

**SYSTEMATIC REVISION OF *PTERIS* L. IN TROPICAL
AFRICA AND ECOLOGY OF FERNS AND LYCOPHYTES
IN LOWLAND TROPICAL RAINFORESTS**

Dissertation

Zur

Erlangung des akademischen Grades

eines

Doktors der Naturwissenschaft

des

Fachbereich 3: Mathematik/Naturwissenschaften

der

Universität Koblenz-Landau

Germany

October 2012

Peris Wangari Kamau

Referent: Prof. Dr. Eberhard Fischer

Korreferent: Prof. Dr. Maximilian Weigend

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LIST OF ACRONYMS

B.J.B.B	Bulletin du Jardin Botanique de l'Etat, Bruxelles; Bulletin du Jardin Botanique Nationale de Belgique
BFP	Budongo Forest Project
BFR	Budongo Forest Reserve
BIOTA	Biodiversity Monitoring Transect Analysis in Africa
BRAHMS	Botanical Research And Herbarium Management Systems
C.F.A	Conspectus Florae Angolensis
DRC	Democratic Republic of Congo
E.J	Botanische Jahrbucher fur Systematik, Pflanzengeschichte und Pflanzenreich
EA	East African Herbarium
EANHS	East African Natural History Society
F.T.E.A	Flora of Tropical East Africa
F.W.T.A	Flora of West Tropical Africa
F.Z	Flora Zambesiaca
GIS	Geographical Information Systems
ICE	Incidence Coverage Estimator
I.F.A.N	Institut Francois d'Afrique Noire
J.B	Journal of Botany
K.B	Kew Bulletin
KIFCON	Kenya Indigenous Forest Conservation Programme
NBG	Nairobi Botanic Garden
NMK	National Museums of Kenya
OTU	Operational Taxonomic Unit
P.O.A	Die Pflanzenwelt Ost- Afrikas und der Nachbargebiete
PAUP	Phylogenetic Analysis Using Parsimony
SABONET	Southern African Botanical Diversity Network
U.K.W.F	Upland Kenya Wild Flowers
U.O.P.Z	Useful and Ornamental Plants in Zanzibar and Pemba
UPGMA	Unweighted Pair Group Average
V.E	Die Vegetation der Erde, IX, Pflanzenwelt Afrikas

SUMMARY

Pteris L. (Pteridaceae) is large genus occupying a variety of ecological niches and represented by approximately 280 species globally. To-date, taxonomic revision has not been done for the ca. 27 species of tropical Africa, making identification and specific delimitation difficult. This study was designed to review the taxonomy of the genus *Pteris* in tropical Africa using morphological characters and biogeographical information.

The historical taxonomic treatment of *Pteris* was established through published and grey literature review. Type specimens as well as other voucher specimens from various herbaria were studied to gather variety of information. To understand the morphological diversity in *Pteris*, specimens from National Botanic Garden of Belgium, (BR); the Natural History Museum (P), France; Royal Botanic Garden, Kew (K), UK; Natural History Museum (BM), UK; East African Herbarium (EA), Kenya; Makerere University Herbarium (MHU), Uganda; National Herbarium of Tanzania, (NHT); National Herbarium of Netherlands, (WAG) and Koblenz-Landau University herbarium, Germany have been studied. To supplement the morphological data from herbarium collections, fieldwork was carried out in Kenya and Uganda to study the natural populations of *Pteris*.

Phenetic analysis using Statistica 7 computer program yielded two major phenons. The key character that was found to be stable in separating the taxa was lamina architecture where the first major phenon had five species which were simply pinnate at times with 1 or 2 bifid basal pinnae. The second phenon had 19 species with lamina pinnate-pinnatifid or highly divided. This second phenon was further subdivided into two sub-phenons, the first one had seven species with veins anastomosing in the lobes or forming narrow areoles along the costa. The second sub-phenon has free veins in the lobes comprising 13 species, which are widely distributed in all the African Phytochoria. Phylogenetic analysis using PAUP 4 software resulted in more or less complimentary clades. Some of the *Pteris* species occurring in this region are morphologically distinct whereas others are cryptically circumscribed; forming taxonomic complexes such as *Pteris catoptera* and *P. atrovirens* whose circumscription included several intermediates and morphotypes. Species boundary delimitation is further complicated by extensive interspecific hybridization such as ones found in *Pteris atrovirens* x *P. burtonii* and *P. hamulosa* x *P. commutata*.

Ferns make up an important component of tropical pteridoflora and serve important functions in ecosystem processes. They occur abundantly in these forests and are highly sensitive to ecological conditions, making them potential indicators of environmental change. In total, 85 and 66 species were recorded in Kakamega and Budongo forests respectively. This high diversity may be due to privileged location of these forests which receive high amount of rainfall. The presence of different microhabitats suitable for establishment and survival of pteridophyte flora distributed across various habitats also contribute to high species diversity. A positive relationship with moisture and humidity suggests that most ferns species have an affinity for damp and shady places. The distribution of different species in the forests clearly show a particular pattern of habitat requirements from open and disturbed sites to secondary, riverine and primary forests. Fern diversity was high in primary forests which are always moist and shaded as compared to secondary forests. Fifty two species out of the total eighty five recorded occur in primary forests. Riverine vegetation harbors different microhabitats providing suitable refuge for fern species. These sites are permanently wet with diverse and unique microclimatic conditions thus sustaining high species diversity. Most of the fern species thrive well in wet environment.

Ferns richness observed was low along forest edges, in forest glades and gaps, and in disturbed sites. Most ferns cannot tolerate the supposed greater incidence of winds and increased light intensity at the edges and in open sites. This is a positive indicator that temperature and moisture levels are critical for their establishment and survival. Disturbed areas had high abundances of invading species that suppresses effective colonization by species typical of forest interiors. The nature of disturbed habitats can create positive “safesites” for some species that prefer disturbed sites and species that grow in such sites were observed to have high recruitment rates. These areas were characterized by colonizers and more adaptable/hardy fern species e.g. *Pteridium capense*, *Cyclosorus dentata*, *Doryopteris kirkii*, and *Dicranopteris linearis* which normally suppress the establishment of other species.

Tree trunks covered by moss that absorb and retain substantial amount of water form ideal habitats for epiphytic ferns and other vascular plants such as orchids. As a result, tree

species covered by bryophyte mats had high composition of epiphytic ferns due to high water storage capacity, allowing a supply of water even during drier periods as well as providing mechanical support. However, creation of forest gaps severely affect epiphytic ferns species, some of which are highly sensitive to sunlight, e.g. *Asplenium theciferum*, *Asplenium mannii*, *Loxogramme abyssinica*, *Pyrrhosia schimperiana*, *Crepidomanes*, *Hymenophyllum* and *Trichomanes* species. Species with succulent lamina e.g. *Asplenium africanum* and *A. ceii* were found to withstand to a certain degree the dry spell and high light intensity.

This study has produced a comprehensive taxonomic account of the genus *Pteris* in tropical Africa. This includes; revised taxonomy of *Pteris*; identification keys for *Pteris*; good reference materials complete with rhizomes; and distribution maps of *Pteris* in tropical Africa. A comprehensive database with *Pteris* images from tropical Africa has also been developed at East African herbarium. During this study a total of 645 specimens of ferns and lycophytes were collected, correctly identified, curated and preserved at EA and duplicates shared with other herbaria. For the purposes of documentation and future conservation measures, conservation assessment of the genus *Pteris* was done using the IUCN Redlisting criteria and conservation status of each species provided. Manuscripts have been developed using results from this study and will be published in peer reviewed journals.

The morphological data provided information about phylogeny of 25 species of *Pteris* occurring in the selected study area. Several gaps were identified especially in species with complexes e.g. *Pteris catoptera* and *P. atrovirens* which need further studies. *Pteris* phylogeny however is not fully resolved having weak bootstrap support of less than 50% for all the species. It is highly recommended that molecular studies be carried out which will greatly improve our understanding of *Pteris* phylogeny occurring in tropical Africa. Results obtained will complement the morphological studies presented here.

This work proposes for a more inclusive *Pteris* classification system that will hold species together rather than splinting the genus to accommodate the more isolated species within the genus such as *Pteris vittata*, *P. longifolia* and their allies. Christenhusz *et al.* (2011a) has already provided a solution to our problems by including some smaller genera into *Pteris*

clade in order to maintain the monophyly of the genus. The relationships of the species currently in *Pteris* need first to be resolved by having good sampling and carrying out phylogenetic analysis on a global scale to study and understand their relationships. This will certainly yield more information to contribute towards the proposed new changes. The previous subgenera applied to various species have been omitted in this work until such time when a holistic approach will be applied to effect the proposed changes. This work provides a good baseline for species occurring in tropical Africa and further studies on the genus may provide crucial information and insight that can be combined to give more comprehensive analysis.

Two species *Pteris intricata* (Pteridaceae) collected along Nyabusabo river and *Bolbitis heudelotii* (Lomariopsidaceae) along Sonso river are new records for Budongo forest as well as geographical flora U2 where Budongo belongs. *Asplenium laurentii* (Aspleniaceae) was collected during the study after the last collection was done in 1934. New records for Kakamega forest included seventeen species belonging to 11 families. These include two tree fern species *Alsophila manniana* Hook. and *Alsophila dregei* (Cyatheaceae); *Pteris atrovirens* (Pteridaceae).

CHAPTER 1. GENERAL INTRODUCTION

Ferns are diverse, estimated to a tune of 15,000 species of which 12,000 are described species of ferns and lycophytes (Chapman 2009). This group has a longer evolutionary history than any other vascular plant and as a result, many of the phylogenetically informative characters may have been lost in the process. Lycophytes and ferns have traditionally been grouped together because they are characteristically all spore bearing and seed-free vascular plants. Because of these common features, their extant members have often been treated as a single entity under various terms, such as ‘pteridophytes’ or ‘ferns and fern allies’ which are a paraphyletic assemblage and should be avoided (Schuettpelz and Pryer 2008). Broad scale morphological and molecular phylogenetic analysis on lycophytes and fern have yielded good results and application of various terms and names used to refer to different clades of ferns are now resolved. The formerly used category of “fern allies” included the current lycophytes (Lycopodiales, club-mosses; Selaginellales, spikemosses; Isoëtales, quillworts) as well as Psilotales (whisk ferns), and Equisetales (horsetails). According to Pryer *et al.* (2001), Psilotales and Equisetales are now accepted to be more closely related to ferns than to extant lycophytes on the basis of molecular evidence. There are a number of apomorphies that characterize the lycophytes which include; roots having endarch protoxylem, stem have an exarch protoxylem and thirdly lycophytes have a sporophytic leaf called lycophyll. Lycophylls have intercalary meristem and lack a gap in the vasculature of the stem, their veins are single and unbranched.

The “fern allies” were a group of genera with no basis of their relationships and therefore proved difficult to place concisely in their rightful families using morphology. However, they are spore-bearing plants and as such treated as lineage allied to ferns. *Selaginella* was since its reproduction figured out as been part of the Lycophyte clade, and so have extant *Isoetes*. Fossil groups prefer to keep the isoetoids separate because they were a dominant lineage in the past. The same applies to *Equisetum*, although the sphenophyta (which includes the fossils and *Equisetum*) have been treated as a separate class, thus it is better to treat them as a subclass within the fern lineages (but its placement is highly uncertain based on molecular data). All these species diverged due to their environment and *Selaginella* and *Isoetes* evolved heterospory as an adaptation to an aquatic environment.

Ferns have been with us for more than 300 million years and in that time their diversification has been tremendous. They originated in ancient tropical habitats and have undergone major evolution to colonize different types of environments (Sharpe *et al.* 2010). Apart from the very dry and very cold regions, ferns are usually present in many places. Ferns and lycophytes were in high numbers during the Carboniferous period (the age of ferns) (355-290 mya) and dominated part of the vegetation at that time (Rothwell and Stockey 2008). During that era some fern-like groups evolved seeds (the seed ferns) making up perhaps half of the pteridophyte foliage in Carboniferous forests (Rothwell and Stockey 2008). Most early fern lineages vanished during two large extinction events at the end of the Carboniferous (300 mya) and at the end of the Permian (240 mya), exceptions being ancestors of today's orders of ferns and lycophytes (Sharpe *et al.* 2010).

Vascular plants form a basal dichotomy separating lycophytes (1% of extant vascular plants) from the euphyllophytes, which in turn form two major clades: the spermatophytes (seed plants) and the monilophytes (ferns) (Fig. 1; Pryer *et al.* 2004; Simpson 2006; Smith *et al.* 2006; Schuettpelz and Pryer 2008). The extant lycophytes all possess lycophylls (leaves with an intercalary meristem) and comprises three main clades; homosporous Lycopodiales (clubmosses), and heterosporous Isoetales (quillworts) and Selaginellales (spikemosses) (Smith *et al.* 2006; Schuettpelz and Pryer 2008). The sister group monilophytes or what is known as "true ferns" are characterized by euphylls [meaning 'true leaves'] (leaves with marginal or apical meristems and an associated leaf gap in the vascular stele), lateral branches that terminate in sporangia, and a distinctively lobed primary xylem strand. Fern researchers have classified ferns in different categories of classification and as such, 4-5 well defined taxonomic groups are recognized. Smith *et al.* (2006) placed ferns into five major orders namely; Equisetales (horsetails), Marattiales (marattioid ferns), Polypodiales (leptosporangiate ferns), Ophioglossales (moonworts) and Psilotales (whisk ferns). Recently, Christenhusz *et al.* (2011a) grouped ferns into four major sub-class namely; Equisetidae (horsetails), Ophioglossidae (moonworts and whisk ferns), Marattiidae (marattioid ferns) and Polypodiidae (leptosporangiate ferns).

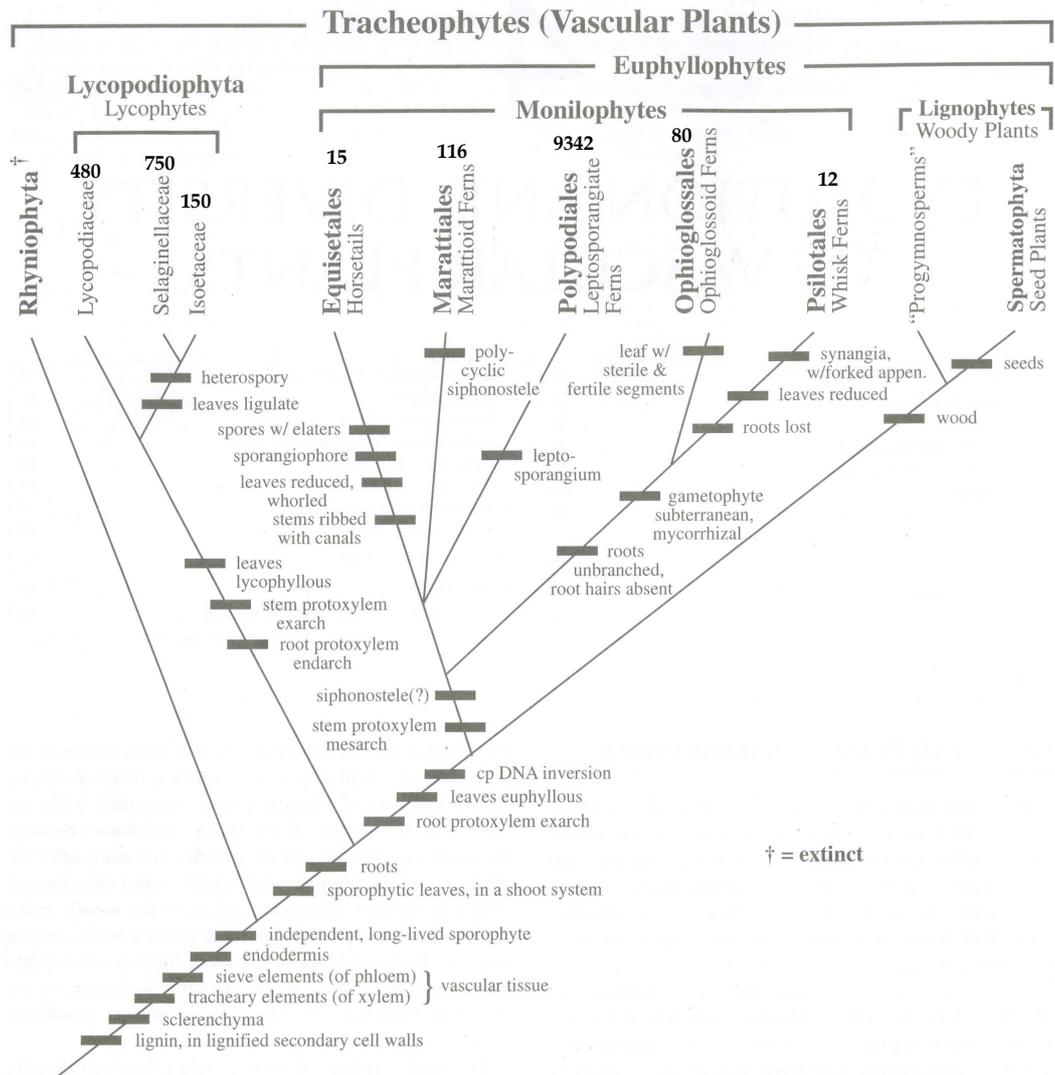


Figure 1. Diagram of vascular plant phylogeny with estimated numbers of ferns and lycophytes

Adopted from Smith *et al.* 2006; Schuettpelz and Pryer 2008.

Deep phylogenetic dichotomy occurred in the early-mid Devonian (ca. 400 mya), separating a group that includes the modern lycophytes from a group that contains all other living vascular plant lineages, the euphyllophytes. According to Rothwell and Stockey (2008), ferns and fern-like plants first appeared in the fossil record during the mid Devonian, 390 mya and underwent evolutionary radiation throughout the carboniferous (Table 1). Subsequent major radiations occurred in the Permian, Triassic, and Jurassic, during which several early branching lineages (e.g. Osmundaceae, Schizaeaceae, Matoniaceae, and Dipteridaceae) evolved (Rothwell 1987). The more derived ferns, the

polypods, which comprise more than 80% of extant fern species (Schneider *et al.* 2004) evolved in the cretaceous time and is continuing today. Recent studies on molecular clock dating has shown that most ferns diversified in the Cretaceous, suggesting an ecologically opportunistic response to the diversification of angiosperms (Schneider *et al.* 2004), and the more diverse habitats these newcomers created.

Table 1. Geological time scale of plants

Era	Geological age	Millions of years ago	Plant development	Diversity of life
Cenozoic	Quaternary period	1.8-present	Flourishing of angiosperms	Age of angiosperms 
	Tertiary period	65-1.8		
Mesozoic	Cretaceous period	135-65	Appearance of gymnosperms	Age of gymnosperms 
	Jurassic period	205-135	Flourishing of conifers	
	Triassic period	250-205	Appearance of cycads	
Palaeozoic	Permian period	290-250	Appearance of ferns	Age of ferns 
	Carboniferous	355-290		
	Devonian period	410-355		
	Silurian period	438-410	Appearance of terrestrial plants	Age of algae 
	Ordovician period	510-438	Flourishing of algae	
	Cambrian period	570-510		
Precambrian		>570	Appearance of green algae, cyanobacteria and bacteria	

Note: Images download from encyclopedia of life; www.eol.org/images

After the mass extinctions, seed plants i.e. (gymnosperms in Mesozoic, 205-65 mya, and angiosperms in Cenozoic, 65 mya to present) increased dramatically and took a dominant role in the ecosystems (Rothwell and Stockey 2008). Most of the extant fern and lycophyte lineages diversified at the same time as the seed plants (Schneider *et al.* 2004). A completely new group of fern known as leptosporangiate appeared at the same time as the gymnosperms and increased in species numbers as was the angiosperms (Rothwell and Stockey 2008). The earliest-known occurrence of leptosporangiate ferns was in the early carboniferous (Galtier and Phillips 1996). Orders included in leptosporangiate ferns are Osmundales, Hymenophyllales, Gleicheniales, Schizaeales, Salviniiales (heterosporous

ferns), Cyatheales (tree ferns) and Polypodiales, which includes major fern families (Stevenson and Loconte 1996; Smith *et al.* 2006; 2008; Pryer *et al.* 2007).

Leptosporangiate ferns are monophyletic and highly diverse group with approximately 9,000 extant species (Pryer *et al.* 2004; Smith *et al.* 2006; Schuettpelz and Pryer 2008). The group is characterized by sporangia that develop from a single cell and have mature sporangium walls that are just one cell thick as opposed to two or more cell thick sporangium walls of eusporangiate ferns (Tryon *et al.* 1990). Most possess a distinctive annulus that serves to eject the spores (Stein 1993; Kenrick and Crane 1997; Pryer *et al.* 2004). Leptosporangiate lineage originated at the onset of Carboniferous period (359.2 Mya) (Galtier and Phillips 1996). This event occurred over 200 million years ago before the evolution of angiosperms and this group according to fossil records have undergone three successive radiations (Rothwell 1987; Lovis 1977; Rothwell and Stocky 2008). The first radiation occurred in the Carboniferous, giving rise to 6 families which are now extinct. A second one occurred in the late Paleozoic and early Mesozoic and resulted into several extant families. The third radiation occurred at the beginning of the Cretaceous period and consist mainly the “polypod” clade. This last radiation that gave rise to polypod ferns coincided with the rise and proliferation of the flowering plants.

Researchers have been putting forward insights and theories associated with diverfication or “burst” of leptosporangiate ferns in the shadow of angiosperms. One theory is that the success of leptosporangiate ferns involved an ecological opportunistic response to the rise and diversification of angiosperms (Smith 1972; Schneider *et al.* 2004) where they strategically colonized both on the forest floors and on the tree canopies. Kwai *et al.* (2003) theorized that the success of leptosporangiate ferns was due to presence of a unique photoreceptor that enhanced their light sensitivity and hence enabled them to occupy shady forest floors where other non-flowering vascular plants could not survive. Evolution of epiphytism traits in some ferns and dessication tolerance in others has been documented to have played a role in some ferns of leptosporangiate group. Schuettpelz and Pryer (2009) came up with a theory that the proliferation of angiosperms across the landscape, and establishment of complex ecosystems, resulted in the formation of new and diverse niches into which leptosporangiate ferns could diversify. These led to a successive

diversification of the leptosporangiate ferns which now represent 3% of total vascular plant biodiversity and compose 10% of the earth's vascular epiphytes (Schuettpelz *et al* 2007).

