris	Burseraceae	Rare in the Kenya Coast
Boscia sp. nr. *mossambicensis*	Capparidaceae	Rare in the Kenya Coast
Bidens pilosa	Compositae	Rare in the Kenya Coast
Erythrocephalum minus	Compositae	Rare in the Kenya Coast
Dactyloctenium giganteum	Gramineae	Rare in the Kenya Coast
Strychnos usambarensis	Loganiaceae	Rare in the Kenya Coast
Cienfugosia hildebrandtii	Malvaceae	Rare in Kenya
Hibiscus schizopetalus	Malvaceae	Rare in Kenya
Dioscoreophyllum volkensii var. *volkensii*	Menispermaceae	Rare in Kenya
Platycerium alcicorne	Polypodiaceae	Rare in Kenya
Lasiodiscus pervillei ssp. *ferrugineus*	Rhamnaceae	Rare in Kenya
Clerodendrum robustum var. *fischeri*	Verbenaceae	Rare in Kenya
Clerodendrum sansibarense	Verbenaceae	Rare in Kenya
Ipomoea shupangensis	Convolvulaceae	Rare in Kenya
Sansevieria robusta	Dracaenaceae	Rare in the Kenya Coast
Bonatea rabaiensis	Orchidaceae	Rare in Kenya
Pavetta linearifolia	Rubiaceae	Rare in Kenya
Psydrax recurvifolia	Rubiaceae	Rare in Kenya
Haplocoelum foliolosum	Sapindaceae	Rare in the Kenya Coast
Cissus phymatocarpa	Vitaceae	Rare in the World
Cyphostemma buchananii	Vitaceae	Rare in the Kenya Coast

In addition to these plant taxa (shown in Tables 7.2 and 7.3), other taxa which have a broader distribution but which are exclusively found in dense forest and the woodland vegetation types are also justifiable termed locally rare. This is because these vegetation types (dense forest and *Brachystegia* woodland) are continually cleared and converted to cultivated land (Boxem *et al.* 1987). As these dense forests and woodland vegetation areas are becoming fragmented, many species become localised in the *kayas* and other protected forest areas, and become locally rare. Generally, at the Kenya Coast, the structure and floristic composition of forest vegetation are affected, and continual replaced by secondary shrub-land through clearing for farming (Boxem et al 1987), plant resource extraction (Hawthorne 1983, Schmidt 1991), metal and stone mining, and expansion of tourists centres on the prime beach areas (White 1983, Robertson & Luke 1993). In this study, it was noted that the area covered by the dense forest community types in *kayas* Mtswakara and Fungo was reducing. With continued reducing size of the vegetation types, possibilities of the population of some affected species dropping below viable levels in the two (and other) *kayas* is likely, hence local extinctions.

Ethnobotanical values

It is evident from the ethnobotanical information recorded in this study and in previous studies (Schmidt 1991; Beentje 1994) that the *Midzichenda* depended and probably will continue to depend for the immediate future, on wild plants for most of their material requirements. The dependence of the *Midzichenda* communities on their natural environment is typical of a pre-industrial society. Some uses of plants are linked to cultural factors such as magical beliefs, superstition, myths, taboos, and religion; while other uses such as weaving, crafting, construction, timber and foods, are fairly universal basic requirements. The ethnobotanical value of the *kayas*, therefore, is fundamental to, and hardly separable from, the lives of the *Midzichenda* communities. In Chapter Five 321 taxa were identified to be of ethnobotanical value to the Duruma and Giriama communities living around the *kayas* forests. Most of these species have been known to be commonly available outside the *kayas* in the past, but with time the distribution of most of these species is becoming localised to the *kayas* only (interviewee 2007). The effects of the species localisation and increased rarity include over-exploitation of the target species which is likely to enhance degradation of the *kaya* forest areas. This is in addition to affecting the customary life styles and shortage to meeting requirements, including basic needs, of the a people whose socio-cultural life is strongly attached to the *kayas*.

Some species were used for more than one purpose e.g. *Dalbergia melanoxylon* (used for construction and for medicinal purpose), and other species were used for the same purpose (e.g. *Milletia usaramensis* and *Combretum illairii* are both used for making fish-traps). Details of the uses illustrate that some of the ethnobotanical uses are shared among the *Midzichenda* ethnic groups, as well as between the *Midzichenda* and other ethnic groups at a regional level (see Chapter Five). It is evident, therefore, that although the *Midzichenda* tribal groups share a common history and origin (Spear 1978), the present status of their linguistics, plant utilisation values and preferences placed on particular plant taxa has some degree of dissimilarity and divergence. It would be interesting for future research work to address both the linguistic and utilisation differences across all the *Midzichenda* tribal groups, to establish comprehensive and comparable ethnobotanical information for all the tribes of the Kenya coast.