Many extant fern families and genera are not clearly derived from, nor are they obviously ancestral to another extant group (Roux 2001). This is caused by lack of information in which primitive or advanced character states can be assessed, evidence having been lost through extinction (Roux 2001). However, knowledge on fern phylogeny is rapidly improving and becoming available from diverse research work that have yielded good results (e.g. Kenrick and Crane 1977; Hasebe *et al.* 1994; Hasebe *et al.* 1995; Pryer *et al.* 1995; Stevenson and Loconte 1996; Pryer *et al.* 2001; Schneider *et al.* 2004; Pryer *et al.* 2004; Smith *et al.* 2006; Schuettpelz *et al.* 2007, Schuettpelz and Pryer 2008; Christenhusz *et al.* 2011a; Lehtonen 2011). Smith *et al.* (2006; 2008), in his phylogenetic work recognized 37 families and approximately 300 genera of ferns. This work was greatly improved recently with a comprehensive treatment given by Christenhusz *et al.* (2011a), who recognized 45 families and 280 genera of ferns, three families and five genera for lycophytes. These form a major advancement toward understanding of ferns and lycophytes phylogeny through development of linear classification. Smith *et al.* (2006) and an updated version Smith *et al.* (2008) concentrated more on ferns classification and did not give a lot of attention to lycophytes. This was probably due to lack of pertinent information on that group, however Christenhusz classification is a step forward towards bringing the knowledge gap on lycophytes and ferns. His work is comparable to the APG-III for angiosperms (Angiosperm Phylogeny Group 2009). The major difference between Smith and Christenhusz classification is that the former did not follow linear classification. Linear classifications are more objective and easy to use in organization of the herbaria, publications of floras, spore banks, checklists and fern books. In fern families there are small ones with few species and large ones with diverse species. Largest families known are Aspleniaceae, Polypodiaceae, Dryopteridaceae, and Pteridaceae.

Pteridaceae is an ancient family and according to molecular clock, it first emerged about 119.85 mya and accounts for about 10% of extant fern diversity (Tryon and Tryon 1982; Schuettpelz *et al.* 2007). The family is not well known from the fossil records and evidence of their evolutionary relations has been lost through extinction (Tryon *et al.* 1990). Leaf

shape and the presence of pseudoindusia allow for the assignment of a fossil *Pteris* from the late Cretaceous to the pteridoid ferns. This family is mainly characterized by sporangia borne abaxially on veins, commonly borne marginally and often covered by a marginal false indusium, spores trilete, and chromosome number of $n= 29$ or 30 , or their multiples (Tryon and Tryon 1982; Tryon *et al.* 1990; Tryon and Lugardon 1990). In some cases there are acrostichoid arrangement of sporangia in few genera such as *Acrostichum*. Pteridaceae is large and diverse family with worldwide distribution preferentially in the tropics. This family has a broad ecological preference, suggesting that the initial diversification in this family was closely linked to ecological innovation and specialization (Schuettpelz *et al.* 2007). The family is well distributed in various habitats and occupies different ecological niches such as aquatic, epiphytic, terrestrial, xeric-adapted as well as in hot deserts (Kornás 1979; Tryon and Tryon 1982; Tryon *et al.* 1990; Tryon and Lugardon 1990; Sharpe and Mehltreter 2010).

Analysis from historical literature (Ching 1940; Copeland 1947; Holttum 1977) shows that various authors had previously segregated and recognized various ranks within Pteridaceae such as tribes, subfamilies and some as families (Table 2). For many years, taxa comprising this family were unsuccessfully moved from one family to another, in an effort to stabilize the family, but still impending taxonomic problems at the familial level were not solved until recently. Copeland (1947) classified the family as a broad one including Dicksoniaceae and Dennstaedtiaceae, while Pichi Sermolli (1977) restricted the family to *Pteris* and its closest allies. Pichi Sermolli (1973) described the family as a strange mixture of genera whose affinities in many cases are certainly remote. The family has been redefined to be monophyletic according to previous molecular studies (e.g. Pryer *et al.* 1995; Hennipman 1996; Gastony and Johnson 2001; Schneider *et al.* 2004; Zhang *et al.* 2005; Christenhusz *et al.* 2011a). Other analysis (Hasebe *et al.* 1995; Schuettpelz *et al.* 2007), gave conflicting results, concluding that the family was paraphyletic, with most of the constituent genera being polyphyletic or paraphyletic. This is because Vittariaceae was placed within the Pteridaceae as a sister group to *Adiantum* (Hasebe *et al.* 1995). However, with molecular advancements with the most recent account been given by Christenhusz *et al.* (2011a) shows that, the relationships among the many subfamilies are now becoming much clearer due to concepts employed in the circumscription.

Table 2. Classification within Pteridaceae family by various authors

Authors	Hooker (1858)	Christensen (1906)	Sim (1915)	Copeland (1947)	Alston (1959) Schelpe 1970	Pichi-Sermolli 1963a, 1966, 1977	Roux (2001)	Smith <i>et al.</i> (2006)	Christenhusz <i>et al.</i> 2011
Family	?	Polypodiaceae	Pterideae s.s.	Pteridaceae	Adiantaceae	Adiantaceae	Pteridaceae	Pteridaceae	Pteridaceae
Other inclusive families				Dicksoniaceae Dennstaedtiaceae		Pteridaceae Gymnogrammaceae Ceratopteridaceae Parkeriaceae Sinopteridaceae Hemionitidaceae		Acrostichaceae Actiniopteridaceae Adiantaceae Anopteraceae Antrophyaceae Ceratopteridaceae Cheilanthaceae Cryptogrammaceae Hemionitidaceae Negripteridaceae Parkeriaceae Platyzomataceae Vittariaceae	
Subfamilies/ sub-class		Pteridinae	Pteridinae Gymnogramminae Cheilanthinae Adiantinae				Adiantoideae, Cheilanthoideae Pteridoideae, Taenitidoideae	Parkerioideae Adiantoideae Cryptogrammaceae Cheilanthoideae Pteridoideae	Cryptogrammoideae Ceratopteridoideae Pteridoideae Cheilanthoideae Vittarioideae
Other genera	<i>Pteris</i> L. <i>Pteridium</i> <i>Gleditsch</i> . <i>Histiopteris</i> (J.G. Agardh) J.Sm. <i>Paesia</i> J.St.-Hil	<i>Pteris</i> L. <i>Actiniopteris</i> Link <i>Anopteris</i> (Prantl) Diels <i>Ochropteris</i> J.Smith <i>Histiopteris</i> <i>Lonchitis</i> L. <i>Pteridium</i> Gleditsch. <i>Paesia</i> J.St-Hil.	<i>Pteris</i> L. <i>Anogramma</i> Link <i>Gymnogramma</i> <i>Ceropteris</i> Link <i>Pellaea</i> Link <i>Doryopteris</i> J.Sm. <i>Adiantopsis</i> Fée <i>Notholaena</i> R.Br. <i>Cheilanthes</i> Sw. <i>Hypolepis</i> Bernhardi <i>Adiantum</i> L. <i>Actiniopteris</i> Link <i>Lonchitis</i> L. <i>Histiopteris</i> . <i>Pteridium</i> Gleditsch.	<i>Pteris</i> L. <i>Lonchitis</i> L. <i>Anisosorus</i> Trevisan	<i>Pteris</i> L. <i>Adiantum</i> L. <i>Ceratopteris</i> Brongniart <i>Actiniopteris</i> Link <i>Doryopteris</i> J.Sm. <i>Pellaea</i> Link <i>Cheilanthes</i> Sw.		<i>Pteris</i> <i>Actiniopteris</i> <i>Anogramma</i> <i>Pityrogramma</i> <i>Actiniopteris</i> <i>Cheilanthes</i> <i>Aleuritopteris</i> <i>Pellaea</i> <i>Doryopteris</i> <i>Coniogramme</i> <i>Adiantum</i> <i>Acrostichum</i> <i>Vittaria</i> <i>Antrophyum</i>	<i>Pteris</i> L. <i>Acrostichum</i> L. <i>Ceratopteris</i> Sw. <i>Adiantum</i> L. <i>Coniogramme</i> Fée <i>Cryptogramma</i> R.Br. <i>Llavea</i> Lagasca NB.For other genera refer to Smith et al. 2006	<i>Pteris</i> L. <i>Coniogramme</i> <i>Cryptogramma</i> <i>Llavea</i> <i>Acrostichum</i> <i>Ceratopteris</i> <i>Anogramma</i> <i>Taenitis</i> <i>Jamesonia</i> <i>Nephiopteris</i> <i>Aspleniopsis</i> <i>Actiniopteris</i> <i>Cheilanthes</i> <i>Pellaea</i> etc
Subgenera		<i>Eupteris</i> Newman <i>Campteria</i> Presl. <i>Litobrochia</i> C.Presl.							

Pteridaceae belong to class polypodiosida order polypodiales. Tryon and Tryon (1982) and Tryon *et al.* (1990) segregated the family into six subfamilies/tribes and 34 genera which are; Adiantoideae, Ceratopteridoideae, Cheilanthoideae, Platyzomatoideae, Pteridoideae, and Taenitidoideae. Smith *et al.* (2006) reorganized and subdivided the family into five monophyletic groups/subfamilies. ca 50 genera, and ca 950 species making it the third largest family of extant ferns. The subfamilies are as follows; Parkerioideae (*Acrostichum* and *Ceratopteris*), Adiantoideae (*Adiantum* and vittarioid genera), Cryptogrammoideae (*Coniogramme*, *Cryptogramma*, and *Llavea*), Cheilanthoideae (*Cheilanthes* and *Pellaea*), and Pteridoideae (*Pteris* and allies). Some of the genera and species are polyphyletic or paraphyletic and in serious need of redefinition. Christenhusz *et al.* (2011a) placed Pteridaceae in subclass Polypodiidae, and divided it in five subfamilies and recognized 52 genera. These subfamilies are: Ceratopteridoideae (*Acrostichum* and *Ceratopteris*); Vittarioideae (*Adiantum* and the former Vittariaceae); Cryptogrammoideae (*Coniogramme*, *Cryptogramma*, and *Llavea*); Cheilanthoideae (*Cheilanthes*, *Pellaea* and its relatives) and Pteridoideae (*Actinopteris*, *Anogramma*, *Jamesonia*, *Onychium*, *Pityrogramma*, *Pteris*, and a few smaller related genera).

Both classification by Smith *et al.* (2006) and Christenhusz *et al.* (2011a) employed the same circumscription hence having more or less the same conclusions. All the subfamilies were monophyletic except the prevailing uncertainty in Cheilanthoidea (Christenhusz *et al.* 2011a; Lehtonen 2011). Despite the recent advancement in Pteridaceae research, there is need for a generic redefinition within pteridoids as already pointed out by various authors in the past studies (e.g. Hasebe *et al.* 1994; Smith *et al.* 2006; Schuettpelz *et al.* 2007; Schuettpelz and Pryer 2007; Christenhusz *et al.* 2011a; Lehtonen 2011; Martinez and Prado 2011). However, there is adequate reference information, and the dream towards having a fully resolved Pteridaceae phylogeny is just a stone throw away. The next area to explore will be the relationships between Pteridaceae and other families. Recently, molecular analysis showed that relationship between Pteridaceae and Dennstaedtiaceae are weakly supported Christenhusz *et al.* (2011a), and their taxonomic boundaries are yet to be resolved (Lehtonen 2011). The relationships of the genera within the Pteridaceae are complex and there are distinctive groups and poorly defined ones (Tryon and Lugardon 1990; Tryon *et al.* 1990; Smith *et al.* 2006; Schuettpelz *et al.* 2007). The number of genera is changing due

to redefinition of the Cheilanthoid genera. The family is considered to have been derived recently from schizaeoid stock (Tryon and Tryon 1982; Smith 1995), together with Aspleniaceae, Polypodiaceae, Vittariaceae and belong to a clade of advanced leptosporangiate ferns which had more than one origin.

Verdcourt (2002) in his Flora of Tropical East Africa (FTEA) account stated that, there are five genera in Pteridaceae globally out of which two occur in the FTEA area namely *Pteris* L. and *Acrostichum* L. The circumscription of the family as accepted by Verdcourt has been changed substantially since his publication. However, recent molecular analyses show that *Acrostichum* is more closely related to *Ceratopteris* rather than to *Pteris* and together belong to the subfamily Ceratopteridoideae (Smith *et al.* 2006; Schuettpelz *et al.* 2007; Christenhusz *et al.* 2011a). For the purpose of clarity and better understanding in this study, the classification of ferns and lycophytes herein follows linear classification by Christenhusz *et al.* (2011a) which is the most updated and recent.

Pteris L. (1753) belongs to Pteridaceae circumscribed in broad sense by Spreng ex Jameson (1821). *Pteris* is the type genus of the family Pteridaceae, subfamily Pteridoideae, while *Pteris longifolia* L. was selected by Smith (1875) as the type species of the genus. *Pteris* being a cosmopolitan genus has in the past been divided into separate genera by some authors, while others attempted to unite it with other genera such as *Pellaea* and *Lonchitis* (Sim 1915; Bower 1928; Price 1974). Its relation with other genera is not yet clear Tryon and Tryon (1982) though it is mostly associated with cheilanthoid in relation to soral characters and with the taenitoid in spore characters. *Pteris* position in familial rank has been controversial with some authors placing it in Adiantaceae although Pteridaceae is a much older name and hence have nomenclatural priority. *Pteris* has many synonyms, a clear indication of divergent views held by various authors about its taxonomic treatment in the past. Recent phylogenetic research has resulted into conflicting conclusions where some authors conclude that *Pteris* is monophyletic (Hasebe *et al.* 1995; Schneider *et al.* 2004; Christenhusz *et al.* 2011a) while other report it to be paraphyletic (Smith *et al.* 2006; Schuettpelz and Pryer 2007; Schuettpelz *et al.* 2007). The debate on its correct circumscription is still ongoing, and research findings ranging from phylogenetic, systematic, cytology, breeding systems, spore analysis are yielding good results.

The monophyly of *Pteris* was seriously called into question by the analyses of Schuettpelz *et al.* (2007), principally because *Pteris vittata* L. was never resolved as closely allied to the remainder of the genus (refer to fig 1 & 2 of Schuettpelz *et al.* 2007). Instead, this species appeared in two different, unsupported positions in the trees: either sister to the genus *Platyzoma* or sister to a clade largely corresponding to the Taenitidoideae. *Taenitis* looks much like *Pteris* and it could be a matter of time before it is also included in this genus. This means that, majority of species of the currently circumscribed *Pteris* would be included in expanded *Campteria* C.Presl or *Litobrochia* C.Presl. To maintain the monophyly of the genus, the definition of *Pteris* would either need to be expanded to include some of genera in pteridoid clade or perhaps more tenably restricted to the small clade of *Pteris longifolia* (the type species), *P. vittata*, and their close allies (Schuettpelz *et al.* 2007). To accommodate these suggestions, Christenhusz *et al.* (2011a) recently took a broad approach and included *Neurocallis* Fee and *Platyzoma* in *Pteris*, because to maintain these monotypic genera, the genus *Pteris* in its traditional sense would have to be divided to maintain its monophyly. These results were strongly supported by analyses done by Lehtonen (2011). The analyses done on this genus show that the circumscription adopted eventually affect the conclusion.

1.1 Study objectives

Objective 1: To revise the taxonomy of the genus *Pteris* in tropical Africa.

Objective 2: To investigate the phylogeny of *Pteris* occurring in tropical Africa.

Objective 3: To investigate ecological significance of ferns and lycophytes following anthropogenic disturbance and fragmentation of Kakamega (Kenya) and Budongo (Uganda) forests along a disturbance gradient.

Objective 4: To analyze the phytogeography of the genus *Pteris* in tropical Africa.

1.2 Research hypotheses

1. Morphological characters are reliable in delimiting closely related species of *Pteris*.
2. *Pteris* phylogeny can be resolved using morphological characters.
3. Ferns and lycophytes play a crucial role in ecosystem dynamics and are good indicators of environmental conditions/health.
4. *Pteris* species are widely distributed throughout the continent, a factor attributed to spores dispersal by wind and water.

CHAPTER 2. TAXONOMIC SURVEY OF THE GENUS *PTERIS*

2.1 History and conspectus of *Pteris* in Africa

The name *Pteris* was used in ancient Greece for certain types of ferns. It is derived from the word *pteron*, meaning feather or wing due to the resemblance of the symmetrical fronds to feathers (Burrows 1990). Linnaeus in his *Species Plantarum* (1753) recognized 15 genera of ferns namely: *Acrostichum*, *Adiantum*, *Asplenium*, *Blechnum*, *Equisetum*, *Hemionitis*, *Lonchitis*, *Marsilea*, *Onoclea*, *Ophioglossum*, *Osmunda*, *Pilularia*, *Polypodium*, *Pteris*, and *Trichomanes* comprising 182 species (Linnaeus 1753). His classification was highly artificial arrangement with distanty related species being grouped together, though it served a good purpose until a more natural system was developed. The authors of 17th and 18th century including Linnaeus relied on few characters such as type of indusium, fruiting parts to define genera. Swartz (1806) in his *Synopsis Filicum* treated 33 genera and 720 species. Both Linnaeus and Swartz based their classification chiefly on the shape and protection of the sori. Fern classification later on was very active as more botanists tried to organize the systems. Due to increase on numbers of genera other characters came in handy in particular the venation patterns, chromosomes numbers, and presence of spinules.

Pteris is a large and diverse genus rather cut off from other ferns and closely related to *Adiantum* and has approximately 50 related genera embedded in Pteridaceae. It comprises 250-280 terrestrial and epiphytic species of predominantly tropical and subtropical distribution except a few species that extend into warm temperate regions of the world (Tryon *et al.* 1990). This places it among the largest genera of leptosporangiate ferns globally. In previous accounts, several other genera (Table 2) had been lumped together in Pteridaceae including *Pteridium*, *Pellaea*, *Cheilanthes* and *Adiantum* among others. However, as more information especially molecular phylogeny become available, a lot of changes were effected, and these genera were subsequently placed in their respective subfamilies of which many are back again to Pteridaceae. Also included in *Pteris* are several complexes containing few to many species which are yet to be resolved. These present great taxonomic difficulties and the interrelationships of the components can often only be deduced by experimental methods (Walker 1958).

The current phylogenetic information shows that the genus *Pteris* is closely related to *Adiantum*, than it is to *Pteridium* and *Pellaea* (Christenhusz *et al.* 2011a). Study of the herbarium specimens revealed that most of the *Pellaea* species were initially identified as *Pteris* though the former belong to Cheilanthroideae, a subfamily in Pteridaceae. The confusion is attributed to morphological similarities between the two species such as having marginal sori, presence of false indusium, colour of stipes, and lamina shape. This is as a result of synapomorphies shown by all Pteridaceae. However, *Pellaea* is now correctly placed in Cheilanthroideae, not Pteridoideae (Smith *et al.* 2008; Christenhusz *et al.* 2011a). The major distinguishing characteristics between the two genera are; *Pellaea* have short, black and shiny stipe whereas in *Pteris* the stipe is mostly straw coloured or brown attaining a length of 1.5 m in some species e.g. *Pteris tripartita*. The margin of the sterile and fertile lobe apices in *Pellaea* are always entire, while in *Pteris* they are mostly distinctly serrate except in some few species where they are entire.

The genus *Pteris* is characterized by having erect or creeping rhizomes, with a dictyostelic vascular system, fronds tufted to widely spaced. Rhizome scales in some species extending to the base of stipe, which are linear-lanceolate to ovate, pale to dark brown or chestnut in colour with entire, pale or hairy margins, at times with dark central stripe. Lamina occurs in various sizes with its texture either herbaceous or coriaceous. Fronds tufted or spaced apart, occasionally dimorphic, simply pinnate to 4-pinnatifid or in some instances tripartite. The terminal pinna usually similar to the lateral ones. Stipes, rachis, costae and costules smooth to sparsely or at times densely spinulose, often armed with costal spines ventrally at the junctions of costulae. Veins free or anastomosing to form a single series of areoles parallel to the costae. In some species veins free (campteroidean venation) or forming a complete reticulum, the areoles lacking free included veins (litobrochioidean venation). Sori marginal, covered by a linear continuous indusium, formed from reflexed lamina margins, opening inward. Sporangia in uninterrupted soral lines, extending from near the sinuses to near apices of the ultimate segments, never covering the apices. Spores tetrahedral or globose, very light brown to almost black in colour, the ornamentation ranging from reticulate to papillose, ridged to rugose. Basic chromosome numbers stable, $x = 29$ or 30 (Walker 1962).

Substantial work on *Pteris* has been done from breeding programs, systematics, cytology, and evolutionary studies based on selected species (e.g Walker 1958; Walker 1962; Smith *et al.* 2006; Prada *et al.* 2008; Zhang *et al.* 2008). The Flora of Tropical East Africa Verdcourt (2002) gives an account of 23 *Pteris* species, three subspecies and three varieties. The taxonomy of the genus is bedevilled by the presence of species complexes consisting of very similar species which frequently intergrade morphologically with one another. The genus as a whole includes a very wide range of cryptic species, which are grouped into species-complexes (Walker 1962) e.g. *Pteris biaurita* L., *P. catoptera* Kunze, *P. similis* Kuhn and *P. dentata* Forssk. and these present great taxonomic difficulties. However, differences exist in such fundamental characters at the level of ploidy, type of breeding systems, features of the spores and morphology of the juvenile plants. The *Pteris catoptera* complex is one of such species showing deceptive morphological resemblance but which could be treated as separate species. This complex contains many species that are very similar superficially but differences never the less exist especially at the level of polyploidy. Besides that, the taxonomy of many groups in *Pteris* is difficult, in some cases complicated by hybridization and apomixis (Verdcourt 2002). Although Hieronymus (1915) proposed a number of African species of *Pteris*, it is apparent from cytological studies Walker (1962) that *Pteris* is a complex of diploid and apogamous triploid populations that are not amenable to orthodox taxonomic treatment.

The precise delimitation of the genus has differed somewhat in detail according to the views held by various authors (Walker 1962; Tryon *et al.* 1990). The available literature shows that most studies on *Pteris* has been done mainly on American and Asian species while African species have been neglected for a long time creating a taxonomic gap. A systematic revision of *Pteris* in Africa has not been attempted before and the same case applies to most of other large fern genera such as *Asplenium*, *Adiantum*, *Thelypteris* and *Dryopteris*. *Pteris* species grow to a large size plant, posing challenges when it comes to collection of herbarium specimens, and interpretation of fragmentary types. With large-leaved species (e.g. *Pteris tripartita*, *P. catoptera*), especially when the frond is pedate, it is almost impossible to collect a complete specimen. Due to such challenges, most of the herbarium specimens examined were incomplete, resulting in gaps for some species.

It is difficult to estimate the number of ferns and lycophytes species that occur in tropical Africa. Most countries have not catalogued their fern and lycophyte flora. In some cases, taxonomic and biogeographical information for the taxa already described from the region is missing (Roux 2009). Some of the publications of the study flora include different parts of the Flora of Tropical East Africa (FTEA), *Conspectus Florae Angolensis* (Schelpe 1977), *Flora Zambesiaca* (Schelpe 1970), *Flore du Cameroun* (Tardieu-Blot 1964a), *Flore du Gabon* (Tardieu-Blot 1964b), and *Flora of Tropical West Africa* (Alston 1959) among others. Many of the published floras are outdated with Roux (2009), Crouch *et al.* (2011) and 26 FTEA parts of ferns and lycophytes representing current research in Africa.

The centre of diversity of *Pteris* in Africa occurs in rainforests of East Africa, and to a lesser extent the central African forests of Congo, Angola and Cameroon. According to Roux (2009) Africa, Madagascar and neighbouring islands have 61 species of *Pteris*. Out of these species, 29 occur in East Africa (Verdcourt 2002), 16 species in west tropical Africa (Alston 1959), and 12 species in *Flora Zambesiaca* (Schelpe 1970). At the country level, Madagascar leads with a record of 26 species (Tardieu-Blot 1958; Roux 2009); Tanzania 22 species; 4 species being endemic, followed by Uganda 18 species with no endemics, Kenya 14 species, with one endemic (Verdcourt 2002; Roux 2009). Congo has 14 species of *Pteris* followed by Cameroon with 13 species, no endemic. Angola and Gabon with 12 and six species respectively (Schelpe 1977; Johns 1991; Verdcourt 2002; Roux 2009). Bioko has 15 species (Benl 1988) and South Africa 22 species (Schelpe 1969; Roux 2009; Crouch *et al.* 2011).

Economically, other ferns species such as *Asplenium* and *Nephrolepis* are widely used as ornamentals particularly as indoor plants and as a combination in banquet flowers. However, *Pteris* is hardly used perhaps because of their large size and specific habitat requirements. Propagating trials of *Pteris* species failed at Nairobi Botanic Garden (NBG) of the National Museums of Kenya (NMK). This is attributed to change in the microhabitat condition because *Pteris* is a forest species which grow in wet forests under canopy or in shaded habitats. Only *Pteris catoptera*, *P. burtonii*, and *P. dentata* were successfully propagated at NBG.

Despite *Pteris* being a large and diverse genus in Africa, contributing significantly in ecological processes, its taxonomic studies for tropical Africa is rudimentary. Precise delimitation of the genus has differed somewhat in details according to the views held by various authors. Literature search shows that there is a knowledge gap on *Pteris* from tropical Africa pertaining to its taxonomic placement. Monographs or detailed taxonomic accounts are crucial in understanding particular species of a region. However, such a monograph on the genus *Pteris* is lacking, not only from Africa but also from other continents where this genus has been widely studied e.g. China, Brazil and Mexico. Lack of such accounts is a taxonomic impediment that hinders advancement of fern studies in tropical Africa as well as in other regions. Identification keys are crucial in taxonomy, but such tools are largely missing for *Pteris*, which makes working with this genus problematic. However, old floral treatments covering some geographical regions from Africa are available. So far, sixty-one species have been recorded from Africa including Madagascar (Roux 2009). This region could be a centre of *Pteris* diversification, a view further supported by the recent description of three species (Verdcourt 2002). These species are, *Pteris mkomaziensis*, *P. albersii* subsp. *mufindiensis*, and *P. albersii* subsp. *uaraguessensis*.

CHAPTER 3. METHODOLOGY

3.1 Morphological studies

The historical background and morphological studies of the genus *Pteris* were established through study of herbarium materials, literature review and internet research. Type specimens from Herbaria of National Botanic Garden of Belgium at Meise, Belgium (BR), the Musée National d'Histoire Naturelle, Paris, France (P), the Royal Botanic Garden, Kew, UK (K), and The Natural History Museum, London, UK (BM) were studied. In addition voucher specimens from herbaria housing African plants e.g. East African (EA) Herbarium of the National Museums of Kenya, Nairobi, Makerere University Herbarium (MHU), Uganda, National Herbarium of Tanzania (NHT), Arusha, National Herbarium of Netherlands, Wageningen branch (WAG), Koblenz-Landau University Herbarium, Germany, were also studied. Natural populations of *Pteris* species were investigated and studied in the field in Kakamega, Taita hills, Tinderet, Mau, Bahati, Aberdares, Mt. Kenya and Budogo forests.

3.1.1 Phenetics

Phenetics also referred to as numerical taxonomy, attempt to classify organisms based on overall similarity. It is defined as “the grouping by numerical methods of taxonomic units into taxa on the basis of their character states”. Phenetics provides a repeatable, operational methodology for the production of a classification, and reduces the subjectivity involved in handling the characters once they have been selected for use (Davis and Heywood 1973). Sokal and Sneath (1963) attempted to reduce the subjectivity of the groupings experienced in phyletics by assigning equal weight to all the phenological characters of a taxon irrespective of ancestral or evolutionary affiliation. In particular they emphasized quality and precise descriptions and measurements as well as standardizing the data analytical procedures.

There is a general belief that a perfect phenetic system would also be a perfect phylogenetic one (Stace 1989). The general similarity of phenetic and phylogenetic systems of classification may also be due to exactly the same hierarchy of taxonomic ranks and the same names as we use to express our phenetic data (Stace 1989). All the characters used are a priori weighted equally according to the methods advocated by Sneath and Sokal.

The reasonable working numbers of characters that are widely accepted and regarded satisfactory for the classification are a minimum of 60 while 80 to a 100 are desirable (Stace 1989).

The basic unit of numerical taxonomy is the operational taxonomic unit (OTU), a term given to the lowest taxon being studied in a particular investigation. The number of OTUs required to represent a homogeneous cluster is estimated to be at least 10 and preferably 25 or more Sneath (1976). Characters are then selected where each character can exist in only two states/attributes, description and/or measurements of the character states are undertaken which are then coded into an acceptable data matrix. The overall similarity between each individual pair of OTUs is determined through grouping of the units using appropriate taxonomic analytic system through computer programs. Then the computer clusters the OTUs according to their overall similarity based on Euclidean Distance. This process is referred to as cluster analysis, a common method used in phenetics. The greater the disparity between two OTUs the greater will be their distance and the more likely group of OTUs will be drawn into different ranks in a dendrogram.

Pteris is a taxonomically problematic genus having many morphotypes whose relationships at infrageneric level is not clearly understood and hence in need of investigation. Use of morphological characters in *Pteris* delimitation has differed among different authors. The few attempted regional floras did not solve the ensuing problems and these present difficulties in the accurate identification of the species. In this study, numerical methods were used in classification of the species on the basis of their morphological grouping for ease of classification and identification. Through literature search and study of herbarium specimens, nomenclature was established for all available names pertaining to specific *Pteris* species from tropical Africa, in order to adopt and apply the correct names for future study of the genus.

Twenty five species of *Pteris* from tropical Africa were studied using herbarium reference collections from different herbaria as well as field observations in Kenya and Uganda. A total of thirty three (33) taxonomically informative characters as well as geographical characters were selected for this study (Table 3). Geographical data for widely distributed

genus such as *Pteris* form a significant part of the taxa concept and such data should be incorporated in the taxon classification. The resulting morphological data matrix was analysed phenetically to investigate any infrageneric variation in *Pteris*. This approach was particularly suitable in investigating species complexes e.g. *P. atrovirens*, *P. catoptera* and *P. dentata*.

Table 3. Character and character states used in phenetic analysis

Character no.	Character	Character states
1.	Rhizome	Creeping (0); erect (1); ascending (2)
2.	Position of sori	Proximal (0); median (1); entire except apex (2)
3.	Sori length	≤1 cm (0); ≥1.1-5 cm (1)
4.	Venation	Free (0); anastomosing (1); areoles (2)
5.	Gemmae	Absent (0); present (1)
6.	Division of lamina	Simple (0); bipinnate (1); tripinnate (2)
7.	Lamina shape	Elliptic-oblong (0); lanceolate-triangular (1); ovate-triangular (2); oblong-lanceolate (3)
8.	Length of lamina when mature	0-50cm (0); 51-100cm (1); over 1m (2)
9.	No. of pairs of fertile pinnae	1-4; (0); 5-9 (1); 10 and above (2)
10.	Basal pinnae	Basisopic spur (0); pinnate (1); bi-tripinnate (2); tripinnate (3)
11.	Margin of apices of pinnae lobes	Entire (0); spinulose (1); dentate (2); variously serrated (3)
12.	Rachis texture	Glabrous (0); scaly (1); spinulose (2); muriculate (3)
13.	Rachis state	Free (0); winged (1); decurrent (2)
14.	Costae texture	Smooth (0); spinulose (1); scaly (2)
15.	Position of urns(spines)	None (0); upper junction of costules (1); underneath junction of costules (2)
16.	Costules texture	Smooth (0); spinulose (1); scaly (2)

17.	Position of spines	None (0); upper surface (1); beneath (2)
18.	Stipe general texture	Glabrous (0); pubescense-scaly (1); spinulose (2); muriculate (3)
19.	Stipe base colour	Straw (0); reddish (1); purplish (2); dark brown (3)
20.	Texture of stipe bases	Smooth (0); scaly (1); spinulose (2); muriculate (3)
21.	Scale shape	Lanceolate (0); linear-lanceolate (1); ovate-acute (2); linear (3)
22.	Scale colour	Brown (0); pale brown; (1); blackish brown (2); chestnut (3)
23.	Margins	Entire (0); pale (1); erose (2)
24.	Mid rib	Dark (0); black (1); red-chest nut (2); none (3)
25.	Guineo-Congolian distribution	No (0); yes (1)
26.	Zambeziian distribution	No (0); yes (1)
27.	Sudanian distribution	No (0); yes (1)
28.	Somalia-Masai distribution	No (0); yes (1)
29.	Afromontane distribution	No (0); yes (1)
30.	Guinea-Congolia /Zambezia distribution	No (0); yes (1)
31.	Guinea-Congolia/Sudania distribution	No (0); yes (1)
32.	Lake Victoria regional mosaic distribution	No (0); yes (1)
33.	Swahilian regional centre of endemism distribution	No (0); yes (1)

3.1.2 Phylogeny

Phylogeny refers to the evolutionary history or pattern of descent of a group of organisms and is one of the primary goals of systematic (Simpson 2006). It is commonly represented in the form of a cladogram or phylogenetic tree, a branching diagram that graphically represents the best estimate of phylogeny. The lines of a cladogram are known as lineages or clades. Any branching of the cladogram represents lineage diversification, the formation of two separate lineages from one common ancestor.

Phylogenetic analysis, also referred to as cladistic analysis or cladistics is a method of analysing phylogenetic data objectively, in a manner similar to that in which phenetic analysis seeks to introduce objectivity into phenetic classifications. Characters are analyzed to distinguish between *homologies* i.e. characters shared between two or more species that were present in their common ancestor, from *analogies* i.e. characters shared between two or more species that were not present in their common ancestor (Simpson 2006). Homologous characters will have the same structure, related to the surrounding parts and well developed in a set of species (Stuessy 1990). In principle, the shortest hypothetical pathway of changes that explains the present pattern is considered the most likely evolutionary route.

Phylogenetic methods differ from phenetic ones in that *a priori* reasoning is used to determine routes of evolutionary change. In phylogenetic analysis, one has to compare only homologous structures. Once homology is established, the polarity (direction) of change in a character state is determined either through fossil evidence or, by use of outgroup comparison (Stace 1989; Stuessy 1990; Judd *et al.* 2002). Fossil evidence is rarely available and hence the use of outgroup comparison is the most common method (Stace 1989). Since two or more states of a character are found in a single monophyletic group, the state that is also found in the outgroup is considered plesiomorphic (primitive) and that found only within the monophyletic group are considered apomorphic (derived). Only monophyletic groups should be recognized as taxa, and sister groups should be recognized at the same taxonomic rank (Hennig 1966).

The basic units that are manipulated in cladistics are evolutionary units (EU). Once a set of data relating to plesiomorphic versus apomorphic states has been organized for all the EUs, a data matrix is constructed and then a phylogenetic analysis is run using the desired method. The cladograms obtained from the analysis of the matrix are usually based upon the most parsimonious way in which the EUs can be connected to account for the data in the matrix. The nodes in a cladogram are considered to represent ancestral monophyletic taxa. These are however hypothetical and are known as hypothetical taxonomic units. They may be regarded as hypothetical ancestral species, but are usually seen as supraspecific categories of various ranks (Stace 1989). The fundamental of parsimony requires establishment of an 'unrooted' and 'rooted' tree. Rooted trees are more informative and help to deduce the position of the deepest ancestor of a group of species. On the other hand, unrooted tree is less informative since it will only show the branching patterns and relationship between species without indication of most recent common ancestor or time dimension.

In this study twenty one (21) informative characters states based on morphological data were selected and coded for the phylogenetic analysis of *Pteris* species occurring in tropical Africa (Table 4). The species under study were scored for these characters and the resultant matrix was analysed using PAUP4.0b10 package (Swofford 2005).

Table 4. Character and character states used in phylogenetic analysis

Character no.	Characters	Character states
1.	Rhizome	Creeping (0); erect (1); ascending (2)
2.	Sori length	≤1 cm (0); ≥1.1-5 cm (1)
3.	Venation	Free (0); anastomosing (1); areoles (2)
4.	Gemmae	Absent (0); present (1)
5.	Division of lamina	Simple (0); bipinnate (1); tripinnate (2)
6.	Lamina shape	Elliptic-oblong (0); lanceolate-triangular (1); ovate-triangular (2); oblong-lanceolate (3)
7.	Length of lamina when mature	0-50cm (0); 51-100cm (1); over 1m (2)
8.	No. of pairs of fertile pinnae	1-4; (0); 5-9 (1); 10 and above (2)
9.	Basal pinnae	Basispic spur (0); pinnate (1); bi-tripinnate (2); tripinnate (3)
10.	Margin of apices of pinnae lobes	Entire (0); spinulose (1); dentate (2); variously serrated (3)
11.	Costae texture	Smooth (0); spinulose (1); scaly (2)
12.	Position of urns(spines)	None (0); upper junction of costules (1); underneath junction of costules (2)
13.	Costules texture	Smooth (0); spinulose (1); scaly (2)
14.	Position of spines	None (0); upper surface (1); beneath (2)
15.	Stipe general texture	Glabrous (0); pubescense-scaly (1); spinulose (2); muriculate (3)
16.	Stipe base colour	Straw (0); reddish (1); purplish (2); dark brown (3)
17.	Texture of stipe bases	Smooth (0); scaly (1); spinulose (2); muriculate (3)
18.	Scale shape	Lanceolate (0); linear-lanceolate (1);ovate- acute (2); linear (3)
19.	Scale colour	Brown (0); pale brown; (1); blackish brown

		(2); chestnut (3)
20.	Scale margins	Entire (0); pale (1); erose (2)
21.	Mid rib of scale	Dark (0); black (1); red-chest nut (2); none (3)

3.1.3 Conservation

Biodiversity loss is one of the world's most pressing crisis with many species declining to critically low levels and with significant numbers going extinct (Vié *et al.* 2008). The World Conservation Union (IUCN) has established procedures for assessing the conservation status of species in the wild. To facilitate in the assessment, IUCN Red List Categories and Criteria were developed (Fig. 2) and are widely accepted as the most objective and authoritative system available for assessing the global risk of extinction for species (Rodrigues *et al.* 2006). The system is objective allowing assignment of species to one of eight Red List Categories. The species in consideration must meet set criteria linked to population trend, size and structure and geographic range. Setting priorities take into account other factors such as ecological, phylogenetic, historical, or cultural preferences for some taxa over others. The probability of success of conservation actions are also put into considerations. The results of the assessments are then communicated in a codified and easily understood form.

New species of ferns and lycophytes continue to be described and many others are yet to be discovered. At the same time, there is an increased habitat destruction and loss threatening the survival of this ecologically important group of plants. Measures need to be put into place to safeguard and ensure their continued existence, and such activity will be of value if it is done early enough before some species disappear. In some areas and ecosystems, ferns and lycophytes of conservation concern are well known and mitigation measures launched. In such cases, conservation efforts has already been put into place which include in-situ and ex-situ conservation. In Kenya and the region, conservation status of ferns and lycophytes are unknown except for the tree ferns. The conservation status of *Pteris* species in this study is assessed through literature review, analyzing information from herbaria, and field surveys. Redlisting assesement for each species is

evaluated and a category assigned. This information accompanies the species accounts in the taxonomic treatment section.

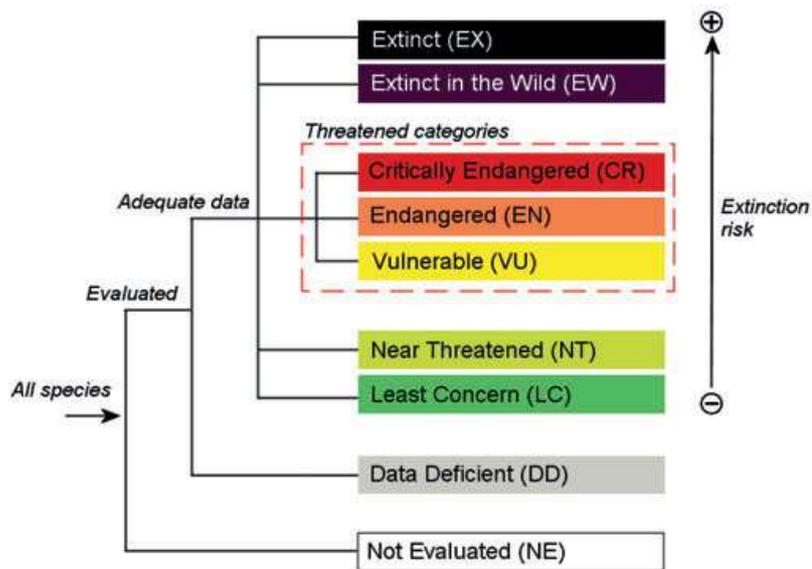


Figure 2. Summarized diagram of Red List assessment approach
Adopted from Vié *et al.* 2008.

CHAPTER 4. RESULTS

4.1 Morphology

Morphology form important tools when other methods for species identification are not available. In most cases, data from other sources such as molecules and chemicals must be correlated with morphological data where possible. Information on morphology of *Pteris* from tropical Africa presented here was gathered from different herbaria, field surveys and literature review.

Most of the names assigned to different species are confusing and in some cases the rules of priority was not applied. It was also found that hybrids exist in some species e.g. *Pteris commutata* x *Pteris hamulosa*. Detailed morphological analysis was done to gather comprehensive data for phylogenetic analysis. The resulting morphological data matrix (Table 3) was analysed phenetically to investigate any infrageneric variation in *Pteris*. This approach was particularly suitable in investigating species complexes (e.g. *Pteris atrovirens*, *P. similis*, *P. catoptera* and *P. dentata*). Illustrations for three species which were described by Verdcourt (Verdcourt 2002) are provided in Figures 3, 4, and 5.

4.1.1 Rhizome

Pteris rhizomes occur in various forms but in most cases they are usually woody, stout and erect. Other forms such as decumbent, creeping to ascending have also been reported. Rhizomes are usually covered by dense and persistent scales, in rare cases the scales are absent. Where scales are present they are mostly sessile, linear, lanceolate or cuneate in shape, brown or dark brown in colour with or without a dark central stripe. The margins of the scales are entire, erose, hairy, or pale.

4.1.2 Frond

Fronds monomorphic or dimorphic, erect or arching, tufted or rarely spaced as observed in two species i.e. *Pteris buchananii* and *P. vittata*. In some species, fronds have gemma e.g. *Pteris atrovirens*, *P. auquieri*, *P. microlepis*, *P. similis* and *P. preussii*. Stipe usually with 1 U-shaped vascular strand or rarely this divided at base into 2 C-shaped strands joining above into a U-shape.



Figure 3. *Pteris albersii* subsp. *uraguensensis* Verdc.
(A) Lamina, (B) Lower surface of fertile pinna, enlarged. All from *Bono* 38 (EA). Drawn by Nicholas Muema.

4.1.3 Stipe

The stipe of a fern frond is homologous to the petiole of seed plants, and has considerable taxonomic importance in describing family, generic, or species relationships. In genus *Pteris*, the stipe is mostly straw-coloured, smooth or sparsely covered with some scales which are larger than those found in rhizomes. In some species, stipes are darker, curved and densely scaly at the base. Stipes occasionally thick and fleshy, in some species thin, glabrous, spinules to muriculate or rarely spiny except in *Pteris intricata*. The distinguishable feature of the stipe used as a taxonomic indicator is number and position of grooves, which in most ferns occur on the adaxial surface or lateral sides. The stipe of *Pteris vitatta* is adaxially sulcate with a single central groove.

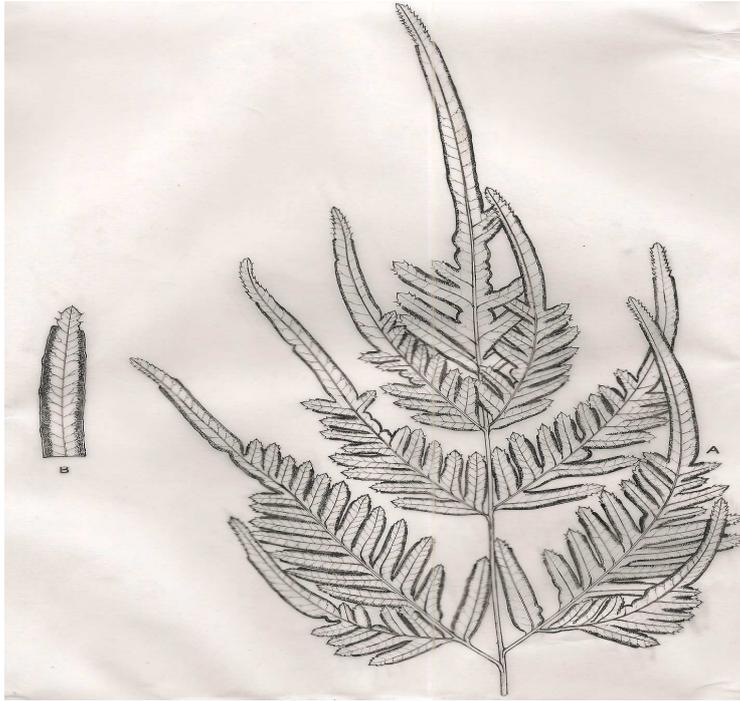


Figure 4. *Pteris albersii* subsp. *mufindiensis* Verdc.
(A) Lamina, (B) Lower surface of fertile pinna, enlarged. All from *Schippers* 1431 (EA).
Drawn by Nicholas Muema.