Historical and cultural values

The *kayas*, being a cultural and natural heritage, could be described as priceless and irreplaceable possessions of the *Midzichenda* community. The loss of *kayas*, through degradation or clearance constitutes not only the disappearance of considerable biodiversity (Robertson & Luke 1993) but also the significant impoverishment of the culture of a people. To date the *kayas* are still utilised for their cultural values (Plates 7.1 and 7.2), and form the main icons for the *Midzichenda* tribal and historical identities (Spear 1978). The continued cultural practices related to the *kayas* have been partly responsible for the existing strong protest by some local communities against the destruction of these forests. The *kaya* forests provide the strong historical bridges for the *Midzichenda*, explaining both the individual tribal histories and, perhaps more importantly, the relationship between the different tribal groups (Spear 1978; Willis 1990). The *kayas* are one of the major remaining assets for the further study of the history and culture of the *Midzichenda* community, and such study is of great importance because much of the historical and cultural information is missing or not clearly known (Helm pers. comm.).

In addition to the biological, ethnobotanical and cultural diversity of the *kaya* forests, which provide good reasons to consider special conservation measures, it is also important to recognise that these forests play an important role as water catchment areas. This function is particularly important in the *kaya* areas where, due to persistent dry conditions, water availability is a serious resource problem (Nyamweru 1997).

7.3.2 Threats facing the *kayas*

Social change

A considerable threat from within the *Midzichenda* societies to the conservation values of the *kayas* is social change (Hawthorne *et al.* 1981) and in particular the deteriorating respect for the *kaya* elders. Social-change in modern times is inevitable, and it would be wrong to imagine the *kayas* have ever been either ethnologically or botanically static. However, the rate of change has undoubtedly increased over the last one hundred years (Hawthorne *et al.* 1981). Hawthorne *et al.* (1981) noted that lack of respect for elders has gone hand in hand with increased destruction of the *kayas* and such internal threats must be considered independently for each *kaya* if they are to be effectively conserved.

In this study it was noted that respect to *kayas* as holy shrines and to *kaya* elders as the custodians of those shrines, was relatively higher in *kaya* Fungo compared to *kaya* Mtswakara. In particular, the plant resource collectors in *kaya* Mtswakara frequently disrespected the existing traditional control system, especially the community members (mainly the youth) engaged in trade on building poles. Although pole collection and trade in building poles were also noted in *kaya* Fungo, it was less intensive compared to *kaya* Mtswakara. In addition to confirming this aspect (disrespect of *kaya* elders), internal power wrangles between different faction groups that were demanding recognition in *kaya* management was also noted. The 'younger' generation in *kaya* Mtswakara contested strongly for power over the management of the *kayas*, challenging the weakness of the 'older' generation, particularly in dealing with the social-change. In *kaya* Fungo, the wrangles were at a clan level, where each clan contested for the spiritual leadership of the *kaya*. These wrangles, if not addressed immediately, are only likely to enhance conflicts that might see the *kayas* deteriorating further.

External threats

As noted previously other external threats facing the *kayas* are development activities such as metal mining (Iron ore in *kaya* Jibana, Titanium in Dzombo), sandstone mining (in *kaya* Waa), sand mining (in *kaya* Mudzi-muvya) and tourism industry e.g. *Chale, Tiwi, Diani, Ukunda, Timbwa, Gonja.*

Timber extraction and the kaya forests

Overexploitation of plant resources can lead to an increasing loss and fragmentation of natural vegetation (Osborn 1997). To assess the relationships between resource use and *kaya* forest ecology, plant species utilisation for building poles and firewood were chosen for investigation in detail (Chapter Six). The relative abundance of harvestable poles of the most utilised and/or most preferred plant species for building poles around *kaya* Mtswakara (Table 7.4) shows that *Manilkara sulcata, Terminalia spinosa* and *Combretum schumannii* were utilised extensively but occurred in low densities in the *kaya* forest. For comparison, *Manilkara sansibarensis, Canthium mombazense, Pycnocoma littoralis* and *Ophrypetalum odoratum* (not shown in Table 7.4) were less utilised but occurred in high densities. The most used and/or most preferred species (Table 7.5) occurred mainly in the dense forest vegetation *Asteranthe* community group, either in one or both the *Scorodophloeus* and the *Hugonia* communities.