4.1.4 Lamina

Lamina of *Pteris* anadromous and or catadromous, occurs in various shapes ranging from ovate, triangular, oblong-ovate, lanceolate, deltoid, or elliptic-oblong. Lamina texture is variable, which could be glabrous or sparsely scaly, papery or leathery. Lamina architecture simply pinnate, bipinnate, tripartite or quadripinnate at the base.

4.1.5 Lobe apices

The margin of lobe apices of fertile and sterile pinna lobes entire, serrate, crenulate, dentate or spinulose - mucronate; rounded, acute to acuminate.

4.1.6 Indumentum

The indumentum of pinnae, stipes, rachis, costae, and costules consist of trichomes and scales, both of which are outgrowth of epidermis. The scales of *Pteris* occur in various shapes such as lanceolate to linear-lanceolate, with entire, toothed, or fringed margins.

4.1.7 Venation

The veins of *Pteris* are either free, simple, or forked; or anastomosing in the lobes with some forming narrow or arched areoles below the costae.

4.1.8 Sori

The sori are marginal, linear and elongate, covered by continuous false indusium formed from reflexed lamina margin. In some species e.g. *Pteris dentata* and *P. commutata*, the indusium is characteristically either erose or irregular along the margin.

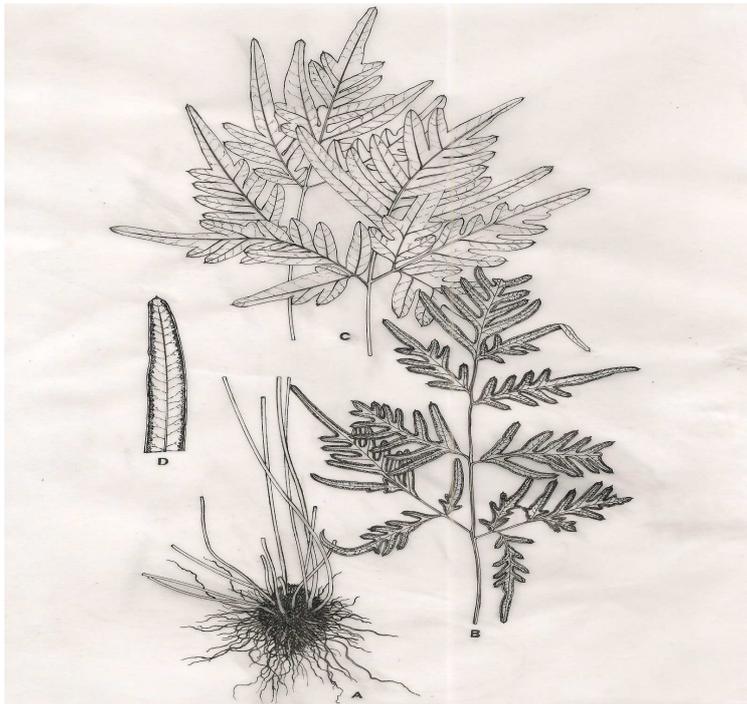


Figure 5. *Pteris mkomaziensis* Verdc.

(A) Rhizome and parts of stipe (B) Fertile frond (C) Sterile frond (D) Lower surface of fertile pinna, enlarged. All from Abdallah, Mboya and Vollesen 96/91 (Type:K). Drawn by Nicholas Muema.

4.2 Cytology

Cytological information for *Pteris* species was provided by (Walker 1962). There are 5 species which are sexual diploids with $2n = 58$. Four species are sexual, tetraploid with $2n = 116$, *Pteris albersii* is probably apogamous, tetraploid with $n = 116$; while *P. cretica* is apogamous, tetraploid with $2n = 116$. *Pteris intricata* is sexual, tetraploid with $n = 87$ at least as far as Swaziland and Zimbabwe material is concerned; *P. similis* is probably apogamous, diploid with $2n = 58$. Summarized information on chromosome numbers for some species is presented in the species account section.

4.3 Phenetic analysis

This analysis aimed at combining overall morphological relationships among the *Pteris* species in tropical Africa. *Pteris microlepis* which had only one incomplete specimen was excluded from the final phenetic analysis. Therefore, 24 species and 23 character states were considered in phenetic analysis (Table 5) and coded for analysis using STATISTICA version 7.

Table 5. Coded data matrix used in phenetic analysis

<i>Pteris catoptera</i>	12100341220001111021121?111111010
<i>Pteris commutata</i>	422000001030112??02111?1101000010
<i>Pteris intricata</i>	1110022113320121124112??110010010
<i>Pteris tripartita</i>	11020222233000000000? ???110000001
<i>Pteris kivuensis</i>	?2100301113001100131021?100000010
<i>Pteris usambarensis</i>	4220032112300110003232? ? 010100001
<i>Pteris auquieri</i>	1210132012300000004311?0110000010
<i>Pteris bavaçanoii</i>	0210032113100111103103? ?000010000
<i>Pteris buchananii</i>	0210022222300111103?22??010110010
<i>Pteris mkomaziensis</i>	0210032003401111103110? ?000100000
<i>Pteris mildbraedii</i>	121303400020000002010?10110000010
<i>Pteris atrovirens</i>	021103000020100000310?11111100001
<i>Pteris burtonii</i>	021113201030112002311?10100000010
<i>Pteris similis</i>	121113312132112003311001111000101
<i>Pteris multifida</i>	?22000401230100??031120?000000010
<i>Pteris linearis</i>	121303301000011000011?10110000010
<i>Pteris albersii</i>	1210032004100111101112??000100000
<i>Pteris pteridioides</i>	41000221233001000231000?111111010
<i>Pteris cretica</i>	022000201410000? ? 030020?110111010
<i>Pteris vittata</i>	022000012130000??03111??111100111
<i>Pteris hamulosa</i>	321303401032112000313?10110000111
<i>Pteris dentata</i>	3210033122202110002113??111111010
<i>Pteris camerooniana</i>	323010301401000??1110011101000100
<i>Pteris preussii</i>	32101321240001111031122?011110110

Cluster analysis by Unweighted Pair-Group Average (UPGMA) method produced 2 major phenons at 100 Euclidean distance (Fig. 6). The most important character used in separating the two phenons was lamina architecture, pinnate versus 2-3 pinnate-pinnatifid.

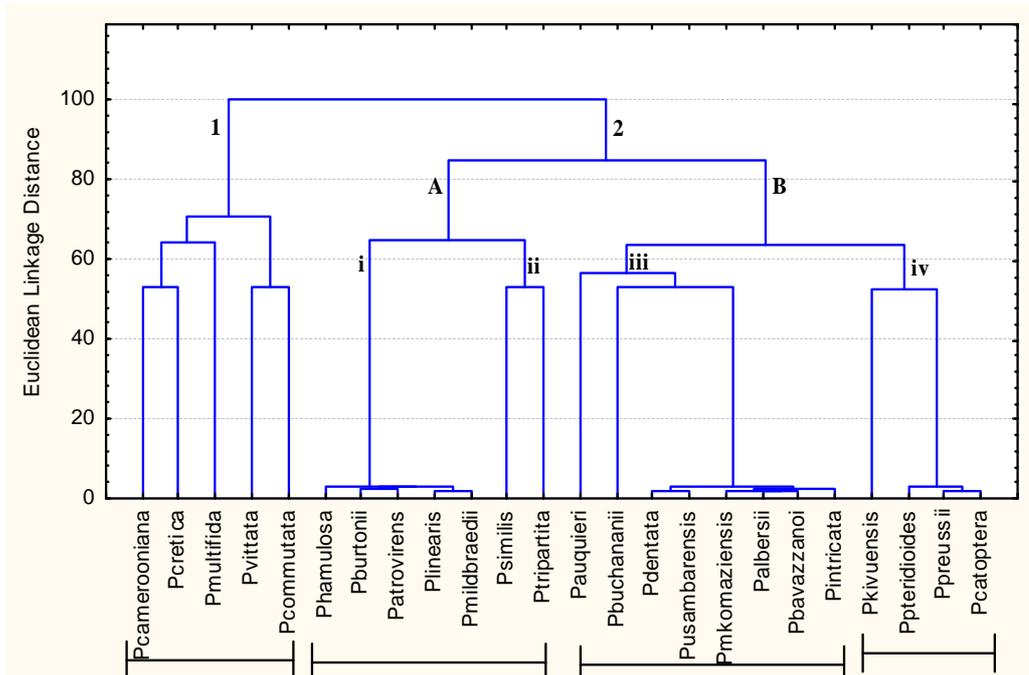


Figure 6. Phenogram of the genus *Pteris* using UPGMA

Phenon one (1) had five species namely, *Pteris camerooniana*, *P. cretica*, *P. multifida*, *P. vittata* and *P. commutata*. The large phenon (2) had all the other 19 species which have lamina architecture bipinnate to quadripinnate. This phenon was further subdivided into two sub-phenons (A and B) at 82 euclidean distance. Sub-phenon ‘A’ constituted of species belonging to former subgenus *Litobrochia*. These species are characterised by having veins anastomosing in the lobes or forming a series of narrow areoles at the base of the costae or costules. This sub-phenon was further subdivided into clusters (i) and (ii). The first cluster (i) had five species which are very closely related with medium sized fronds of up to 1 m high. Species in this cluster are not very distinct from each e.g. *Pteris burtonii* and *P. atrovirens* which are morphologically very similar and they are mostly found growing together. In this cluster, species share most of the characters such as having costae with spinule, sterile lobe apices crenate-serrulate. Cluster (ii) is composed of two species namely; *Pteris similis* and *P. tripartita* distinct from cluster (i) by their large fronds measuring up to 6 m tall with pinnae up to 30 pairs.

Sub-phenon 'B' was composed of species that belong to former subgenus *Pteris* characterized by free veins in their pinnae lobes. This was further subdivided into clusters (iii) and (iv). Cluster (iii) had eight species with *Pteris auquieri* and *P. buchananii* clearly separated from the other six species. *Pteris auquieri* has gemmae on the rhacis while *P. buchananii* has lamina which is tripartite. The other species were clumped together united at a higher level by having sterile lobe apices crenate-serrulate to spinuos mucronate teeth. Cluster (iv) had four species which are characterized by having lamina length more than 1 m long, pinnules numerous up to 51 pairs, stipe glabrous with scaly bases.

4.4 Phylogenetic analysis

This analysis was performed with an objective of providing an overview of the phylogenetic relationship among the *Pteris* species of tropical Africa. Twenty five (25) species of *Pteris* included in this analysis were scored for morphological characters resulting into a coded matrix (Table 6).

Table 6. Data matrix of species and character states used for phylogenetic analysis

<i>Pellaea dura</i>	202000021020?0210003
<i>Pteris catoptera</i>	11003412201111021121?
<i>Pteris commutata</i>	420000010112??02111?1
<i>Pteris intricata</i>	1100221131121124112??
<i>Pteris microlepis</i>	100134112012120110?22
<i>Pteris tripartita</i>	10202222310000000????
<i>Pteris kavuensis</i>	?1003011111100131021?
<i>Pteris usambarensis</i>	4200321121110003232? ?
<i>Pteris auquieri</i>	3101120223000034110?0
<i>Pteris bavaççanoi</i>	0100321131111103103??
<i>Pteris buchananii</i>	010022221111103?22??
<i>Pteris mkomaççiensis</i>	0100320031111103110??
<i>Pteris mildbraedii</i>	113034000100002010?10
<i>Pteris atrovirens</i>	011030000100000310?11
<i>Pteris burtonii</i>	011132010112002311?10
<i>Pteris similis</i>	111133121112003311001
<i>Pteris multifida</i>	?20004012100??031120?
<i>Pteris linearis</i>	113033010011000011?10
<i>Pteris albersii</i>	1100320041111101112??
<i>Pteris pteridioides</i>	40002212311000231000?
<i>Pteris cretica</i>	020002014100? ? 030020?
<i>Pteris vittata</i>	020000121100??03111??
<i>Pteris hamulosa</i>	313034010112000313?10
<i>Pteris dentata</i>	3100331221110002113??
<i>Pteris camerooniana</i>	330103014000??1110011
<i>Pteris preussii</i>	31013212401111031122?

The resultant matrix was analyzed using PAUP4.0b10 (Swofford 2005) using a two-step search strategy resulting into Fig. 7. All the characters were treated as unordered, with equal weight and were assumed to be parsimony informative. In the first step, heuristic search was performed on the matrix using at least 100 replicates of random stepwise taxon addition to find the most parsimonious trees. One tree was held at each step during stepwise addition (Maddison 1991). In the second step, the sampled trees were subjected to branch swapping using Tree Bisection Reconnection algorithm (TBR) and a maximum number of 10,000 most parsimonious trees saved in each replicate. Clade support was assessed with 1000 bootstrap replicates with simple taxon addition and TBR branch swapping, while permitting only 10 trees per replicate to be held. *Pellaea dura* in subfamily Cheilanthesoideae was used as outgroup.

From the results of analysis, all the 21 characters were parsimony informative. A total of 361 most parsimonious trees were recovered and the best tree was obtained at length 136 Consistency Index (CI) 0.3971, Homoplasy Index (HI) 0.6029, Retention Index (RI) 0.4969 and Rescaled Consistency Index (RC) 0.1973. The results (Fig. 7) and phylogeny tree topology was not very well supported by both Strict Consensus and Majority 50% trees. Phylogenetic analysis of the genus *Pteris* produced three main clades A, B, and C.

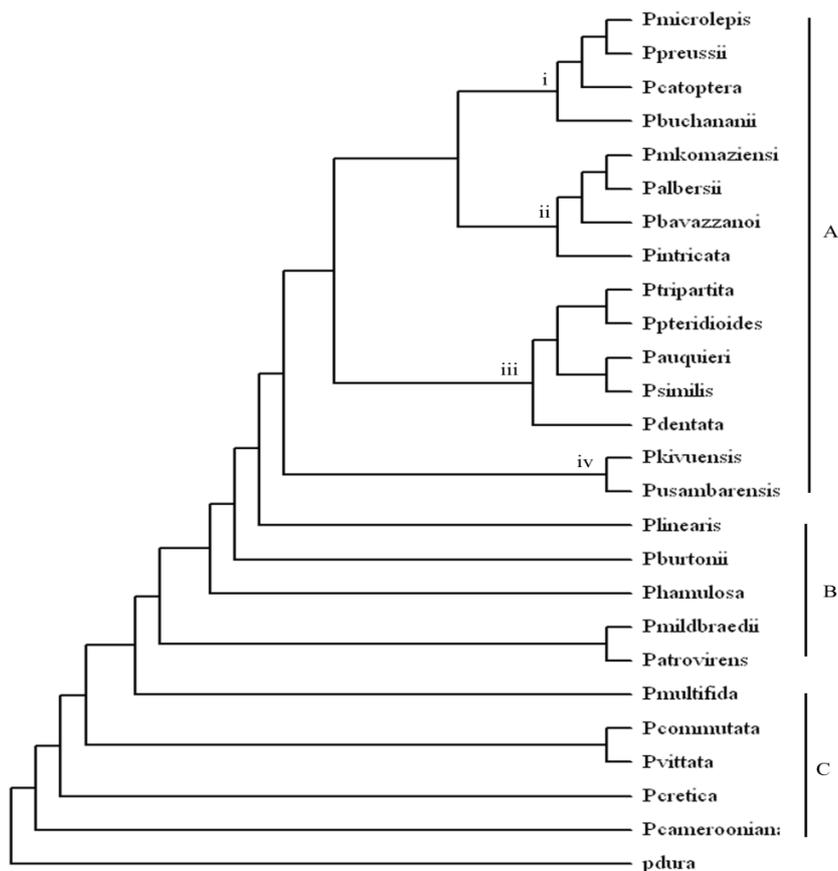


Figure 7. The most parsimonious tree obtained from phylogenetic analysis

Clade 'A' consisted of species with lamina pinnate-pinnatifid to bipinnate above, with some species 3-4 pinnatifid at the base. The clade is again characterized by having free, branched or forked veins in their ultimate lobes, except *Pteris similis* and *P. tripartita*. Species in this clade have costae with spinules on the upper surface at junction with costulae except *Pteris auquieri* which have smooth costae and costulae. This clade is again subdivided into four small sub-clades i, ii, iii, and iv. The sub-clade (i) is made up of species with sterile apices of their ultimate lobes entire except *Pteris buchananii* which have sterile margins strongly serrate. Sub-clade (ii) is composed of species with sterile apices of their ultimate lobes spinulose-mucronate. *Pteris mkomaziensis* and *P. albersii* species have fronds which are dimorphic and more conspicuous in the former. All species in sub-clade (iii) are united together by having costae spinulose on upper surface. *Pteris pteridioides* and *P. tripartita* are united by having lamina which is distinctly tripartite, thus the fronds have three branches of more or less equal length in both species. Each branch is again subdivided into numerous pinnules and ultimate lobes. Sorral length in both species is less than 1 cm

long and sori mostly at the middle of the lobes, at time appearing sunken into a depression. *Pteris auqueri* and *P. similis* both have proliferous fronds with 1-3 buds along the rachis. Sub-clade (iv) composed of *Pteris kivuensis* and *P. usambarensis* both of them have stipes which are longer than blades, and basal pinnae distinctly stalked.

The second clade 'B' is made up of species with anastomosing veins in their lobes, some forming narrow areoles or a triangular arch along the costa. In this clade *Pteris atrovirens* is closely allied to *P. mildbraedii* both of them have 2-7 pairs of pinnae, costae and costulae smooth. These species belongs to a subgenus formerly referred to as *Litobrochia*, but with the new proposed rearrangement of the genus *Pteris* a new name need to be selected for the species with anastomosing veins.

The third clade 'C' had species with lamina simply pinnate at times or with the basal pinnae 1-2 fid. All the species in this clade are free veined. *Pteris multifida* is a naturalized species in Africa recorded only from Uganda and mostly inhabits old abandoned buildings. Many countries outside Africa list it as an invasive species, capable of spreading very fast due to ease of spore dispersal.

Bootstrap/Jackknife analysis was performed, however the tree collapsed due to low support of the changes involved in evolution of the species.

CHAPTER 5. DISCUSSION AND CONCLUSIONS

5.1 Phenetic observations

Phenetic results showed the importance of morphological characters in the taxonomic revision of the genus *Pteris* in tropical Africa. Two major phenons were clearly distinct in phenetic analysis. The most important and taxonomically significant character used in defining and separating major phenons is the lamina architecture. There are three types of lamina architecture observed in *Pteris* species of tropical Africa namely; simply pinnate, bipinnate/bipinnatifid or tripinnatifid. However, morphological groupings of African *Pteris* species assessed fall into two major phenons. The first (1) major phenon had five species all characterized by having lamina simply pinnate at times with 1 or 2 bifid basal pinnae. Species in this phenon have free venation in their lobes. The nodes were well supported with branch length of the same sizes, the species also have free or slightly branched veins.

These characters have been used to delineate species of *Pteris* in other regions as reported by Martinez and Prado (2000). In other genera such *Asplenium*, *Dryopteris* and *Thelypteris* lamina architecture was found to be a useful character to rely on in species identification and delimitation. Some of the species with simply pinnate lamina were reasonably unique and stood out from the rest such as *Pteris vittata*, *P. cretica* and *P. multifida*. It was also possible to identify these species while in sterile state. In the same phenon, *Pteris camerooniana* and *P. commutata* had extra ordinary morphological variations in terms of their lamina length and width at times reaching 1.1 m. This was triggered by the habitats conditions and was common with species growing in deeply shaded areas.

The second (2) major phenon with nineteen species had lamina pinnate-pinnatifid or highly divided. This phenon was then divided into 2 main sub-phenons 'A' and 'B'. This sub-phenons are clearly distinct from each other with 'A' having anastomosing veins and 'B' having free veins. Sub-phenon 'A' was divided into clusters (i) and (ii) which were well defined. Cluster (i) was composed of closely related species and there is a high likelihood that hybridization do occur among some of the species such as *Pteris burtonii* and *P. atrovirens* as observed during field survey in Budongo forest. Phenetic analysis failed to define the morphological boundary between *Pteris burtonii* and *P. atrovirens* based on their morphology. These two species are difficult to delineate using morphology, and the

characters analyzed did not give substantial taxonomic standing. Verdcourt (2002) had suggested combination of this two species due to lack of clear species boundary. It was found that most of the herbarium specimens were all mixed up and was extremely difficult to separate them based on morphological characters. The presence of spines and the distinct number of pinnae found in *Pteris burtonii* that had been used in the past as reliable characters were not taxonomically informative. Evidently, intermediates are common both in the field and in herbarium specimens and taxonomic judgement shows that these two species are most likely cryptic species. Geographical element of both species is not distinct and therefore *Pteris burtonii* and *P. atrovirens* could not be treated as separate entities neither as subspecies. A combination of the two species is done in this study and *Pteris atrovirens* take the priority of the name. More detailed information in taxonomic treatment section.

Pteris hamulosa which also belong to this sub-phenon was clearly distinct from the rest of the species, however all the specimens observed using herbarium collection and field observations were at odds with the type specimen. Type specimen has costae smooth while most of the other materials had characteristically costae densely spinulose. Delineation of *Pteris mildbraedii* a West African species, was hampered by lack of complete type specimen, as the one at Paris herbarium (P) *Preuss* 357 was an illustration of a fragment of a pinnae. Since this study was based on morphological characters from the herbarium specimens, there was no reference point to ascertain some of the characters found in this specimen. Due to identification difficulties, most of the herbarium specimens of *Pteris mildbraedii* were previously identified as *P. atrovirens*. The two species closely resemble each other except that the former has stipes that are distinctly muriculate.

Cluster (ii) of two species, *Pteris similis* and *P. tripartita* was distinct from the others by their numerous pinnae and pinnules. The fronds of these species can grow up to 6 m tall. Both species have veins forming conspicuous narrow areoles along the costae. Sub-phenon 'B' was composed of all the other *Pteris* species of the study area. Cluster (iii) have species whose sterile lobes are variously serrated and stipes smooth except for *Pteris intricata*. This species is distinct by having all its axis chestnut in colour, long spines at times reaching 1 cm long. Cluster (iv) is a mixture of *Pteris* species without clear taxonomic boundary except *Pteris preussii* and *P. catoptera* which have lobes apices entire.

5.2 Phylogenetic relationships

Results obtained in phylogenetic analysis complement the results from phenetic analysis. The bootstrap analysis did not support the topologies generated in the analyses meaning that they had less than 50% bootstrap support. The results from this analysis form a weakly supported monophyly of the genus *Pteris* in tropical Africa. In other words, *Pteris* monophyly from tropical Africa is highly questionable considering that no node had a bootstrap support. This is a clear indication that phylogenetic signals were very weak and hence the evolutionary relationships and path among the species are very uncertain and barely reliable. Some species such as *Pteris catoptera*, *P. dentata*, *P. auquieri*, are widely distributed in many of the ecological zones, they grow in lowlands to afro-montane an indication that they are highly derived and specialized enabling them to colonize in different habitats.

Molecular studies have been going on for some of the *Pteris* species from other regions (e.g. Sanchez-Baracaldo 2004; Schuettpelz *et al.* 2007), unfortunately such studies have not been done African species. The present research on *Pteris* using morphological characters will serve as a starting point for other scientists interested in advancing fern research. Schuettpelz *et al.* (2007) had proposed that since *Pteris* is polyphyletic, most of the species of the currently circumscribed *Pteris* would be included in an expanded *Campteria* or *Litobrochia*. However as suggested in the literature, this work proposes for a more inclusive *Pteris* classification system that will hold species together rather than splinting the genus to accommodate the more isolated species within the genus such as *Pteris vittata*, *P. longifolia* and their allies.

Christenhusz *et al.* (2011a) has already provided a solution to our problem by including some smaller genera into *Pteris* clade in order to maintain the monophyly of the genus. The previous subgenera applied to various species of *Pteris* are in this study referred to as former due to the proposed changes suggested and as more results of molecular studies of the genus *Pteris* becomes available. This is because the lectotype of the genus *Pteris* which is *Pteris longifolia* with simply pinnate lamina is strongly isolated within the genus. The more divided species need to be referred to by another subgenus name. Therefore, until such a

time when more data becomes available on African species as well as from other regions, this study avoided grouping the clades into subgenera.

Some of the characters that had fairly strong support for some clades included the presence of spinules on the costae and costulae, lamina architecture, colour of the stipe bases, type of the rhizomes, presence of gemmae though other authors e.g Verdcourt (2002) indicated that two species cannot solely be delimited on the bases of presence or absence of gemmae. Sanchez-Baracaldo (2004) argues that the scale colour can help in scoring some of the closely related genera. For example, *Pteris* is clearly distinguishable from *Afropteris* by comparing its scales color.

Afropteris as a genus was embedded in *Pteris* clade as evidenced by recent classification using molecular phylogeny (Christenhusz *et al* 2011a). However, morphological data available during the course of this study did not fully agree with the previous authors conclusions. This is attributed to scarcity of reference materials available as only one specimen was studied and as such not enough to make a conclusive taxonomic statement. It is however recommended that more reference materials should be studied and data obtained collaborated with the molecular data already available.

5.3 Conclusion and recommendations

The morphological analysis provided information on phylogeny of 27 species of *Pteris* including sub-species occurring in the selected study area of tropical Africa. Several gaps were identified especially in species with complexes e.g. *Pteris catoptera* and *P. atrovirens* which need further studies. *Pteris* phylogeny however is not fully resolved having weak bootstrap support of less than 50% for all the species. Future studies should always have a molecular component in order to compare two set of generated data. It is highly recommended that molecular studies be carried out which will greatly improve our understanding of *Pteris* phylogeny occurring in tropical Africa. Results obtained from such studies will be used to complement the morphological data presented here.

The relationships of the species currently in *Pteris* need first to be resolved by having good sampling and carrying out phylogenetic analysis on a global scale to study and understand their relationships. *Pteris* is widely distributed genus mainly in the tropics, therefore studies of the relationships between the African lineages and those of Madagascan and Asian, and the tropical American groups are highly recommended. This will help in understanding of their evolutionary paths and relationships. This work provide a good baseline for species occurring in tropical Africa and further studies on the genus may provide crucial information that can be combined to give a more comprehensive analysis. Therefore, there is an urgent need for more studies on a global scale on genus *Pteris*, which will yield more information to contribute towards the proposed new changes. Apart from some few combinations effected in this study, no extensive rearrangement was made until more information/data is available.

This study strongly agree with previous authors that with the data available, it is not necessary to reorganize and reassign species and affect the extensive nomenclatural changes required to separate the majority of species from the few *Pteris vittata* and *P. longifolia* allies as also noted by He and Zhang (2010). It is important that more research on *Pteris* should be carried out globally and data obtained compared in order to make good taxonomic judgement. The wide range of information including phylogenetic analysis now available tend to have same conclusion that *Pteris* as it was previously circumscribed is not monophyletic. Based on such conclusions it is clearly unfolding that many people would opt for a more inclusive genus *Pteris* as proposed by Christenhusz *et al.* (2011a) instead of separating it into many number of monotypic genera.

5.4 Systematic treatment of *Pteris* of tropical Africa

Pteris L. Sp. Pl. 2: 1073 (1 May 1753); Walker (1958, 1962); Schelpe (1969); Tryon *et al.* (1990); Verdcourt (2002); Smith *et al.* (2006, 2008); Christenhusz *et al.* (2011a). Lectotype: *Pteris longifolia* L., designated by J. Smith (1875: 295). Selected by Christensen among the Linnaean species (Copeland 1947).

Etymology: Brake (Greek *Pteris*, fern, derived from Pteron, wing or feather, for the closely spaced pinnae, which give the leaves a likeness to feathers).

Synonyms

Litobrochia C. Presl, Tentamen pteridographiae: 148 (Oct. 1836). Type: *Litobrochia denticulata* (Sw.) C. Presl; *Pteris denticulata* Sw.

Pteris L. subgen. *Litobrochia* (C. Presl) Hook. Species Filicum 2, 7/8: 207 (Jan–Sep. 1858).

Pycnodoria C.Presl, Epimeliae botanicae: 100, 101 (1851). Type: *Pycnodoria opaca* (J.Sm.) C. Presl; *Pteris opaca* J.Sm.

Lathyropteris Bonap. In Bulletin de l'Herbier Boissier, ser.

Afropteris Alston in Boletim da Sociedade Broteriana, Ser.2, 30:5 (1956a), as '*Aropteris*'. Lectotype: *Afropteris repens* (C.Chr.) Alston; *Pteris repens* C.Chr.

Lonchitis L. Sp.Pl. (1753) 1078

Campteria Presl, Ten. (1836) 146

Pycnodoria Presl, Epim. Bot. (1849) 100

Heterophlebium Fee, beneral (1850-52) 139, Pl.11 A, f. 9-12.

Antiosorus Roemer: Kuhn, Chaetopterides (1882) 347.

Anisosorus Trev. Atti 1st. Veneto II 2 (1851) 166: Maxon, Pterid. Porto Rico (1926) 429.

Pteris L. is a large, diverse, pantropical, and isolated genus with 280 species, of which 61 occur in Africa, (Arbeláez 1995; Roux 2009). *Pteris* has long resisted attempts to either unite it with other genera in a higher monophyletic unit or divide it into convenient natural groups (Price 1974). *Pteris* has reclaimed its obvious relatives *Schizostege* Hillebrand (Wagner 1949) and *Hemipteris* Rosenst. (Holttum 1966) whereas the only superficially similar *Lonchitis* L. is now placed in Lonchitidaceae (Christenhusz *et al.* 2011a). The most recent attempt to subdivide *Pteris* was that of Shieh (1966), who only dealt with the 34 species of Japan and

nearby islands and failed to make the exhaustive morphological study necessary or finding the new and well-defined characters undoubtedly required for classification within the genus (Price 1974). Many of the infrageneric groups form intricate complexes (Walker 1962) and critical characters for differentiating within and among these groups have been difficult to discover. In the most recent classification of the genus, Christenhusz *et al.* (2011a) opted for an inclusive monophyletic *Pteris*, including the phylogenetically embedded genera *Afropteris*, *Anopteris* (Prantl) Diels, *Campteria*, *Hemipteris*, *Heterophlebium*, *Lathyropteris*, *Lemapteris* Raf., *Litobrochia*, *Neurocallis* Fee., *Ochropteris* J.Sm., *Peripteris* Raf, *Platyroma* R.Br., *Pycnodoria*, and *Schizostege*, a classification which is followed here.

Key to genus *Pteris* of tropical Africa

1. Fronds simply pinnate, basal pinnae usually simple; 1-3 lowermost basal pinnae with 1-3 basiscopic lobes2
1. Fronds pinnate- pinnatifid to highly divided or tripartite above; basal pinnae 1-4 pinnate or pinnatifid, basiscopic pinnae or pinnules larger than the rest6
2. Pinnae up to 55 pairs; basal pinnae all simple, gradually and conspicuously reduced in size1. *P. vittata*
2. Pinnae 3-14 pairs; basal pinnae with 1-3 basiscopic lobes, no variation in pinnae sizes.....3
3. Fronds dimorphic; sterile ones broader than fertile one; sori less than 15 cm long; lamina ovate to triangular; middle pinnae shortly stipulate or decurrent4
3. Fronds monomorphic; sori 3-22 cm long; lamina \pm oblong to broadly ovate; lateral pinnae always sessile never decurrent5
4. Lamina with 3-10 pairs of pinnae; fertile linear, shorter than sterile ones, 6-25 cm long, 0.7-1.5 cm wide; sterile lanceolate, up to 35 cm long, 0.7-2.5 cm wide with conspicuously sharply serrate to spinulose-margins; rachis free2. *P. cretica*
4. Lamina with 4-6 pairs of pinnae; fertile longer and narrower than sterile ones, 8-25 cm long, 2-7 mm wide; sterile ones 1-15 cm long, 0.5-1.2 cm wide, margins serrate; rachis prominently winged from decurrent pinnae bases3. *P. multifida*
5. Costae and costulae smooth beneath; pinnae margin regular/entire4. *P. camerooniana*
5. Costae and costulae spinulose beneath; pinnae margin undulating or irregularly lobed5. *P. commutata*
6. Veins anastomosing throughout the lobes and below the sinuses some forming areoles along the costa; with or without free included veinlets.....7
6. Veins free, forked or branching near the margin or from the costules; clearly visible in the lobes13
7. Lamina distinctly tripartite; basal pinnae always larger than the rest, reaching up to 1 m long8
7. Lamina not tripartite; basal pinnae of equal size as lateral pinnae, less than 85 cm long.....9
8. Rhizome erect; fronds tufted and arching; lamina ovate triangular; veins oblique; costal areoles arched; stipe stout, 0.5-2 m long11. *P. tripartita*

8. Rhizome widely creeping; fronds spaced and upright; lamina broadly triangular; veins visible; costal areoles narrow; stipe 0.7-1.2 m long**12. *P. buchananii***
9. Fronds without gemmae; sinus not covered by sori10
9. Fronds with 1-3 terminal gemmae; sinus covered by sori11
10. Lobe apices of sterile and fertile pinna lobes strictly entire; rounded..**21. *P. linearis***
10. Lobe apices of sterile and fertile pinna lobes serrate-crenulate or dentate; acute to acuminate12
11. Basal pinnae with a basispic pinnule or spur measuring upto 11 cm long; lamina triangular, 15-50 cm long, 14-39 cm wide; pinnules 8-20 pairs**6. *P. atrovirens***
11. Basal pinnae without a spur, instead pinnate-pinnatifid; lamina lanceolate, up to 5.2 m long and 60 cm wide; pinnules (12-20)-29 pairs**7. *P. similis***
12. Rachis and costae densely spinulose beneath; stipe smooth, 30-75 cm long.....**8. *P. hamulosa***
12. Rachis and costae smooth beneath; stipe muriculate, 50-120 cm long**9. *P. mildbraedii***
13. Stipe and rachis densely spiny; spines erect or recurved measuring (0.3-0.5)-1 cm long; all axes chestnut coloured**13. *P. intricata***
13. Stipe and rachis not spiny; axes variously coloured14
14. Ultimate lobes large; 1.5–10.5 cm long; sori 0.5–7.5 cm long, occupying more than ½ of the lobes margins; basal pinnae sessile or stalked; lamina leathery15
14. Ultimate lobes small; 0.4–1.8 cm long; sori 1-8 mm long, mainly median in position, occupying up to 1/3 of the lobes margins; basal pinnae always stalked; lamina papery**14. *P. pteridioides***
15. Lobes margin of sterile and apices of fertile ones mucronate or spinulose-serrate, fertile lamina 2-4 pinnatifid at base16
15. Lobes margin of sterile and apices of fertile ones dentate to entire, fertile lamina bipinnate- pinnatifid at base20
16. Lower pinnae with distinct stalks 0.5-10 cm long; stipe longer than the blade; restricted to eastern arc mountains; pinnules 10-31 pairs, 0.5-3.5 cm long.....17
16. Lower pinnae sessile or shortly stipulate; stipe almost the same size as the blade; widespread; pinnules 4-22 pairs, 1.8-11 cm long.....18
17. Pinnae gradually tapering upwards into a medium sized tail 5-12 cm long; middle and upper pinnae stalked; pinnules close together with their edges touching; sterile part of fertile segments irregularly minutely serrate with sharp mucronate teeth; blade light green**16. *P. kivuensis***
17. Pinnae abruptly tapering into a long tail 8-23 cm long and 4-15 mm wide; middle and upper pinnae sessile; pinnules at a distant from each other; sterile part of fertile segments coarsely serrate; blade dark green.....**17. *P. usambarensis***
18. Fronds distinctly dimorphic; fertile longer than sterile, reaching 35-50 cm long; rhizome shortly creeping; pinnae 3-4 pairs**18. *P. mkomaziensis***
18. Fronds monomorphic; rhizome erect or creeping; pinnae 3-8 pairs19
19. Fertile lamina quadripinnatifid at base; 5-8 pairs of pinnae; rachis clearly distinct in all length of blade**15. *P. bavazzanoi***
19. Fertile lamina tripinnatifid at base; 3–4 pairs of pinnae; rachis not clearly distinct in the upper half of blade**19. *P. albersii***

20. Costae and costulae with spinules above at junction with costulae; pinnae 4-23 pairs21
20. Costae and costulae smooth above; pinnae 3-(7-8) pairs, approximately 55 cm long and 5-12 cm wide**10. *P. auquieri***
21. Sterile margin dentate, usually with numerous teeth; basal pinnule of only the basal pinnae 2-pinnatifid; pinnules fulcate, decurrent on the costa**20. *P. dentata***
21. Sterile margin entire; pinnules oblong to lanceolate, sessile or shortly stipulate22
22. Fronds without gemmae at apex; rhizome scales with pale hairy margin**24. *P. catoptera***
22. Fronds gemmiferous; rhizome scales with erose margins23
23. Sori extending for most of the length of the lobes 2.5-4.2 cm long.....**23. *P. preussii***
23. Sori short, 2-7 mm long at the middle of the pinnae lobes.....**22. *P. microlepis***

1. ***Pteris vittata*** L. Sp. Pl. 2: 1074 (1 May 1753); F.D.-O.A.: 46, footnote (1929); U.O.P.Z.: 260 (1949); Tardieu, in Mem. I.F.A.N. 28: 69, t. 10, figs. 1-2 (1953); & Fl. Madag. 5 (1): 85 (1958); Alston, Ferns W.T.A.:40 (1959); Tardieu, Fl. Cameroun 3: 154, t. 21, figs. 1-2 (1964); Schelpe, Contr. Bol. Herb. 1: 59 (1969) & F.Z. Pterid.:115 (1970) & Expl. Hydrobiol. Bassin L. Bangweolo & Luapula 8 (3) Pterid.: 56 (1973) & C.F.A. Pterid.: 90 (1977); Schelpe & Diniz, Fl. Mozamb., Pterid.: 115 (1979); W. Jacobsen, Ferns S. Afr.: 235, figs. 53, 167 (1983); Schelpe & Anthony, F.S.A. Pterid.: 105, fig. 31/1 (1986); Burrows, S. Afr. Ferns: 158, t. 25/7, fig. 38/158, 158a (1990); Johns in Pterid. Trop. E. A. 31 (1991); Schippers in Fern Gaz. 14: 186 (1993); Thulin, Fl. Somalia 1: 13, fig. 7 (1993); Faden in U.K.W.F. ed. 2: 20 (1994); Roux, Consp. S. Afr. Pterid., SABONET, 13: 80 (2001); Verdcourt, F.T.E.A. Pterid. 6, 8, fig. 2/1 (2002); Roux, Swazi. Ferns & Ferns All. SABONET, 19: 99 (2003); Roux in Strelitzia 23: 176 (2009); Crouch *et al.* Ferns S. Afr. 316-317, t. 1-5 (2011). **Type:** China, *Osbeck s.n.*, (lectotype, chosen by Tryon 1964: 191: LINN-1246.3).

Synonyms

Pteris ensifolia Poir., Encyl. Meth. Bot. 5: 711 (1804), nom. nov. based on *P. lanceolata* Desf., non L. (1753: 1073). Type: Cette plante croit en Espagne & dans les environs d'Alger, fur le bord des ruisseaux. **Type:** Algeria, Algiers, by rivers, Desfontaines s.n. (holotype: P).

P. diversifolia Sw., Synopsis filicum: 96 (Mar.-Apr. 1806b). Type: Java, *sine coll. s.n.*

P. lanceolata Desf., Flora atlantica 2, 9: 401 (Jul. 1799). Type: Same as for *P. ensifolia*.

P. longifolia sensu Hieron. in P.O.A. C: 79 (895) & in V.E. 2: 45 (1908); Sim, Ferns S. Afr. ed. 2: 252, t. 125 (1915); F.D.-O.A.: 46 (1929); Ogata, 1c. Fil. Japan 3: t. 146 (1930), non.

P. costata Bory ex Wild., Sp. Pl., ed. 4, 5, 1: 367 (Jun. 1810). Type: Habitat in insula Mauritii, Bory de St. Vincent s.n. (holotype: B-W, isotype: P).

Rhizomes short, creeping, much branched with brown lanceolate scales. Fronds tufted and occur in massive colonies, 4.0-1.3 m tall. Stipes dark brown, (3-)13-33 cm long, bases dark brown and densely scaly. Laminae elliptic-oblong, 0.45-1.00 m long, 15-42 cm wide, subcoriaceous, simply pinnate. Pinnae 23-55 pairs, 6-21 cm long, 0.5-1.5 cm wide, narrowly lanceolate, systematically reduced in size towards the base, the lowest often appearing as auricles. Rachis glabrous or slightly muriculate. Veins free, at times once-forked. Fertile pinnae narrower than sterile ones. Sori linear, covering most of the pinnae

length as long as 19 cm long. Margins of sterile pinnae and apices of fertile pinnae minutely crenulate.

Ecology: Often in exposed areas, rock crevices and coral rag, roadsides, river banks and wet evergreen forests.

Distribution: Algeria, Angola, Botswana, Burundi, Cameroon, Cape Verde Isl., Comoro Is., Djibouti, DRC, Ethiopia, Ghana, Kenya, La Reunion, Lesotho, Libya, Madagascar, Mauritius, Malawi, Mascarene Is., Morocco, Mozambique, Namibia, Rwanda, Sao Tome, Socotra, Somalia, South Africa, Sudan, Swaziland, Tanzania, Tunisia, Uganda, Zanzibar, Zambia, Zimbabwe, tropical Asia, Australia, Polynesia, Europe, tropical America.

Elevation: 0-1960 m

Chromosome numbers: Sexual tetraploid, $n = 58$ (Manton 1959: 79; Walker 1962:32, [www.tropicos.org/Pteris vittata](http://www.tropicos.org/Pteris_vittata)).

Conservation status: Least Concern (LC)

Note: *Pteris vittata* is often confused with *P. longifolia* L., a New World species which differs in having pinnae which are articulate to the rachis. However, this is the only *Pteris* species in Africa that is uniformly pinnate. The pinnae width of specimens from DR Congo are extraordinarily narrower 1-5 mm wide, their stipe bases are densely scaly. Some specimens have sparsely muriculate stipe, others have pinnae either stalked or sessile.

Representative specimens examined: **Burundi:** Bujumbura, Gitaza, 6 Dec. 1974, *Reekmans M* 3994 (K); Bujumbura, Mutumba, 20 Nov. 1971, *Reekmans M* 912 (EA); **DRC:** Beni, Albert National Park, Entre Kitwara (Route Goma Sake) et le Volcan Rumoka, 7 Nov. 1937, *Louis J* 4935 (EA); Albertville, 5 Nov. 1946, *Van Meel L* 32 (EA); Goma, Goma-Sake road, 23 Dec. 1957, *Napper DM* 673 (EA). **Ethiopia:** Floor of Bole Canyon, 14 Feb. 1971, *Asb JW* 733 (EA). **Ghana:** Gold Coast, Bibiana W.P, 18 Nov. 1954, *Daeko KO*1058 (EA). **Kenya:** Taita Taveta district, Msau river valley, 3°24' S, 38°24' E, 18 May 1985, *Kabuye et al.* 609 (EA); Kakamega Forest, Kibiri block, south side of Yala river, 1°10' N, 34°52' E, 21 Jan. 1970, *Faden RB* 70/24 (EA); Mombasa, Bamburi Nature Trail "Kaya", 0°04' S, 39°43' E, 20 Dec. 1991, *Robertson SA* 6525 (EA). **Sudan:** Sunni, Gebel Marra, 22 Dec. 1965, *Kassa M* 774 (EA). **Tanzania:** Mbulu, Lake Manyara National Park, Endabash, 3°30' S, 35°45' E, 20 Nov. 1969, *Vesey-FitzGerald LDEF* 6447 (EA); Mpwapwa, 6°30' S, 36°30' E, 30 July 1936, *Hornby* 721 (EA); Ngare Nanyuki, near entrance to Mt. Meru, 3°09' S, 36°51' E, 9 Jul. 1968, *Spang S* 2506 (EA). **Uganda:** Ankole, Bunyaruguru, near Rugazi, 19 Sept. 1969, *Faden RB* 69/1178 (EA).