Table 7.4: Selected plant species used for building poles, their utilisation (%) in homesteads (n=100), preference levels, harvestable pole availability in the *kaya*, and the vegetation units in which were recorded most (data from *kaya* Mtswakara)

Species	Percentage utilisation	Preference level	Density of Harvestable poles	Vegetation unit most recorded
Cynometra suaheliensis	66	High	High	Asteranthe community group
Manilkara sulcata	55	High	Low	Asteranthe community group
Terminalia spinosa	55	High	Low	Acacia community
Scorodophloeus fischeri	47	High	High	Scorodophloeus community
Grewia plagiophylla	46	Moderate	High	Acacia community
Diospyros consolatae	37	High	High	Hugonia/Brachystegia community
Croton pseudopulchellus	36	High	High	Asteranthe community group
Canthium mombazense	26	Moderate	High	Hugonia/Brachystegia community

The high densities of some of the most preferred species in *kaya* (e.g. *Cynometra suaheliensis*) contrasted the complaints of unsatisfied demands for building poles from most of the respondents. In the presence of this 'unsatisfied' demand together with the potential to supply (high harvestable pole densities of 'best' species), meant that the dense forest vegetation in *kaya* Mtswakara was vulnerable and threatened by exploitation, particularly pole cutting once the *kaya* became free of the traditional controls.

The relative abundance of harvestable poles of the most utilised and/or most preferred plant species for building poles around Fungo (Table 7.5) shows that *Dombeya taylorii* was utilised extensively but in the *kaya* forest the species had low densities of harvestable poles. While *Cola minor, Ophrypetalum odoratum, Julbernardia magnistipulata, Grewia densa, Lamprothamnus zanguebaricus, Psydrax faulknerae* and *Canthium mombazense* (not shown in Table 7.2) had high densities of harvestable poles in the *kaya* forest, and they were not utilised extensively. Although the most used and/or most preferred species for building poles were recorded in *Acacia* community (Table 7.5), higher densities of harvestable poles were recorded in the dense forest *Uvariodendron* community (see also Table 6.48). The dense forest *Uvariodendron* community and the *Acacia* community are, therefore, likely to be affected by increased intensities of pole cutting.

The fragmentation of the forest vegetated areas has significant negative impact on their ecological functionality and long-term sustainability (Osborn 1997). The effects of fragmentation and anthropogenic gap creation can include an increase in generalist and alien species which displace pioneer (indigenous) species within a vegetation unit (Osborn 1997). Thus signals of indigenous vegetation transformation can be predicted through invasion by competitive (particularly alien) species. The species *Lantana camara, Thespesia danis, Thevetia peruviana,* and *Opuntia vulgaris* were recorded in the *kayas* in this study. These introductions represent a threat to the native plant populations, because these invasive plant species are capable of spreading rapidly, and to indigenous vegetation types by changing the spatial and temporal vegetation dynamics and reducing biodiversity (Patrick 1998). Rare, endemic and/or ethnobotanically important species may be lost in such vegetation transformation and alien species invasion processes, which can lead to local extinctions of such indigenous species. The vulnerability of the dense canopy forest community types, which are relatively richer in the plant species used for building poles (Section 6.4), can be appreciated in the rarity of these vegetation types in the farmland areas surrounding the *kayas*.

Table 7.5: Selected plant species used for building poles, their utilisation (%) in homesteads (n=60), preference levels, harvestable pole availability in the *kaya*, and the vegetation units in which were recorded most (data from Fungo)

Species	Percentage Utilisation	Preference level	Density of harvestable pole	Vegetation unit recorded most
Grewia plagiophylla	88.3	High	High	Wet/dry vegetation
Acacia robusta	75	Moderate	High	Acacia community
Thespesia danis	58.3	Moderate	High	Acacia community
Terminalia spinosa	55	High	High	Acacia community
Croton talaeporos	50	Low	High	Acacia community
Acacia reficiens	21.7	Moderate	High	Acacia community
Dombeya taylorii	21.7	High	Low	Uvariodendron community
Dalbergia melanoxylon	21.7	High	High	Acacia community
Croton pseudopulchellus	18.3	High	High	Uvariodendron community
Combretum schumannii	11.7	High	High	Uvariodendron community
Manilkara sulcata	6.7	High	Low	Uvariodendron community

Although invasions by specific known alien species recorded in the current study were not at alarming levels, the necessity to avoid threatening levels of these invasive species is clear. In addition, from field observations and from indigenous historical knowledge, it was noted that the *Acacia* vegetation types in Mtswakara and Fungo were relatively 'alien' to the *kaya* areas (Chapter Four). However, it was not established for how long these vegetation types have been part of the overall *kaya* vegetation, and how rapidly they have spread and replaced the dense canopy forest community types. The dynamics of vegetation change requires further investigation.

Although Bazzaz (1996) noted that patches of anthropogenically-changed vegetation within a region could eventually converge in species composition to the original vegetation if allowed enough time without disturbance, this might not be true for the *Acacia* community, particularly in *kaya* Fungo. The *Acacia* community in *kaya* Fungo, most likely derived through slashing, burning and grazing in the *Uvariodendron* dense forest community, was considerably a stable vegetation type (i.e. not under going any rapid or directional change). The development of *Acacia* community in *kaya* Fungo was not likely to be reversible to change (back) into the presumed (based on field observation data and historical information) original vegetation type, the *Uvariodendron* community. It may be proposed that in the human disturbance of the original forest vegetation structure significant changes in the soil (White 1983) has resulted in the establishment of a new edaphically-determined vegetation type. This argument, however, was not investigated in the current study, and thus the conclusion for the persistence of the *Acacia* communities is a speculation. However, it is interesting to note that according to White (1983) the *Brachystegia* community develops following persistent clearing and burning activities that in the long-term have impoverished the soil fertility to levels that no other vegetation type can develop. Certainly, this study gives clear support to the 'edaphic climax' status of *Brachystegia* vegetation in the two *kayas*. Human activities, particularly burning and clearing and perhaps relatively low levels of disturbance such as resource harvesting, may become agents of the vegetation transformation through indirect changes to soils. Thus, if the language of equilibrium states is used, when plant communities are changed by stressors to beyond their normal amplitude they do not have the resilience to return to the previous natural state (Hobbs 1999).

7.4 MANAGEMENT OF THE *KAYAS*

Clearly, conservation management initiatives suggested by this study should aim at minimising degradation of the remaining vegetation types especially the closed canopy forest communities in both *kayas*. The actual and potential threats to the dense canopy forest were mainly as a result of slash and burn to achieve cleared areas for cultivation and grazing, and excessive extraction of plant resources. Conservation management initiatives based on ecological principles need to be implemented in the context of the existing cultural, socio-economic, and political conditions at the local, national and regional scales. Various conservation management issues are considered below particularly those of importance at the local scale.

Plant resource extraction

From an historical perspective, the utilisation of plant resources in the *kaya* forests is not new, and such current utilisation may be inevitable in the present socio-economical conditions. However, as human needs and numbers increase, conflicts between the interests of local communities and priorities for conservation arise (Aumeeruddy-Thomas, Saigal, Kapoor & Cunningham 1999), which often can lead to increased degradation of the indigenous vegetation. Although it might be wrong to imagine that the *kayas* have since time immemorial remained floristically static, the current vegetation transformation rates, most of which are due to human factors, have undoubtedly increased to a level that threatens the *kayas* indigenous vegetation (Hawthorne et al 1981). In order to plan for the sustainable use of woody species, it will be necessary to understand the dynamics of the supply and demand (Patrick 1998), so as to create a balance between the protection of the *kayas* and their use to provide products and services needed by the people.

The assumption that in the *kaya* forests resource extraction can be regulated entirely by the traditional system is, currently, an unrealistic position. Socio-economic forces operating now are very different from those that operated in passed times, and economic incentives can result in opportunistic harvesting of scarce resources without any regard for their management (Cunningham 1994). Traditional and modern (scientific) management thinking should, therefore, form a joint basis for natural resource management (Pollett & Mander 1994) and thus the conservation of the *kaya* forests.