2. *Pteris cretica* L., Mantissa Pl.:1: 130 (15-31 Oct. 1767) & Syst. Nat. 2: 688 (1767); Schelpe in Contr. Bolus Herb. 1: 60 (1969) & F.Z. Pterid.: 117 (1970) & C.F.A., Pterid.: 91 (1977); Kornas, Distri. Ecol. Pterid. Zamb. 70 (1977); Johns in Pterid. Trop. E. A. 30 (1991); Schippers in Fern Gaz. 14: 185 (1993); Faden in U.K.W.F. ed 2: 20, pt. 170 (1994); Roux in SABONET, 13: 78-79 (2001); Verdcourt, F.T.E.A. Pterid. 9, fig 2/2 (2002); Roux, Swazi. Ferns & Ferns All. SABONET, 19: 95 (2003); Roux in Strelitzia 23: 171 (2009); *Crouch et al.* Ferns. S. Afr.: 316-317 t. 1-5 (2011). **Type:** Hab. in *Creta, Ilva insula, *P. Arduino s.n.* (lectotype, designated by Tryon 1964: 193: LINN-1246.7, lecto.).

Etymology: *cretica*= from the island of Crete (Greece).

Synonyms

Pteris cretica L. var. *plurilobata* Bonap. In Notes Pteridologiques 14: 311 (1923). Type: Congo (Kinshasa), Rutshuru, Galerie forestiere, Sol ombrage, 1914, J.C.C. Bequaert (holotype: P).
P. cretica L. var. *balansae* Rakotondr. in the natural history of Madagascar: 310 (2003), nom. nud. (McNeil *et al.* (2006) Art. 32.1(d) & Art. 41.3).
P. serraria Sw. in J. Bot. (Schrader) 1800 (2): 65 (1801). Type: Brazil, G.W. Freyreis *s.n.* (holotype: S).
P. nervosa Thunb., Flora Japonica: 332 (Aug. 1784). Type: Japan, Ganso, C.P. Thunberg *s.n.* (holotype: UPS-Thunb.).
P. pentaphylla Willd., Species plantarum, edn 4, 5, 1: 362 (25-27 Jun. 1810). Type: Reunion, Habitat in rupibus insulae Borboniae, J.B.G.M. Bory de St.-Vincent *s.n.* (holotype: P).
P. triphylla M.Martens & Galeotti in Mémoires de l'Académie Royale des Sciences, Lettres et Beaux Arts de la Belgique 15: 51, pl. 14, fig. 1 (1842), nom. illeg. hom. (McNeil *et al.* (2006) Art. 35.1), non *P. triphylla* J. Agardh (1839: 16). Type: Mexico, Veracruz, Xalapa, H. Galeotti 6393 (holotype: BR)
P. treacheriana Baker in Journal of Botany, British and Foreign 8: 65, 66 (Mar. 1879). Type: Philippines, Sulu Archipelago, F.W.T. Burbidges *s.n.* (holotype: K)
P. serraria Sw. in Journal für die Botanik (Schrader, HA, ed.) 1800, 2: 65 (1801). Type: Brazil, Freyreis G.W. *s.n.* (holotype: S).

Plant terrestrial, rhizome ascending or creeping at times forming a woody stock covered by fibrous roots. Rhizome scales brown, lanceolate, with entire margins. Fronds tufted, dimorphic, 0.3-1.1 m tall. Stipes 30-90 cm long in fertile specimens (about ½ of this in sterile fronds) glabrous, base dark brown. Fertile lamina ovate-triangular, 29-45 cm long, 10-26 cm wide, pinnate; pinnae 3-10 pairs; fertile pinnae narrower, linear with acuminate apex, 6-26 cm long, 0.3-1.5 cm wide with entire margins except serrated tips. The upper pinnae adnate to the rachis, the basal pair of pinnae usually unequally bifid, rarely unbranched, acroscopic one larger than basispic. Sterile lamina ovate, sterile pinnae at times double the width of fertile pinnae with conspicuously serrate-spinulose margins. Veins free, sori linear and marginal, covering ¾ of the pinnae length, indusium continuous and entire.

Ecology: This species occupy wide range of habitats from damp river banks in evergreen montane forests, valley vegetation by streams and rivers to shaded and moist roadsides banks. At times found among huge boulders along streams and rivers.

Distribution: Fairly widespread species throughout the tropics, subtropics and Southern Europe, Angola, Algeria, Ascension Isl., Ethiopia, DRC, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Mascarene Is., South Africa, St. Helena, Swaziland, Tanzania, Uganda, Yemen, Zambia, Zimbabwe.

Elevation: 1350-2700 m

Chromosome numbers: tetraploid apomicts, n=58; 2n= 116 (Walker 1962: 30; www.tropicos.org).

Conservation status: Least Concern (LC)

Uses: To ward off bullet, the Sesotho warriors wore the plants as a veil, or they could bathe in water mixed with powdered fronds (Zepp 1982). A popular ornamental plant, mainly indoors or in shaded gardens. Varieties of horticultural cultivars and variegated forms are cultivated.

Note: * Linnaeus presumed the plant was from Crete, but it is not known naturally from there. The dimorphic character and sharply serrate to spinulose sterile margins readily distinguishes this species from any of the *Pteris* species.

Representative specimens examined: **Burundi:** Isinga, Muramwya, 6 Aug. 1971, *Reekmans M* 872 (EA). **Kenya:** Nyandarua, Sasumua Dam, 0°45'79" S, 36°41'13" E, 30 Nov. 2010, *Kamau P* 552 (EA); Mount Kenya Forest reserve next to KWS main gate, 17 Jun. 2010, *Kamau P* 478 (EA); Nakuru district, Subukia forest near a Catholic shrine, 0°01'37" S, 36°15'40" E, 26 Dec. 2010, *Kamau P* 562 (EA); Road East of Lake Ol'Bolossat, 0°09' S, 36°28' E, 2900 m, 19 Mar. 1987, *Beentje HJ* 3265 (EA); Mount Kenya, NE, Thai sacred lake, crater lake a few km West of the town of Meru, 0°09' S, 37°18' E, 30 Jul. 1978, *Zogg E* 257 (EA); Machakos/Kajiado, Chyulu Hills, North, East/Central Chyulu Hills, 2°35' S, 37°52' E, 30 Dec. 1987, *Luke WRQ* 844 (EA); Kenya, Kericho, Sotik, Kibojet estate, 6 Oct. 1948, *Bally PRO* 6466 (EA); **Tanzania:** Arusha, Mount Meru, Naroko saw mill, 3°14' S, 36°45' E, 31 Oct. 1965, *Vesey-FitzGerald LDEF* 4820 (EA); Arusha, Mount Meru, East slopes of Mt. Meru, 3°14' S, 36°45' E, 21 Feb. 1966, *Greenway PJ & Kanuri* 12364 (EA). **Uganda:** Ankole, Buhweju, Rugongo, near a village chapel, 0°22' S, 30°29' E, 7 Jan. 1971, *Rwaburindore* 502 (EA).

3. *Pteris multifida* Poir. in *Encycl. Meth.* 5: 714 (1804); Verdcourt, F.T.E.A. *Pterid.* 17 (2002); Roux in *Strelitzia* 23: 174 (2009); **Type:** Cultivated at the Jardin des Plantes, Paris, of unknown origin, Anon. (holotype: P-LAM!, microfiche).

Plant terrestrial, rhizome short, erect or decumbent. Rhizome scales dark brownish, linear lanceolate, margin usually entire, occasionally glandular. Fronds tufted, 10-21 cm long, dimorphic, sterile pinnae shorter and wider than fertile ones. Lamina light green, ovate; stipes glabrous, stramineous to brown. Pinnae up to 5-6 pairs, with a similar terminal pinnae, lower pinnae 2-3(-5) fid. All upper pinnae decurrent on rachis forming a conspicuous green wing. Fertile pinnae 8-25 cm, 0.2-0.7 cm wide, sterile pinnae reaching 15 cm long and 0.4-1.2 cm wide. Veins free, sori uninterrupted, occupying most of the pinnae margin. Sterile pinnae margin as well as apices of fertile pinnae serrate.

Ecology: Disintegrating wall of old buildings, limestone walls of pits.

Distribution: Uganda (naturalised), India, China to Japan, Korea, Burma, Thailand, Sri Lanka, Malay Peninsula, Florida, Antilles, naturalised in the neotropics.

Elevation: 1200 m

Chromosome numbers: n=58; 2n=116, sexual tetraploid (www.tropicos.org)

Conservation status: Least Concern (LC)

Notes: This species is naturalised in many countries including Uganda. Its prominent wings on the rachis make it readily distinguishable from other *Pteris* species. Commonly grown as a houseplant or outdoor bedding in tropical countries.

Representative specimens examined: **Uganda:** Mengo district, Kampala area, 1 km South of Muninyo, 6 Nov. 1996, *Rwaburindore* 4051 (MHU).

4. ***Pteris camerooniana*** Kuhn, Fil. Afri.: 207 (1868), nom. nov. for *P. camerooniana* Mett.ex Kuhn, non *P. mannii* Baker (1867c:168). Roux in *Strelitzia* 23: 170 (2009). **Type:** Mt. Cameroon, Mann 1385 (lectotype: K.), sensu Tardieu-Blot (1964:155).

Synonyms

Pteris manniana Mett. ex Kuhn, Fil. Afr. 84 (1868); Schelpe in *Contr. Bolus Herb.* 1: 59-60 (1969); Benl, *Acta Botanica Barcinonensia* 38: 166 (1988); Type: As for *P. camerooniana*.

P. jungneri Brause & Hieron., in *Bot. Jahrb. Syst.* 53: 388 (191

5). Syntypes: Cameroon, Bibundi, bei Tsoroi, Jan. 1891, *Jungner* 49 (BM!); Mt. Cameroon in der Pflanzung Bubundi an einem trockenen Wasserlauf 5 Nov.1905, *Hubert* 1105 (BM!).

Rhizome erect or short creeping, rhizome scales lanceolate, brown with a central thick-walled and lateral thin-walled paler cells. Fronds tufted, 0.3-1.1 m tall, with 1-2 bulbils at the base of upper pinnae. Stipes 9-70 cm long, grooved, chestnut to brown, base red and scaly. Rachis channelled above. Lamina 20-40 cm long, 10-25 cm wide, oblong-lanceolate, coriaceous, pinnate. Pinnae 3-(8-14) pairs, linear-lanceolate to falcate, 5.0-23.5 cm long, 0.5-1.6 cm wide, sessile or shortly petiolate, their bases strongly cuneate. Two basal pinnae bifid. Fertile pinnae narrower and longer than sterile ones. In most of the specimens, basal pinnae are slightly stalked, middle ones sessile and upper pinnae decurrent, the apical pinnae similar with lateral one, long stalked. Sterile pinnae margins and sterile tips of fertile ones entire. Costa channelled on upper surface, smooth. Veins free, parallel, simple or forked from the base, sori marginal, 5.7-21.0 cm long.

Ecology: Rock crevices of lava rocks in ravine, gullies, rain forest and high mountains.

Distribution: Bioko, Cameroon, Central Africa Republic, Chad, Equatorial Guinea, Ivory Coast, Madagascar, Nigeria.

Elevation: 100-1400 m

Chromosomes numbers: Sexual diploid, $n = 29$ (Manton, 1959:79; Walker 1962: 29; www.tropicos.org)

Conservation status: Least Concern (LC)

Notes: A native of West Africa.

Representative specimen examined: DRC: Kivu province, Kalehe in Minova, 11 Jun. 1959, *Leonard A* 4606 (EA).

5. ***Pteris commutata*** Kuhn in von der Decken, *Reisen nach Ost-Afrika* 3 (3) Bot.: 20 (1879); Tardieu in *Mem. I.F.A.N.* 28: 70, t. 10, fig. 5 (1953) & in *Fl. Cameroun* 3: 156, t. 21, fig. 5 (1964) as (*'communata'*); Schelpe in *Contr. Bol. Herb.* 1: 61 (1969); Johns in *Pterid. Trop. E. A.*, 30 (1991); Verdcourt, *F.T.E.A. Pterid.* 9-10 (2002); Roux in *Strelitzia* 23: 171 (2009); **Type:** Congo (Kinshasa), R. Diagbe, *Schweinfurth* 3118 (lectotype, selected by Schelpe 1969:61, B) (duplicates: BM!, K!).

Synonyms

Pteris grossiloba Christ in *Ann. Mus. Congo Belge* 5, 3: 29 (1909). Syntypes: Congo (Kinshasa), environs of Amadi, *Seret* 339 (BR!) & between Bambili and Amadi, *Seret* 182 (BR!) & Bena-Dibele, *Flamigni* 58 (BR!).

P. pseudocretica Bonap., *Notes Pterid.* 14: 313 (1923). Syntypes: Congo (Kinshasa), Kalagwa, Penga, *Bequaert* 1606 (BR!) & Walikale to Lubutu, *Bequaert* 6684 (BR!).

Plants terrestrial, fronds tufted, 0.45-1.40 m tall, rhizome mostly erect or rarely creeping. Rhizomes scales brown, linear-lanceolate, midrib dark. Stipes sparsely muriculate 22-(50-76) cm long, straw-coloured, stipe base purple in colour with brown scales. Lamina oblong, 25-40(-60) cm long, 23-40 (-60) cm wide, pinnate occasionally bipinnate. Pinnae oblong-lanceolate, 4-9 pairs, sessile, except 2-3 basal pinnae, 5-30 cm long, 1.1-3.0 cm wide. Terminal pinnae long attenuate 15-23 cm long, 1.1-2.7 cm wide, occasionally bilobed. Some basal pinnae robust measuring up to 48 cm long and 3.5 cm wide, usually 2- or 3-fid; lateral pinnae with acute apex, base cuneate. Pinnae margins undulating or irregularly lobed. In some cases e.g. *Kamau* 331 as observed in Budongo forest, pinnae have abortive pinnules. Rachis glabrous, slightly winged from decurrent pinnae bases. Costae smooth or densely spinulose on the lower side. Veins branching or anastomosing. Sori marginal, 12.5-19.0 cm long, mainly covering most of the length of the fertile pinnae. Margins of sterile pinnae serrate.

Ecology: *Pteris commutata* is a forest species preferring dense and shaded canopy, by swampy or stream sides.

Distribution: Uganda, Tanzania, Cameroon, Democratic Republic of Congo and Sudan

Elevation: 800-1200 m

Conservation status: Least Concern (LC)

Notes: Some specimens e.g. *Kamau* 331(EA) from Budongo forest showed great morphological variations as compared with other specimens. *Kamau* 331 was bipinnate with lamina as wide as 1.1 m.

Specimens examined: Uganda: Bunyoro, Budongo Forest, Nature reserve, at intersection of river Sonso and Nyabusabo, 1°42'06" N, 31°31'56" E, 4 Nov. 2009, *Kamau* P 324 (EA) & same locality 15 Mar. 2009, *Kamau* P 233 (EA); Mengo, Mpanga research forest, 5 km East of Mpigi, 0°13' N, 32°18' E, 9 Sept. 1969, *Faden* RB 1010 (EA).

6. *Pteris atrovirens* (Willd.) Kamau, comb. nov.; *Pteris burtonii* Bak. In Ann. Bot. 5: 218 (1891) as *burtonii*; Sp. Pl. ed. 4. 5, 1:385 (1810); Tardieu in Mem. I.F.A.N. 28: 72, t. 10, figs. 6, 7 (1953); Alston, Ferns W.T.A.:42, fig.10 (1959); Tardieu, Fl. Cameroun 3:158 (1964) & Fl. Gabon 8: 10, t. 18, figs. 1-4 (1964); Schelpe in Contr. Bol. Herb. 1: 60 (1969) & C.F.A. Pterid.:92 (1977); Benl, Acta Botanica Barcinonensia 38: 7 (1988); Johns in Pterid. Trop. E. A. 29 (1991); Roux, Consp. S. Afri. Pterid., SABONET, 13: 80-81 (2001); Verdcourt, F.T.E.A. Pterid. 10-11 (2002); Roux in Strelitzia 23: 170 (2009). **Type:** Ghana, *Burton* & *Cameron* s.n. (holotype: K!).

Synonyms

Pteris atrovirens Wild.var. *inermis* Bonap., in Notes Pteridologiques 14: 229 (23 Nov. 1923). Type: Congo belge Lubefu River. Sept. 1910 *T. Kassner* 3400 (holotype: P!).

P. atrovirens Wild. forma *atrovirens* in F.T.E.A, Pterid., 13 (2002).

P. atrovirens Wild. forma *laevicosta* Verdc. in F.T.E.A, Pterid., 13 (2002). Type: Tanzania, Lushoto District, E. Usambaras, Amani, by Dodwe stream, *Faden* RB 70/259 (holotype: K!; Isotype: EA!).

P. spinulifera Schum. in Kongel. Dansk. Vid. Selk. Naturvid. Afr. 4: 233 (1829). Syntypes: Ghana, Aquapim, (Guinea), *Hornemann*, s.n. (C, 2 sheets) & Guinea, *sine coll.* s.n. (C, 5 sheets).

P. aethiopica Christ in Journ. De Bot. ser. 2, 2: 21 (1909). Syntypes: Ivory Coast, between Abidjan and Makonguie, *Chevalier* 15608 (P!) and Bouroukrou, *Chevalier* 16752 (P!).

P. atrovirens Willd. var. *cervonii* Bonap. in Bull. Mus. Hist. Nat. 19: 388 (1913), nomen. Syntype: Mission geodesique et forestiere de la Ivory Coast, en fevrier-mars 1909, *Cervoni s.n.* (P); Cote d'Ivoire. Region entre l'Agneby et la Bia, *Rousseau, s.n.* (P).

P. burtonii Bak.var. *aethiopica* (Christ) Tardieu in Mem. I.F.A.N. 28: 72, fig. 8 (1953).

P. burtonii Bak. In Ann. Bot. 5: 218 (1891) as *burtoni*. Type: Ghana, *Burton & Cameron s.n.* (holotype: K!).

Pteris johnstonii Bak. in Ann. Bot. 5: 218 (1891), as *johnstoni*. Type: Sierra Leone, Wilberforce, *Johnston s.n.* (holotype: K!).

Terrestrial plant, rhizome firm and woody, shortly creeping or erect, scales lanceolate with a black narrow central stripe and pale margins. Fronds tufted 0.2-1.1 cm tall, with or without a gemmae, when present 1-2 at the base of terminal pinnae. Stipes 12-65 cm long, smooth or sparsely spinulose, often reddish at the base. Lamina 13-50 cm long, 14-40 cm wide, triangular-ovate to deltate in outline, pinnate-pinnatifid or simply pinnate (west African materials). Pinnae 3-5(-9) pairs, oblong-lanceolate, 10-26 cm long, 2.0-9.0 cm wide, sessile or shortly stalked, two basal pinnae with a basiscoopic spur/pinnule. Pinnule 8-20 pairs, 2.0-5.0 cm long, 1.0-1.3 cm wide. Fertile pinnules narrower, longer, and distanced from each other, oblong-lanceolate, subfalcate, sterile ones wider and short, oblong, lobes touching each other at the tips. Rachis narrowly winged by decurrent pinnae bases. A group of dense hairs present at junction of pinnae base and rachis. Apices of sterile lobes margins distinctly crenate-serrate to dentate; obtuse to \pm rounded in shape, those of fertile ones acute-acuminate. Terminal segment, triangular, 4-7 cm long and 1.0-1.3 cm wide. Costae \pm spinulose on both sides for East African materials, specimens from West Africa always spinulose. Veins densely anastomosing in the lobes, narrow coastal areoles formed along the costae. Sori covering $\frac{3}{4}$ at times whole lobes margins except the apex.

Ecology: Along riverine, or moist/swampy lowland evergreen forest, common in full shade and humid undergrowth.

Distribution: Angola, Benin, Bioko, Burundi, Cameroon, Central Africa Republic, Congo, DRC, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Liberia, Nigeria, Pemba, Principe, Sao Tome, Seychelles, Sierra Leone, Sudan, Tanzania, Togo, Uganda.

Elevation: 80-1400 m

Chromosome numbers: Sexual tetraploid, $n = 58$, $2n = 116$ (Walker 1962: 29)

Conservation status: Least Concern (LC)

Notes: Intermediate forms between *P. burtonii* and *P. atrovirens* exist, making use of morphological characters in differentiating them difficult. The characters formally used in distinguishing these two species are narrowly distinct at times overlapping. Many of the specimens observed were found to share some of the key morphological characters e.g. stipes spinulose or muriculate, presence of gemmae on rachis, presence of spinules on costae and costulae. It was common to have costae from the same specimen spinulose and others smooth. The fronds of *P. burtonii* are either simple or pinnate pinnatifid. The West Africa species exhibit the former, the eastern Africa exhibits the later. The situation is particularly intricate as both species in some areas occur side by side. The distribution range of the two species overlap occurring from West Africa through Congo Basin with *P.*

burtonii having its eastern most boundary in Kakamega forest. After examining many specimens named as *Pteris atrovirens* and others as *P. burtonii*, it was clear that there is no distinct morphological boundary, and taxonomically the two taxa are the same. The slight variation observed did not warrant recognition of *Pteris burtonii* as a distinct species. The two species are combined here and the oldest name *Pteris atrovirens* take the principle of priority. There is a lot of confusion between *P. burtonii*, *P. atrovirens* and *P. similis* and further work on this complex is highly recommended. The entire complex is highly polymorphic. Having DNA analysis will help solve the problem of this complex.