The use of natural resources by local people must occur within the ecological carrying capacity of the local ecosystem(s) (Patrick 1998). In Chapter Six the demands for building poles and firewood were noted to be very high, reliance on plant species for these resources was in over 90% of the homesteads, and these basic needs were met with difficulty by most of them. Informal trade in building poles, timber planks, firewood, charcoal, craft-work, domestic tools, edible fruits, medicinal plants, and toothbrush sticks, is being practised by the community members living around the *kayas* in an effort to alleviate their economic poverty. These resources are gathered in the rural (*kaya*) areas and sold at both local villages and main urban centres (where the majority of the collected materials were sold), in a house to house trade carried out mainly by female members of the community. Although the specific sources of these plant resources, the quantities sold and the economic contribution in the society still require more investigation, there would seem to be a strong need that *kaya* management policies stop plant resource extraction from the *kaya* forests for commercial purposes. Alternatives are available such sisal and mangrove species for poles, but these have problems of availability and cost. Also using mangrove species may move the conservation problems from one ecosystem to another.

For the *kaya* forests, there are no data detailing sustainable harvesting rates for either specific plant resources or for specific plant species. Management strategies in sustainable harvesting of plant resources, therefore, need to be based on the known effects that plant extraction processes have on different vegetation types.

The conservation problems created by plant resource extraction would be best addressed by reducing the collections of plant resources from the *kayas*. One solution is through the expansion of the ongoing CFCU/FD forestry programme, as farmers develop their own wood-lots, and provide a resource-buffering effect for the *kaya* forests. Fast growing plant species important for building and for firewood need to be available to the farmers, with the necessary education in plant domestication and care. It could be important to involve the local administration so as to publicise and encourage the farmers on the idea of agroforestry, which is relatively new to most of the local farmers. Potential agroforestry species for these coastal areas of Kenya include *Casuarina equisitifolia, Eucalyptus sp.*, *Markhamia lutea, Cassia siamea* and *Cassia spectabilis* (Kibugi pers. comm.).

Improving services such as electricity provision to households is also likely to reduce dependency on wood resources like firewood. However, this is likely to be a long-term strategy as many families in the study area were noted to be unable to afford these services at the present. There was no families among the *kaya* Mtswakara or Fungo communities that had access to electricity, or any future plans to use this facility. The communities, therefore, were totally dependent on the natural resources for fuel energy. There was a very small utilisation rate of paraffin as an alternative fuel, but exclusively used by the relatively 'rich' families.

Grazing

Livestock farming is common around both *kayas*, and grazing inside the *kaya* areas was noted. It would seem not to be against the traditional conservation system for the communities to graze the outskirts of the *kayas*, however, it was not known to what extent, and for how long, parts of the *kayas* have been subjected to grazing. In addition to direct grazing and browsing, domestic animals cause physical disturbance that creates suitable conditions for wild bush-fires, which may have even more severe effects on the vegetation. A solution to the grazing problem would be to assist the farmers to create their own fodder banks, through practising agroforestry farming (Patrick 1998), where livestock fodder species such as *Lucina lucosifala* (Kibugi pers. comm.) are grown. The most effective method of protecting the *kaya* areas from grazing livestock would have been fencing, particularly certain sections that the animals use for access into and across the *kaya*. However, the costs of fencing and the likelihood of vandalism render this method uneconomical to the neighbouring farmers, and the method needs more deliberation to perhaps obtain outside funding through CFCU.

Wildfires

Wildfires are a sudden and unselective process that in the long term may promote uniformity of floristic composition (Mitchell 1995), and can be particularly damaging to the soil seed bank of some plant species (Ausden & Treweek 1995; Oates 1992). Since fire is not a natural phenomenon in *kayas*, it should be completely prevented. To prevent burning in *kayas*, it would require a strategic management intervention, like creation of a buffer zone area (firebreak) around the outskirts of the *kaya*. This will also require to be complemented by introduction of effective and strict disciplinary or legal actions against people who start fires deliberately within the *kaya* boundaries.

Ecological monitoring

The formulation of management initiatives and kaya-specific management plans for both vegetation types and specific plant species (both desirable and invasive), should be associated with structured monitoring programmes. During the current study small populations of rare species such as *Huernia archeri* and *Platycerium alcicorne* were noted as well as the alien invasive species discussed above. Detailed ecological work must be directed to safeguard against loss of scientific interest and to detect and predict change at an early stage so that management regimes can be applied or changed accordingly (Mitchell 1995).