Representative specimens examined: **DRC:** Isangi, Yangambi, 22 km a l' est de Yangambi, 0°46' N, 24°27' E, 21 Sept.1939, *Louis J* 16089 (EA). **Cameroon:** 24 km NE of Douala, along road to Edea, 13 Aug. 1965, *Leeuwenberg AJM* 6342 (EA). **Kenya:** Kakamega Forest, Yala nature reserve near Yala river, along hiking trail to Rondo retreat centre, 0°12'05" N, 34°52'32" E, 31 Oct. 2008, *Kamau P* 163 & same locality 23 Sep. 2009 *Kamau P* 286 (EA); Kwale, Shimba Hills, Pengo forest, 9 miles SW of Kwale, 300 m, 11 Feb. 1953, *Drummond RB* 1204 (EA); Kilifi, Pangani, 1 km NE of Pangani on Chonyi-Ribe road, 3°52' S, 39°40' N, 5 May 1972, *Faden RB* 72/226 (EA); Kwale district, Simba hills, Mwele, 0°42'00" S, 39°22' E, 16 Oct. 1991, *Luke WRQ*, 2936 (EA). **Sierra Leone:** Wilberforce, West coast, 11 Mar. 1883, *Johnston* 95 (EA). **Tanzania:** Morogoro district, Kanga mountains, South ridge, 1100-1300 m, 27 Nov. 1970, *Pócs T* 6139/H (EA); Northern Uluguru mountains 900-1100 m, *Faden RB*, *Evans A* & *Pócs T* 70/359 (EA); Eastern Usambara mountains, Amani station, along Dodwe stream, 940-1000 m, 27 Jun. 1970, *Faden RB* 70/262 (EA); Morogoro region, NE Uluguru mountains, Kinole, 915-1050 m, 28 Sep. 1970, *Faden et al.* 70/678 (EA); NE Uluguru mountains, Kinole, *Pócs T* and *Harris* 6165/G (EA); Lushoto district, East Usambara mountain, near Amani, 31 Dec. 1969, *Pocs TS* 6106E (EA); Gologolo Mountain, Mwanihana forest reserve near Sonjo in the Kilombero valley, 29 Mar. 1970, *Pocs T* 6144 (EA). **Uganda:** Bunyoro, Budongo Forest, Compactment N1, 1°43'12" N, 31°32'54" E, 8 Mar. 2009 *Kamau P* 209 (EA); Bunyoro, Budongo Forest, Compactment N4, 1°44'12" N, 31°31'90" E, 13 Mar. 2009, *Kamau P* 227 (EA).

7. *Pteris similis* *Kuhn* in Von der Decken, Reisen Ost. Africa. 3, 3 Bot.: 21 (1879); Alston, Ferns W.T.A.: 42 (1959); Tardieu, Fl. Cameroun 3: 168 (1964); & Fl. Gabon 8: 114, t. 19, figs. 5, 6 (1964); Schelpe in Contr. Bol. Herb. 1: 61 (1969) & C.F.A. Pterid.: 92 (1977); Benl, Acta Botanica Barcinonensia 38: 18 (1988); Johns in Pterid. Trop. E. A. 30 (1991); Schippers in Fern Gaz. 14: 186 (1993); Roux, Consp. S. Afri. Pterid., SABONET, 13: 81 (2001); Verdcourt, F.T.E.A. Pterid.11-12, fig. 3 (2002); Roux in Strelitzia 23: 175 (2009). **Type:** Congo (Kinshasa), Assika, *Schweinfurth* 3311 (isotypes: BM!, K!; syntype: B) & Mbruole, Mando's Gebit, *Schweinfurth* 3087 (syntype: B).

Synonyms

P. congoensis Christ in Ann. Mus. Congo ser. 5, 3: 29 (1909) as 'congoensis'. Type: Congo (Kinshasa), Buta to Bima, *Seret* 92 (holotype: BM!, photo!).

P. spinulifera sensu Tardieu, Mem. I.F.A.N. 28: 78, t. 11, fig. 7 (1953), non Schum.

P. molundensis Hieron. in B.J. 53: 417-419 (1915). Type: Cameroun, Molundu region, Ngoko, *Mildbraed GWJ* 4164 (holotype: B; isotype: P).

Large fern with erect rhizome covered with linear-lanceolate scales with a black stripe and entire margins. Fronds tufted, trailing or scandent 1.4-6.0 m tall, usually hanging down, 1-2 gemmae present on the rachis, often rooting when the fronds touches the ground. Stipes muriculate throughout, straw-coloured, channeled above, 15-70 cm long, base purplish brown, scaly. Lamina ovate-lanceolate in outline, membranous, 0.4-3.0 (-5.2) m long, and 30-60 cm wide, pinnate-pinnatifid at base. Pinnae oblong-lanceolate, 5-28 pairs, 8-28 cm long, 2-10 cm wide, pinnatifid, sessile, distantly spaced along the rachis. Pinnules, oblong-lanceolate, 12-20 (-29) pairs, 2-6 cm long, 4-11 mm wide, sterile margins serrate-crenate. Terminal segment long caudate, 3-7 cm long. Rachis muriculate, slightly winged. Costae with spinules beneath, costulae usually smooth. Veins forming a narrow and regular series of areoles along the costa and densely anastomosing in the lobes. Sori linear, continuous along the margin, 3.0-5.1 cm long, sterile apices toothed.

Ecology: Primary forest in constantly dampy habitats such as *Raphia* swamps and shady margins of permanent watercourses.

Distribution: Angola, Bioko, Cameroon, Central Africa Republic, Congo, DRC, Equatorial Guinea, Gabon, Ghana, Guinea, Ivory Coast, Kenya, Liberia, Nigeria, Pemba, Sierra Leone, Sudan, Tanzania, Togo, Uganda.

Altitude: 650-1200 m.

Chromosome numbers: $2n = 58$ (Walker 1962:32).

Conservation status: Least Concern (LC)

Notes: Easily distinguished from *Pteris atrovirens* by its numerous pinnae and scandent fronds, densely spinulose/muriculate stipes, rachis and costae.

At Kew herbarium, two microfiche of *P. similis* labeled as *Schweinfurth* 3301 is an error, should be *Schweinfurth* 3311.

Specimens examined: **Burundi:** Bururi, Kigwena, 4°10' S, 29°32' E, 26 Jan. 1979, *Reekmans M* 7554 (EA). **DRC:** Kimvula, Province Leopoldville, territory Popokabaka, 5 Jan. 1959, *Paauwels L* 1045; Isangi, Yangambi-reserve flore Isalowe, 29 Jun. 1939, *Louis J* 15660 (EA). **Uganda:** Mpanga research station, Mpanga forest reserve, 5 km east of Mpigi, 0°13' N, 32°18' E, 9 Sept. 1969, *Faden RB* 1015 (EA); Lindi, Rondo plateau, Rondo forest reserve, 10°07' S, 39°13' E, 14 Feb. 1991, *Bidgood S* 1556 (EA); Mengo, West of Kisubi on Kampala-Entebbe road, 0°45' N, 32°30' E, 7 Sept. 1969, *Faden RB* 958 (EA); Mengo, Ssezibwa falls, 10 km West of Lugazi, 0°21' N, 32°51' E, 8 Sept. 1969, *Faden RB* 974 (EA).

8. *Pteris hamulosa* (Christ) Christ in Ann. Mus. Congo, Bot. ser. 5, 3: 30 (1909); Schelpe in Contr. Bolus Herb. 1: 62 (1969) & in F.Z. Pterid.: 120 (1970) & C.F.A., Pterid.: 94 (1977); Schelpe & M.A. Diniz, Fl. Mozamb., Pterid.: 121 (1979); Jacobsen, Ferns S. Afr.: 243, fig. 175 (1983); Pic.-Serm. in Webbia 37: 125 (1983); Benl, Acta Botanica Barcinonensia 38: 19-20 (1988); Schippers in Fern Gaz. 14: 186 (1993); Roux, Consp. S. Afr. Pterid., SABONET, 13: 81 (2001); Verdcourt, F.T.E.A. Pterid. 14, fig. 2/5 (2002); Roux in Strelitzia 23: 173 (2009). **Type:** Congo (Kinshasa), near Kisantu, *Gillet s.n.* (holotype: BR!).

Synonyms

P. quadriaurita Retz var *hamulosa* Christ in Ann. Mus. Congo. Bot., ser. 5, 1: 4 (1903). Type: Environs of Kisanu, 1901, *Gillet JB s.n.* (holotype: BR!).

P. acanthoneura Alston in Contr. Conhec. Fl. Mozambique 2 in Est. Ens. Doc. Junta Invest. Ultramar 12: 15, t. 4-5 (1952); Tardieu in Mem. I.F.A.N. 28: 78, t. 11, fig. 6 (1953); Alston, Ferns W.T.A.: 42 (1959); Tardieu, Fl. Cameroun 3: 164 (1964). Johns in Pterid. Trop. E. A. 29 (1991); Syntypes: Uganda, Bunyoro District, Budongo Forest, *Taylor G.* 3337 (BM!, two sheets).

Terrestrial plant, rhizome erect or suberect, fleshy becoming woody, rhizome scales linear with a dark central stripe and pale margins. Fronds tufted, 0.8-1.5 m tall, often arching. Stipes 32-75 cm long, straw coloured, dark and scaly at the base. Lamina ovate-oblong to narrowly deltate, 20-75 cm long, 20-30 cm wide, pinnate-pinnatifid above. Pinnae 3-6 pairs, oblong to oblong lanceolate, 17-26 cm long, 3.5-6.0 cm wide, basal pinnae longest with a basispic pinnule, few specimens with acroscopic pinnule. Terminal pinna bilobed. Pinnules 17-28 pairs, 2-4.5 cm long, 6-8 mm wide, narrowly oblong, falcate with the sterile tips finely crenate-serrate. Apical segment triangular-lanceolate, 1.5-5.0 cm long, 4-9 mm wide, sterile tips crenulate. Rachis slightly winged, spinules and grooved. Tubercles of hardened hairs at axil of rachis and pinnae bases. Costae densely spinulose beneath, spines recurved, costulae mostly smooth or faintly spinulose. Veins anastomosing along the costa to form narrow or arching areoles, free-forking in the lobes. Sori 0.5-4.0 cm long, occupying most the lobes margin except the apex.

Ecology: Lowland rainforests of *Cynometra*, *Celtis*, *Antiaris*. *Milicia* species and in semi-shaded plantations.

Distribution: Angola, Bioko, Burundi, Cameroon, Central African Republic, Congo, DRC, Equatorial Guinea, Ivory Coast, Ghana, Kenya, Mozambique, Nigeria, Pemba, Sudan, Tanzania, Uganda.

Altitude: 15-1300 m

Chromosome numbers: Sexual diploid, $2n = 58$ (Walker 1962:29).

Conservation status: Least Concern (LC)

Notes: Specimens collected from Budongo forest, Uganda e.g. *Kamau* 213 (EA) are presumed to be hybrid between *P. hamulosa* and *P. commutata*. They possess combinations of characters from both species.

Specimens examined: Kenya: Kwale, Shimba Hills, Mwele, 4°16' S, 39°22' E, 16 Oct. 1991, *Luke WRQ* 2937 (EA); Shimba Hills, Longomagandi, 4°14' S, 39°25' E, 17 Mar. 1991, *Luke WRQ* & *Robertson SA* 2729 (EA). **Uganda:** Mengo, Bwola-Mabira forest, Kyagwe county, 0°20' N, 33°10' E, 24 Jul. 1971, *Katende AB* 1162 (EA); Bunyoro, Budongo Forest, Compactment N2, 1°43'46" N, 31°33'07" E, 9 Mar. 2009, *Kamau P* 213 (EA); Toro District, Mwamba forest, 4 Dec. 1957, *Allan KSL* 3690 (EA); Mengo, Kyagew county, Ssezibwa falls, 10 km west of Lugazi, 0°21' N, 32°51' E, 8 Sept. 1969, *Faden RB* 976; Mengo, Mpanga forest reserve and research station, 5 km east of Mpigi, 0°13' N, 32°18' E, 9 Sept. 1969, *Faden RB* 1014 (EA); Mengo, 1.5 km NE of Nansagazi, 0°00'70" N, 32°58'00" E, 11 Sept. 1969, *Faden RB* 1030 (EA).

9. *Pteris mildbraedii* Hieron. in E.J. 53: 415 (1915); Tardieu, in Mem. I.F.A.N. 28: 77, t. 12, figs. 4-5 (1953); Alston, Ferns W.T.A.: 42 (1959); Tardieu, Fl. Cameroun 3: 165, t. 23, figs. 4-5 (1964); & Fl. Gabon 8: 112 (1964); Schelpe in Contr. Bol. Herb. 1: 63 (1969); Benl, Acta Botanica Barcinonensia 38: 20-21 (1988); Roux, Consp. S. Afri. Pterid., SABONET,

13: 81 (2001); Verdcourt, F.T.E.A. Pterid. 14-15 (2002); Roux in Strelitzia 23: 174 (2009);
Type: Cameroon, 58 km east of Kribi, *Mildbraed* 5986 (holotype: B).

Etymology: Species named in honor of Mildbraed GWJ, a botanist who collected extensively in Cameroon in the 19th century.

Synonyms

Pteris biaurita var *africana* Bonap., Not. Pterid. 1: 61 (1915). Type: Congo (Brazzaville), Benito, *Reutlinger* s.n. (holotype: P!).

P. barombiensis Hieron. in B.J. 53: 413, 414 (1915); Roux in Strelitzia 23: 169 (2009). Type: Kamerun: Borombi station, 24 Jun. 1890, *P.R. Preuss* 357 (holotype: B; Isotype: P!).

P. quadriaurita var *africana* Bonap., Not. Pterid. 5: 71-72 (Dec. 1915d). Type: Madagascar, eastern flora region, Analamazoatra forest, *Perrier de la Bathie* 6102 (holotype & isotype: P)

P. sp. (sub *P. atrovirens*); Schippers in Fern Gaz. 14: 185 (1993).

Rhizome erect with lanceolate scales with a dark mid rib, margin pale. Fronds tufted, 0.6-1.6 m tall. Stipes 50-75 (-120) cm long, always longer than lamina, spinulose to muriculate, base scaly and reddish in colour. Lamina ovate in outline, 33-46 cm long, 28-42 cm wide. Pinnae 2-4 (-6) pairs, distantly spaced from each other, lanceolate to narrowly obovate, 20-30 cm long, 4-7 (-11) cm wide, abruptly caudate with a terminal triangular-lanceolate segment, 2.5-4.5 (-11.0) cm long, 5-7 mm wide. Pinnae bases decurrent on the rachis. Pinnules 19-24 (-32) pairs, 3.3-6.0 cm long, 0.7-1.5 cm wide, oblong-lanceolate, falcate, apex acute to rounded. Margins of sterile lobes serrate to crenulate near the apex. Rachis, costae and costulae smooth. Veins free in lobes, occasionally with slight anastomosis, lowest veins of two lobes forming a costal areole. Sori 1.6-5.5 cm long, in some specimens sori covering whole margin length of the lobes including tips.

Ecology: Evergreen forests, moist woodlands and in shaded wet rocks.

Distribution: Benin, Bioko, Cameroon, Congo (Brazzaville), DRC, Equatorial Guinea, Gabon, Ghana, Nigeria, Sudan, Tanzania, Uganda.

Elevation: 100-1400 m.

Conservation status: Least Concern (LC)

Notes: The available isotype is a drawing of a fragment in Paris herbarium (P) which make comparison with other specimens difficult. Generally, *Pteris mildbraedii* is a highly variable species ranging from small to large sized plant depending on habitats occupied. Specimens from East Africa vary variably from those of West Africa in most of their characters e.g. intense of spinules, shape of terminal segment. Specimen collected by *Poulsen, Katende, Mubanguzi* and *Nkuutu* 545, Uganda (which is a photocopy of the specimen at Kew) is a robust specimen with more than 10 pairs of pinnae. Presence or absence of spinulose on spines could not be verified. Some of the East African specimens have sparsely spinulose stipes while others e.g. *Reutlinger s.n* (EA) from Congo (Brazzaville) has densely spinulose costae. Generally, typical *P. mildbraedii* have spinulose to muriculate stipes. *P. mildbraedii* is closely allied to *Pteris dubia* known from Comoro-Is Johanna, however, the latter have serrulate pinna apices and more acute lobes.

Representative specimens examined: **Cameroon:** SW province of Cameroon, Mt. Cameroon, Scipio Camp, *Tchouto* 804; Limbe, Mt. Cameroon, Bakingili-Nja Keta path, 600 m, *Thomas, Wheatley & Agby* 9122. **Tanzania:** Morogoro, Mwanihana forest reserve above Sanje village, Kilombero district, Morogoro region, 0°50'07" S, 36°55'00" E, 30 Aug. 1984,

Thomas DW 3695. **Uganda:** Bushenyi district, Kasyoha-Kitomi forest reserve, NE Kyambura river, 1300 m, *Poulsen et al.* 545 (K).

10. ***Pteris auquieri*** *Pic. Serm.* in B.J.B.B. 53: 219-223, figs. 5, 6 (1983); Roux in *Strelitzia* 23: 173 (2009); **Type:** Rwanda, Cyangugu, 23 km from Pindura on road to Burundi frontier, Nyungwe forest, *Auquier* 3744 (holotype: LG, on 3 sheets; isotype: FI-PS).

Etymology: Dedicated to the late Dr. Paul Auquier.

Plant with rhizome shortly creeping or erect, usually woody, scales brown, linear lanceolate with a dark brown central midrib. Fronds tufted, 0.6-2.2 m tall, apical pinna with a bulbil, young plantlets grow vegetatively when the bulbil touches the ground. Stipes sparsely muriculate, 30-75 cm long, straw-coloured, chestnut towards base and scaly. Lamina subcoriaceous, dark green, ovate-lanceolate in outline, 30-50 cm long, 13-44 cm wide, 2-pinnatipartite. Pinnae 3-8 pairs, oblong-lanceolate, 30-55 cm long, 5-12 cm wide. Pinnae tapering into a long caudate segment at the apex reaching 7 cm long, 0.8 cm wide. Basal pinnae long stalked c. 3.5 cm long, upper pinnae shortly stipitate. Pinnules narrowly lanceolate, falcate, 14-22 pairs, 4.2-10 cm long, 0.8-1.0 cm wide. Fertile pinnules narrower with an open look than sterile one which are somehow crowded, with their edges touching each other. Costae and costulae smooth on both surface, rachis deeply grooved. Small tubercles of prickles at axil of pinna and main rachis. Veins free, simple or forked, some branching from costulae. Sori marginal occupying most the middle section of the lobes reaching to 6 cm long. Sterile margin and apices crenate-serrate.

Ecology: Streamside forests with abundant *Alsophila manniana*, and in closed forest on steep slopes.

Distribution: Burundi, Cameroon, DRC, Rwanda, Tanzania, Uganda.

Elevation: 600-2000 m

Conservation status: Least Concern (LC)

Notes: This species differs from *Pteris preussii* also with bulbiferous fronds by the sterile apices of segment crenate-serrulate and texture of lamina coriaceous, venation free, with two adjacent lobes having veins running directly from costa to the bottom of the sinus or just above it.

Representative specimens examined: **Tanzania:** Morogoro, Mkungwe Hill, NE part of northern Uluguru mountains, 6°52' S, 37°55' E, 5 Jul. 1970, *Faden* RB 70/363 (EA); Morogoro district, Uluguru Mountains, West slope of Lupanga above Morogoro, 6°55' S, 37°42' E, 1 Nov. 1969 *Pocs* T 6065/B (EA) & Mwere valley, 6°55' S, 37°42' E, 26 Sept. 1970, *Faden et al.* 70/597 (EA). **Uganda:** Ankole, Bunyaruguru, Kalinzu forest, 2.5 miles NW of saw mill, West Rubuzigye, 0°15' S, 30°00' E, 19 Sept. 1969, *Faden et al.* 69/1133 (EA).

11. ***Pteris tripartita*** *Sw.* in *Schrad. J. Bot.* 1800 (2): 67 (1801); Hook, *Syn. Fil.*: 172 (1867); Tardieu, in *Mem. I.F.A.N.* 28: 80, t. 11, fig. 5 (1953) & *Fl. Madag.* 5 (1): 105 (1958); Schelpe in *Contr. Bol. Herb.* 1: 61 (1969) & *C.F.A. Pterid.*: 93 (1977); Benl, *Acta Botanica Barcinonensia* 38: 15, 16 (1988); Johns in *Pterid. Trop. E. A.* 31 (1991); Roux, *Consp. S. Afri. Pterid.*, SABONET, 13: 81 (2001); Verdcourt, *F.T.E.A. Pterid.* 16, fig. 2/3 (2002); Roux in *Strelitzia* 23: 176 (2009). **Type:** Java, *Thunberg C.P.* 24968 (lectotype, designated by Christenhusz, 2009: UPS-Thunb.-24968, duplicate UPS-Thunb.-24969).

Synonyms

Pteris marginata Bory, Voy. Quart. Prin. Iles Afri. 2: 192 (1804); Alston, Ferns W.T.A.: 42 (1959); Tardieu, Fl. Cameroun 3: 170 (1964). Type: Reunion, Grand Brule, *Bory de St. Vincent s.n.* (holotype: P!).

Litobrochia tripartita (Sw.) C. Presl, Tent. Pterid.: 150. (Oct. 1836).

Litobrochia marginata (Bory) C. Presl, Tent. Pterid.: 149. (Oct. 1836).

P. pellucens sensu Kuhn, Filices africanae: 87 (Oct. 1868), non J. Agardh (1839: 43).

Terrestrial plant, rhizome forming a stout erect rootstock, scales broad, concolorous. Fronds tufted, arching, 1-3 m tall. Stipes straw coloured, 0.5-2.0 m tall, fleshy and thick deeply grooved. Lamina deltoid-ovate to triangular, tripartite, all branches of equal length up to 1 m long and 25 cm wide, middle branch deeply bipinnatifid, the two lateral branches each bearing a smaller similar branch on their basiscopic side, all being bipinnatisect with up to 37 pairs of pinnules. Pinnules 5.0-11.5 cm long, 1.5-3.5 cm wide, ultimate segments falcate or oblong, 15-20 pairs, 0.4-3.0 cm long, 0.4-0.6 cm wide. Basal pinnules in each branch greatly reduced compared to middle ones. Old branches usually die off and hang onto the plant when new ones sprout. Pinnules bases with black aerophores. Sterile apex of lobes rounded, margin crenulate. Costae irregularly spinulose on upper surface. Veins joined along costa to form a single row of narrow and arched areoles, some veins anastomosing in the lobes. Sori extending from base of sinus to about halfway or nearly top of lobes.

Ecology: Moist evergreen forest of *Khaya anthotheca-Cynometra alexandri* species.

Distribution: Bioko, Cameroon, Comoro Isl., Diego, Garcia, DRC, Equatorial Guinea, Gabon, Ghana, Ivory Coast, Kenya*, Liberia, Madagascar, Mauritius, Nigeria, Principe, Reunion, Sao Tome, Seychelles, Tanzania, Uganda, Zanzibar, Polynesia and Australia; naturalized in American tropics.

Elevation: 80-1500 m

Chromosome numbers: $n = 29$, $2n = 58$ (Walker 1962: 31).

Conservation status: Least Concern (LC)

Notes: *The only Kenyan collection of a juvenile and sterile specimen needs further confirmation on occurrence of this species in Kenya. Several expeditions and focused searches were conducted on the same locality, but with no success of recollecting it. Generally, *P. tripartita* is a gregarious species as observed in Budongo forest and its record of occurrence in coastal area of Kenya based on a juvenile collection from a single specimen is not clear and therefore highly doubtful. Its eauthenticity could not be verified since it was sterile. *Pteris tripartita* is the largest *Pteris* species known in Africa.