Vegetation monitoring through temporal sampling requires consistency in the sampling methodology to minimise observer bias and to ensure that differences are the result of vegetation change and not anomalies in methods (Westfall, Van Stader, Panagos, Breytenbah & Greef 1996). Vegetation can be monitored by using key species or by re-sampling fixed areas (quadrats). Key species can be monitored to detect population changes (Patrick 1998) where such key species are species that can help monitor change in plant communities as a whole or are species which management specifically aims to maintain, remove or promote; such species can be utilised species, invasive species or rare species. To determine a wider range of changes including those to soils and other environmental variables the re-sampling of permanent fixed plots is necessary (Westfall *et al.* 1996), such as the 10m x 20m plots set up in this study, and this must be regarded a long-term programme (Patrick 1998). However, such ecological monitoring can be extremely time consuming, labour intensive and generally difficult to conduct (Mitchell 1995). Other approaches to regular monitoring (surveillance), using relatively more rapid and simple techniques are possible. These include: fixed -point photography sites; counts of individuals in defined size classes; and estimations of the presence/absence of key species. Such techniques may be appropriate in many situations where work has to be conducted by non-specialists (Mitchell 1995).

Social-economic monitoring

Monitoring of the people's perceptions and attitudes towards conserved areas provide valuable information regarding the effectiveness of management interventions (Patrick 1998). Therefore, in addition to biological monitoring, the utilisation of the *kayas* by the local communities' and their general involvement with and perceptions of, *kaya* conservation strategies need to be periodically assessed to provide feedback on management activities which may need immediate modification. For the monitoring to be effective it should be conducted regularly and accurately, and it should be repeatable by different workers and be flexible enough to accommodate changes to the management programme (Goldsmith 1991). Local people should be involved in the monitoring of their environment especially as many environmental impacts are erratic and visible for short periods of time, and therefore can only be detected by local people (Patrick 1998). This thesis can contribute to the formulation of such monitoring as it provides both baseline vegetation (from fixed plots) and social data for *kayas* Mtswakara and Fungo.

Environmental education

For effective conservation and management activities, environmental education is important in increasing the awareness of the ecological processes that maintain natural resources (Patrick 1998). There is an ongoing environmental education programme run by CFCU and this needs to introduce new ideas to the local people who are faced with a changing environment and changing social-conditions. It has become clear that there is a need for an enlightened community that participates in the conservation of protected areas. Environmental education, therefore, need to target the empowering of local management committees for the *kaya* forests, so that they can have a reasonable understanding of the *kaya* conservation strategies, especially the natural resource management, from both a cultural and a scientific perspective. The key to the success of this is that it must always complement traditional views of conservation practice.

Institutional links and local capacity building

As indicated by the historical information (Spear 1978), the concept of conservation is not new for the *kayas*. There is evidence that these forests were inhabited and protected as early as the 8th century (Willis 1996). The modern conservation in the *kayas* started only in the late 20th century, after identification of the cultural values, biological wealth and threats facing the *kayas* (Robertson & Luke 1993). Although the respect to the *ngambi* has been noted to be growing relatively weaker over time (Spear 1978; Robertson & Luke 1993), the traditional resource control system for the *kaya* communities still forms the starting point towards a successful management practice. It is probably true to say that there is an international consensus that the implementation of 'sustainable management' should be based on local solutions derived from community initiatives (Leach *et al.* 1997). Thus, for conservation agencies to gain popular support from the local community, the concept of the inclusion of 'community based natural resource management' needs to be effected (Patrick 1998). The challenge for natural resource managers today is the merging of the traditional and the formal institutions (Gombya-Ssembajjwe 1997). Reviews by several researchers have shown that many forestry projects have failed because the managers had ignored the social aspects of local traditional institutions governing the local forests (Gombya-Ssembajjwe 1997). According to Gombya-Ssembajjwe (1997) local institutions can be both learned from and built on. Some institutions may be effective and strong without any outside support, while others may be weak and may benefit from outside influence.

Like many other African peoples, the dependence of the *Midzichenda* on their environment and its management is governed by cultural factors such as magical beliefs, superstition, myths and taboos. In these indigenous management systems, culture plays an important role in people's decisions and behaviour, and are not based on modern knowledge and scientific thinking (Gombya-Ssembajjwe 1997). However, although for the *kayas* the traditional institutions have been in existence for centuries, they are currently facing increasing threats from social-change, and becoming weaker as a result. Thus, initiatives meant to revive the cultural and traditional practices in favour of conservation e.g. the traditional ceremonies, could play a significant role towards continued *kaya* conservation.

The *kayas* are, in practice, community property, owned by no one, with resources that are accessible to everyone. Due to social change and changes in priorities, some people around the *kayas* were noted to use the resources opportunistically. In order to foster sound practices, and encourage only genuine and sustainable plant resource extraction, the *kaya* elders need to be assisted to acquire the lost powers to implement appropriate management strategies (or be augmented in a way that they can achieve their traditional role). Rules concerning access and use of the resources in the *kayas* need to be re-introduced, possibly after a review which seeks to meet the recent social changes. The penalties against defaulters need to be stipulated and applied without discrimination. For this to be realistic, the *kaya* elders, who are the key stakeholders will require support facilitated by outside conservation agencies such as CFCU, local administrative and political authorities, and other government departments like the Forest Department. A wider participation and interactive management of the *kayas*, therefore, is inevitable as the different players would share perspectives on a problem situation, consider divergent interests, identify possible solutions and ultimately agree on an action plan. In this process a platform thinking (Rölling 1994) is established, which is a social process for conflict resolution, for negotiation, for institutional and leadership development, and for empowerment programmes (Patrick 1998). The use of platform thinking is vital if policy making, management, extension programmes and social interventions in the use of natural resources are to be effective, particularly in the long term (Patrick 1998). According to Rölling (1994), we have in the present times entered an era in which agreement between people, and resource use negotiation, have lead roles to play in building the capacity for people to manage their natural environments.

The long-term future of the conservation of the *kayas* depends on the strong partnership between culture, utilisation, conservation and development. If any of these are compromised, the future may be bleak. Since the traditional and customary management systems of the *kaya* forests have been noted to have limitations especially in the control of resource extraction, this calls for a joint management system between the conservation department, CFCU, and the *kaya* elders. In the first instance, a small number of selected *kayas* could each form a Joint Management System (JMS) which has been successful in Indian conservation areas (Aumeeruddy-Thomas *et al.* 1999). The various parties would consult and discuss effective management and control systems that suit local conditions, demands and practices, as well as ecological aspects and conservational priorities.

Other considerations

Gender relations are important considerations for environmental sustainability in general. Empowering women can contribute to social sustainability, which in turn can contribute to environment sustainability (Goodland 1995). In the current study women were identified as the main collectors and users of firewood, a plant resource that is in daily demand and has the greatest bulk than any other plant resource used in the rural areas. The problems involving firewood scarcity directly affect women. Therefore, solutions for these problems need to be addressed jointly with women, whom from a cultural perspective are weak and voiceless in the male-dominated cultures and customs. Although most activities in farming are done by women (Hawthorne *et al.* 1981; Nyamweru 1997), in this study it was noted that the small number of agroforestry tree species domesticated were mostly intended for building poles (used by men), and none were grown specifically for firewood. Fast growing plant species important for firewood need to be supplied to the women, whom need to be empowered to make and take decisions on such issues which particularly affect them. The agroforestry plant species which could be important for firewood include *Eucalyptus sp.*, *Cassia siamea*, and *Cassia spectabilis* (Kibugi pers. comm.).

Further research work

The phytosociological work described in Chapter Two provides for the first time a comprehensive overview of the vegetation of the two *kayas* studied. Since the principal applicability of the Braun-Blanquet method (Braun-Blanquet 1964) is the description of vegetation at national scales, it is clear that similar studies of the other *kayas* could use the same methodology and extend the database needed for sound conservation management of these forest patches. By using the Braun-Blanquet approach for the description of vegetation types, a degree of comparability between *kayas* can be achieved, which might not be accomplished using non-hierarchical methods. The considerable variation between the vegetation types identified in the Shimba Hills (Schmidt, 1991) and those identified in *kayas* Mtswakara and Fungo in this work, is evidence that there are possibilities of identifying other different and important vegetation types with different ecological values in other *kayas*. The hierarchical classification results provided in Schmidt (1991) and in this thesis might serve as a basic structural guideline for future phytosociological analysis. Vegetation description must serve as the basis from which effective conservation management programmes for the *kayas* are formulated.

For successful management of rare and other biologically important species, the autecology of selected species, particularly information on recruitment and propagation, need to be clearly understood. The CFCU plant nursery facility at the Ukunda office could be of great use for more formal research initiatives that generate data useful for conservation managers through selection of the most appropriate techniques in species management techniques.

The results in this study suggest that practical steps towards sustainable utilisation rather than over-exploitation are possible and that strategies combining ecological values, such as the maintenance of biological diversity, with socio-economic benefits, can be implemented. However, the details of successful approaches towards these strategies were not made in this study, but the traditional management systems are believed to be the best starting point for successful conservation strategies. Research work entailing the identification and documentation of the existing local institutions and management practices for each *kaya*, could help in understanding and addressing the problems within these traditional systems. This can also guide the conservation agencies (such as CFCU) in policy formulation and the achievement of the goal of a successful fusion of the traditional and the scientific approaches to conservation.

Plate 7.1: *Kaya* Fungo elders conducting a rain-prayers ceremony, following signs of failure of the long rains. (Photo taken in 1995)

Plate 7.2: *Kaya* Rabai elders conduct a thanks-giving ceremony after a good harvesting (Photo taken in 1996)

INTERVIEWEES CITED IN THE TEXT
(Arranged in ascending order of serial numbers)

Number of Interviewee	Gender	Age group	Religion	Village	Kaya
1001	Male	Mid-aged	Christian	Fulugani	Mtswakara
1003	Male	Old	Practicing traditional beliefs	Fulugani	Mtswakara
1006	Male	Old	Christian. Was the village chairman	Fulugani	Mtswakara
1037	Male	Old	Christian	Bopo-ra-peku	Mtswakara
2007	Male	Mid-aged	Practicing traditional beliefs	Gandini	Fungo
2018	Male	Old	Muslim	Gogo-re-ruhe	Fungo
2008	Male	Mid-aged	Christian	Gandini	Fungo
2026	Male	Mid-aged	Practicing traditional beliefs	Gogo-re-ruhe	Fungo
2027	Male	Very old	Muslim	Gogo-re-ruhe	Fungo
2048	Male	Old	Christian	Ndzoweni	Fungo
2049	Female	Old	Christian	Ndzoweni	Fungo
2052	Male	Mid-aged	Christian	Ndzoweni	Fungo
2053	Male	Old	Christian	Ndzoweni	Fungo
3004	Female	Very old	Practicing traditional beliefs	Ziyani	Mtswakara
3016	Female	Old	Muslim	Chigojoni	Mtswakara
3055	Female	Old	Christian	Majengo	Mtswakara
4023	Female	Old	Muslim	Gotani	Mtswakara
4054	Female	Old	Practicing traditional beliefs	Gogo-re-ruhe	Fungo
4058	Female	Old	Practicing traditional beliefs	Gogo-re-ruhe	Fungo
4065	Female	Mid-aged	Christian	Mnyndzeni	Fungo
4067	Female	Mid-aged	Christian	Miyani	Fungo
4083	Female	Mid-aged	Christian	Ndzoweni	Fungo
4089	Female	Mid-aged	Christian	Ndzoweni	Fungo

PERSONAL COMMUNICATION CITED IN THIS THESIS

(Arranged in alphabetic order of the surnames)

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Abdallah Bega **Alluwi** – *Kaya* elder for *kaya* Mrima

Tsuma Kagumba **Befukwe** – Was a *kaya* elder and spiritual leader for Rabai *kayas* (passed away in 1998)

Mganga **Chiberya** – *Kaya* elder for *kaya* Mtswakara

Mwatela **Chuphi** – Was a community *kaya* guard for *kaya* Mtswakara (replaced during a conflict resolution)

Sidi **Chondo** – A native female member of the community near *kaya* Fungo

Prof. Fred **Ellery** – Lecturer, School of Life and Environmental Sciences, University of Natal (South Africa).

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Abdallah **Mnyendze** – *Kaya* elder and spiritual leader for *kaya* Kinondo

Fatuma Ali **Mramba** – A local community member met collecting firewood at Mwache Forest Mazeras, Kenya.

Nyae **Mrisa** – Was a community *kaya* guard for *kaya* Mtswakara (replaced during a conflict resolution)

Kavila **Mtaveta** – A local smiths at Gogorenhe near *kaya* Fungo

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Chuphi **Mwayaya** – Was a *kaya* elder for *kaya* Mtswakara (was replaced in a conflict resolution)

Zandra **Smeda** – Technical staff at the Cedera soil laboratories, Pietmaritzberg, South Africa

Kazungu **Torophe** – Community *kaya* guard for *kaya* Fungo

Chritine **Umazi** – A community member met collecting firewood at Mwache Forest Reserve. Mazeras, Kenya

Mwero **Yawa** – Chairman of the elders committees for *kayas* Mtswakara, Gandini and Chonyi (Kwale).

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