Specimens examined: **DRC:** Isangi, Yangambi, Le long de la piste de Yangolo, 31 May 1939, *Louis J* 15056 (EA). **Tanzania:** Morogoro, Uluguru Mountains, Mwere valley, 19 Jul. 1970, *Pocs T* 6220/J (EA); Morogoro, Uluguru Mountains, Kimboza forest reserve between Mkuyumi and Matombo, 26 Oct. 1969, *Pocs T* 6054/H (EA); Muheza-Amani road, 18 Oct. 1985, *Schippers R* 1075 (EA). **Uganda:** Bunyoro, Budongo Forest, Nature reserve, 1°43'59" N, 31°31'21" E, 1 Nov. 2009, *Kamau P* 310 (EA).

12. *Pteris buchananii* Baker ex Sim, Ferns S. Afri. ed. 1:111, t, 46 (1892); Hieron. in P.O.A.C.: 80 (1895); Sim, Ferns S. Afr. ed. 2: 259, t, 130 (1915); F.D.-O.A.: 48 (1929);

Schelppe in Contr. Bolus Herb. 1: 62 (1969) & F.Z. Pterid. 1: 120 (1970); Jacobsen, Ferns S. Afr.: 242, fig. 174 (1983); Schelppe & Anthony, F.S.A., Pterid.: 109, fig. 32 (1986); Burrows, S. Afr. Ferns: 162, t. 26.3, figs. 39, 161, 161a, b (1990); Johns, Pteridophytes of Tropical East Africa, 29 (1991); Schippers, Fern Gaz. 14: 185 (1993); Faden in U.K.W.F. ed 2: 20 (1994); Verdcourt, F.T.E.A. Pterid. 16-17 (2002); Roux in Strelitzia 23: 170 (2009); Roux, Consp. S. Afr. Pterid., SABONET, 13: 80 (2001); Crouch *et al.* Ferns. S. Afr.: 322-323 t. 1-5 (2011). **Type:** South Africa, Natal, Inchanga, *Buchanan*, 196 (Lectotype: K!). Lectotype designated by Schelppe (1969: 62).

Etymology: Named after Rev. John Buchanan who collected plants widely in Kwa-Zulu Natal.

Synonym

Pteris subquadripinnata Chiov., Racc. Bot. Miss. Cons. Kenya: 147 (1935). Type: Kenya, Mt. Kenya, NE distr. Meru a Kaja, *Balbo* 816 (holotype: TOM).

Plant terrestrial, rhizome woody and stout, widely creeping, scales brown, linear-lanceolate. Fronds tripartite, 1.0-2.2 m long, widely spaced (fide Kamau, 382). Stipes thick, glabrous, straw-coloured, base dark brown reaching 1.2 m tall. Lamina broadly triangular - deltoid, up to 1 m high and 60-80 cm wide. Basal pinnae deeply 3-4 pinnatifid, secondary pinnae basiscopically developed, ovate-triangular, pinnules 5-10 pairs, oblong-lanceolate, 5-24 cm long, 3.5-8.0 cm wide, pinnatifid; ultimate segments in 12-22 pairs, oblong, falcate, 1.5-3.0 cm long, 0.3-0.6 cm wide. Margin of sterile pinnae and fertile pinnae apex serrate. Costae spinulose above at the junction with costules. Veins anastomosing to form long and shallow areoles along the costules. Sori marginal extending $\frac{1}{2}$ to $\frac{3}{4}$ the length of the lobes.

Ecology: An evergreen forest species growing in areas receiving high light intensity and high rainfall. Occurs along dry forest margins in steep slopes with stream and swamps.

Distribution: Kenya, Uganda, Tanzania, Zimbabwe and South Africa.

Elevation: 1050-2735 m.

Conservation status: Least Concern (LC)

Chromosome numbers: Sexual diploid, $2n = 58$ (Walker 1962: 29).

Notes: A solely African species, easily distinguished from similar-looking *P. dentata* by having a creeping rhizome, veins fairly anastomosing and fronds tripinnate while those of *P. dentata* are bipinnate at the base.

Representative specimens examined: Kenya: Mount Kenya, Chogoria track, 0°10'51" S, 37°27'54" E, 27 Jan. 2010, *Kamau* P 382 (EA); Kiambu, Upland forest station, NE of Limuru, 1°03' S, 36°41' E, 12 July 1970, *Faden* RB 70/388 (EA); Embu, Irangi forest station, 0°21' S, 37°27' E, 30 April 1972, *Faden* RB 72/189 (EA).

13. *Pteris intricata* C.H. Wright in K.B. 1906: 252 (1906); Alston, Ferns W.T.A.; 42 (1959); Schelppe in Contr. Bolus Herb. 1: 63 (1969) & F.Z. Pterid.: 117 (1970) & C.F.A., Pterid.: 94 (1977); Kornas, Distri. Ecol. Pterid. Zamb. 70 (1979); Benl in Acta Botanica Barcinonensia 38: 19-20 (1988); Johns, Pteridophytes of Tropical East Africa, 30 (1991); Faden in U.K.W.F. ed 2: 20 (1994); Roux, Consp. S. Afri. Pterid., SABONET, 13: 81 (2001); Verdcourt, F.T.E.A. Pterid. 17 (2002); Roux in Strelitzia 23: 173 (2009). **Type:** Uganda, Mengo District, Mawokota, *Brown* 158 (holotype: K!, one plant on 4 sheets; isotype: BM!; microfiche, P).

Synonyms

Pteris adamii Tardieu in Mem. I.F.A.N. 28: 76, t. 12, fig. 1 (1953). **Type:** Guinea, Massif du Ziama, *Adam* 4265 (holotype: P!; photo, BM).

Plant terrestrial, rhizome woody, erect or ascending with several fronds tufted together. Scales dark brown, linear-lanceolate. Fronds tufted, arching, 0.6-2.0 m tall. Stipes and rachis chestnut in colour, polished, sparsely to densely spinulose, some spines up to 1 cm long; stipes 0.4-1.0 m tall, base black and densely scaly. Lamina broadly ovate to deltate, dark green, tripartite at the base, reaching 1 m high and 95 cm wide, bipinnate to tripinnate above. Pinnae 3-9 pairs, narrowly triangular, 15-(40-50) cm long, 18-25 cm wide, basal pinnae basiscopically developed, tripinnate, attaining 55 cm long, with well developed stalk measuring 7cm long. Terminal pinnae 10-12 cm long, 4-5 cm wide, deeply pinnatifid. Secondary pinnae up to 20 cm long, 3-4 basal pinnae usually stalked, upper ones sessile. Pinnules 4-9 pairs, ovate 8-14 cm long, 3-4 cm wide. Ultimate lobes 6-(10-16) pairs, falcate or oblong in outline, 2-3 cm long, 4-7 mm wide, apex acute to obtuse. Costae spinulose beneath, costulae with a single spinules above at junction with costa. Veins free, sori 5-7 mm long, restricted to half of the lobes margins. Sterile margins conspicuously serrate.

Ecology: Evergreen swampy and riverine forests or steep forest slopes on wet soils and in deep shade.

Distribution: Kenya, Uganda, Tanzania, Mali, Guinea, Sierra Leone, Ghana, Nigeria, Cameroon, Bioko, Central Africa Republic, Madagascar, Congo (Kinshasa), Rwanda, Burundi, Angola, Zambia, Mozambique:

Elevation: 1080-1900 m.

Chromosome numbers: Sexual tetraploid, n=58 (Walker 1962: 30).

Conservation: Least Concern (LC)

Notes: Typically a riverine species easily distinguishable by having all axes chestnut coloured and spiny. Collection from Tanzania, *Luke WRQ et al.* 10383, look extraordinary having stout spines on stipe and rachis, it however agree with the species description.

Representative specimens examined: Uganda: Bunyoro, Budongo forest, Nature reserve off the grid line along river Nyabusabo, 1°42'06" N, 31°31'56" E, 6 Nov. 2009, *Kamau P* 330 (EA); Mount Kenya, Irangi forest station, 0°21' S, 37°27' E, 30 April 1972, *Faden RB* 72/196 (EA) (1 plant in 7 sheets); Mengo, Mpanga forest reserve, 0°12' N, 32°18' E, 21 July 1972, *Katende AB* 1717 (EA); Mengo, Mpanga forest, 5 km east of Mpigi, 0°13' N, 32°18' E, 9 Sept. 1969, *Faden RB* 69/999 (EA). **Tanzania:** Ndundulu forest reserve, 07°48' S, 36°30' E, 7 Sep. 2004, *Luke WRQ, Butynski T, Ehardt C & Jones T.* 10383 (EA).

14. *Pteris pteridioides* (Hook.) Ballard in K.B. 1937: 348 (1937); Tardieu, in Mem. I.F.A.N. 28: 80, t. 11, figs. 3-4 (1953) (as *pterioides*); Alston, Ferns W.T.A.: 42 (1959); Tardieu, Fl. Cameroun 3: 170 (1964); Schelpe in Contr. Bolus Herb. 1: 64 (1969) & in F.Z. Pterid.: 117 (1970); Schelpe & Diniz, Fl. Mozamb., Pterid.: 117 (1979); Jacobsen, Ferns S. Afr.: 237, fig. 169 (1983); Benl, Acta Botanica Barcinonensia 38: 9 (1988); Burrows, S. Afr. Ferns: 163, t. 26.4, figs. 39/162a, b (1990); Johns, Pteridophytes of Tropical East Africa, 30 (1991); Schippers in Fern Gaz. 14: 186 (1993); Faden in U.K.W.F. ed. 2: 20 (1994); Verdcourt, F.T.E.A. Pterid. 18 (2002); Basionym: *Hypolepis pteridioides* Hook., A second

century of Ferns: pl. 59 (1860) (1861): Type: 'Peak of Fernando Po, *Mann G* 348 (holotype: K!). **Type:** Bioko (Fernando Po), St. Isabel Peak, *Mann G*. 348 (holotype: K!).

Etymology: A *Pteris* that look like *Pteris*.

Synonyms

Pteris brevisora Baker in Synopsis Filicum 5: 162 (8 Jul. 1867c). Type: As for *P. pteridioides* Hook.

P. pteridioides (Hook) F. Ballard in Bulletin of Miscellaneous information, Royal Gardens, Kew 1937, 6: 348 (1937).

P. muricella Fee in Memoires de la Societe des sciences Naturelles de Strasbourg 5: 73 (1857b). Roux, Consp. S. Afri. Pterid., SABONET, 13: 79 (2001); Roux in Strelitzia 23: 174-175 (2009).

Pretty fern, rhizome erect or ascending, woody, scales brown narrowly ovate, entire. Fronds tufted, arching, 0.4-1.8 m tall. Stipes 0.3-1.2 m long, \pm spinulose, straw coloured with basal scales. Lamina tripartite, triangular in outline up to 54 cm long, and 35 cm wide, each part almost equal in length, pinnate-pinnatifid, 45 cm long, 36 cm wide, membranous. Pinnules 12-22 pairs, 4.2-17.0 cm long, 0.7-3.0 cm, wide, oblong to linear-lanceolate, sessile, tapering into a caudate apex. Pinnules longest at the middle of each pinnae, basal ones reduced. Ultimate lobes oblong, 7-30 pairs, 0.4-1.8 cm long, 2-5 mm wide. Sterile apices crenate-serrate. Costae channeled above, with spinules at the junction with costules and with scattered hairs on lower side. Veins free, sori seem to be sunk into a cavity or depression, short and thick, occupying 1/3 of the length of the lobe and positioned nearer to the sinuses.

Ecology: Common in undergrowth of moist forests along steep slopes, along riverine vegetation, streams and swamps.

Distribution: Bioko, Burundi, Cameroon, DRC, Ethiopia, Ivory Coast, Kenya, Liberia, Madagascar, Malawi, Mozambique, Rwanda, Sao Tome, Sudan, Tanzania, Uganda, Zimbabwe.

Altitude: 1050-2700 m.

Conservation status: Least Concern (LC)

Notes: Roux (2009) reduced *P. pteridioides* to a synonym of *P. muricella*. After literature search, I found that *P. muricella* only occur in Mexico and not in Africa. However, this two species are closely related and both belong to the former subgenus *Litobrochia*. This species is closely related to *P. tripartita*, which have tripartite fronds.

Representative specimens examined: **Burundi:** Muramvya, Teza, 3°13' S, 29°33' E, 9 Apr. 1979, *Reekmans M* 7775 (EA). **Ethiopia:** Kaffa, path to waterfall, catholic mission, 3 kms north of Bonga, 8 Jan. 1972, *Asb JW* 1481 (EA). **Kenya:** Kericho, near the tea research institute, ca. 5 km east of Kericho, along the Timbili (Dimlitch) river and a small tributary, 0°22' S, 35°20' E, 11 Jun. 1972, *Faden RB* 72/304 (EA); Kajiado, South of Chyulu Hills, 2 Jul. 1938, *Bally PRO* 7551; Kakamega, Kakamega forest, Salazar 1, 14 Oct. 2008, *Kamau P* 70 (EA); Taita Taveta, Mbololo hill forest, 3°19'83" S, 38°26'98" E, 26 Mar. 2010, *Kamau P* 446 (EA); Nakuru, Mau forest, SW Mau forest through Chagaik road, 0°21'87" S, 35°22'91" E, 22 Jul. 2010, *Kamau P* 522 (EA). **Tanzania:** Morogoro, Uluguru mountains, Mwere valley, 26 Sept. 1970, *Faden RB* 70/587 (EA); Udzungwa mountain NP, Mt. Luhombero plot 131, 7°47' S, 36°33' E, 28 Sept. 2000, *Luke WRQ* 6735 (EA). **Uganda:**

Mengo, Mpanga research forest, 5 km East of Mpigi, 0°13' N, 32°18' E, 9 Sept. 1969, *Faden* RB 69/992 (EA); Ankole, Kalinzu forest reserve, 2.5 miles NW of saw mill, West of Rubuzigye, 19 Sept. 1969, *Faden* RB 69/1157 (EA).

15. *Pteris bavazzanoi* *Pic.Serm.* in *Webbia* 27: 422, fig. 11 (1972); Johns, *Pteridophytes of Tropical East Africa*, 29 (1991); Schippers in *Fern Gaz.* 14: 185 (1993). Verdcourt in *F.T.E.A. Pterid.* 21 (2002); Roux in *Strelitzia* 23: 169-170 (2009). **Type:** Tanzania, Arusha District, Mt. Meru, slopes of crater, *Bavazzano* 54 (holotype: FT; duplicates: FI-PS, 25185, 25186).

Synonym

Pteris kilimensis Bonap., *Not. Pterid.* 7: 297 (1918), nom. nud. Type: Tropical Africa, south east of Kilimanjaro, montane forests, 2700 m, Oct. 1908, *Alluand* 43, 43¹, 43² (holotype: P!).

Terrestrial plant, rhizome always creeping, scales lanceolate, chestnut with a hair tip. Fronds tufted 0.3-1.1 m tall. Stipes 50-73 cm long, glabrous, base dark brown and sparsely scaly. Lamina ovate-triangular, 20-60 cm long, 12-25 cm wide, 2-4 pinnatipartite at base, 1-2 pinnate above. Pinnae 5-8 pairs, lanceolate, 12-27 cm long, 2-5 cm wide. Lower pinnae shortly stipillate, upper ones sessile. Pinnules 4-(16-22) pairs linear lanceolate, 2.5-11 cm long, 0.3-2.6 cm wide, ultimates segments linear-lanceolate, 13-21 pairs, 2-3 cm long, 3-4 mm wide. A set of hairs or tubercles present at the axil of pinnae bases and rachis. Costa and costules spinulose above. Sori covering $\frac{3}{4}$ of the lobes margin, sterile tips strongly spinulose-serrate.

Ecology: Often growing in forests of *Prunus africana*, *Olea*, *Podocarpus*, on steep slopes of ravines and bases of lava cliffs.

Distribution: Known only from Tanzania

Elevation: 2100-3200 m

Conservation status: Least Concern (LC)

Notes: A Tanzanian endemic only found in Mts. Kilimanjaro and Meru. *Pteris bavazzanoi* is allied to *P. albersii* Hieron. from Kwai (Tanzania) more than to any African species, however they are clearly distinct from each other. *P. bavazzanoi* have fertile lamina quadripinnatipartite while that of *P. albersii* is tripinnatipartite.

Representative specimens examined: Tanzania: Arusha, Mount Meru crater, 3°14' S, 36°45' E, Jul. 1968, *Gilbert VC* 3817 (EA); Arusha, Mount Meru, East slope, NE end of the Caldera wall, 3°14' S, 36°45' E, 23 Jun. 1969, *Greenway PJ& Vesey-Fitzgerald LDEF* 13618 (EA); Arusha National Park, Meru Crater, 21 Jul. 1968, *Vesey-Fitzgerald LDEF* 5864 (EA); Moshi, Kilimanjaro, near Bismark Hill, 3°04' S, 37°22' E, 27 Feb. 1934, *Greenway PG* 3820 (EA); Arusha National Park, 2440 m, 23 Dec. 1972, *Harris BJ & Vesey-Fitzgerald D B JH* 6667 (EA).

16. *Pteris kivuensis* *C. Chr.* in *Dansk. Bot. Arkiv.* 9, 3:71, 72 (1937c); Schelpe in *Contr. Bolus Herb.* 1: 64 (1969); Pichi Sermolli in *Webbia* 32: 1: 72-73 (1977); Schippers in *Fern Gaz.* 14: 186 (1993); Verdcourt in *F.T.E.A. Pterid.* 22 (2002); Roux in *Strelitzia* 23: 173 (2009). **Type:** Tropical Africa, Congo (Kinshasa), West of Lake Kivu, *Humbert H* 7826 (holotype: BM!).

Etymology: Named after type locality, Lake Kivu.

Rhizome erect, scales lanceolate, black with pale margins. Fronds tufted, 0.6-1.4 m tall. Stipes 0.5-1.0 m long, stramineous, base densely covered with castaneous scales. Lamina oblong-elliptic, light green, shiny and leathery, 35-60 cm long, 20-26 cm wide. Pinnae 5-11 pairs, 18-21 cm long, 2-3 cm wide, gradually tapering upwards into a long tail, middle and upper pinnae stipicellate, pinnate, basal pinnae bipinnate, long stipicellate, less developed, all pinnae bases cuneate. Pinnules numerous, falcate, 23-31 pairs, 0.5-3.5 cm long, 5-7 mm wide, crowded and close to each other. Edges with a hardened cartilaginous straw-coloured commissure. Costae spinulose on the upper surface at junction with costules; costules smooth. Veins free, in sterile margins ending in a conspicuous spinous teeth. Sterile part of fertile segment irregularly and minutely serrate ending in an acute mucronate apex. Sori extending for most of the lobes length except the apex.

Ecology: Along seasonal streams, riverine vegetation and in dense shaded forests.

Distribution: Burundi, DRC and Rwanda

Elevation: 2000-2400 m

Conservation status: Least Concern (LC).

Representative specimens examined: **Burundi:** Muramvya, Nyabigondo, plantation de the', 4 Nov. 1969, *Lewalle J* 3995 (EA) & same locality 8 Mar. 1970 *Lewalle J* 4540 (EA); Muramvya, Teza, Mt. Ngoma, 3°10' S, 29°30' E, 4 May 1976, *Reekmans M* 5031 (EA) & same locality 18 Apr. 1974 *Reekmans M* 3275 (EA).

17. *Pteris usambarensis* Hieron. in P.O.A. C: 80 (1895); Schelpe in Contrib. Bolus Herb. 1: 63-64 (1969); Johns, Pteridophytes of Tropical East Africa, 31 (1991); Schippers in Fern Gaz. 14: 186 (1993); Verdcourt in F.T.E.A. Pterid. 21-22 (2002); Roux in Strelitzia 23: 176 (2009). **Type:** Tanzania, Lushoto district, East Usambaras, Mbalamu, *Holst* 2499 (holotype: B; isotype: K!).

Etymology: Type collected from Usambaras mountains.

Rhizome erect or shortly creeping, woody, scales dark brown, linear. Fronds tufted 0.6-2.0 m tall; stipes black, 0.48-1.1 m long, longer than the lamina, glabrous, slightly curved near the base and sparsely muriculate. Lamina triangular, subcoriaceous, 30-90 cm long, 10-30 cm wide, dark green, base bipinnate, imparipinnate near apex. Pinnae (3-8)-11 pairs, 16-30 cm long, 3-7 cm wide, abruptly ending into a long tail 8-23 cm long, 4-15 mm wide, lanceolate; basal pinnae bipinnate with a well developed basiscopic pinnule. Lower set of pinnae with distinct stalks 2-8 cm long. Pinnule 2.0-4.5 cm long, 5-9 mm wide; oblong. Costae spinulose above at the junction with costulae; veins free, sori 1.5-3 cm long covering even the sinus. Sterile margins serrate.

Ecology: Upland evergreen wet and mist forest.

Distribution: Kenya (Taita hills); Tanzania.

Elevation: 1050-2000 m.

Conservation status: Least Concern (LC).

Notes: Endemic in eastern arc mountains. This species is closely related to *P. kivuensis*, however, *P. usambarensis* have long caudate terminal lobe and dark green lamina. The long stalked basal pinnae give the plant an open look. Most common *Pteris* species in Mbololo forest (Taita hills) of Kenya.

Representative specimens examined: Kenya: Taita Taveta district, Taita Hills, Mbololo Hill, Mraru ridge, 3°18'85" S, 38°27'45" E, 23 Mar. 2010, *Kamau P* 409 (EA); Taita Taveta district, Mbololo Hill, 3°17' S, 38°28' E, Sep. 1932, *Gardner HM* 2944 (EA); Taita Taveta district, Taita Hills, Mbololo forest, 3°19' S, 38°27' E, 13 May 1985, *Faden RB et al.* 412 (EA); Taita Hills, Ngangao forest, base of Ngangao, 7 Jul. 1969, *Faden RB & Evans A* 868 (EA). **Tanzania:** Udzungwa Mountain NP, Mt. Luhombero, 7°47' S, 36°33' E, 29 Sept. 2000, *Luke WRQ et al.* 6769 (EA); Tanga, Eastern Usambara Mountains, Amani area, Bomole Hill, 30 Jun. 1970, *Faden RB et al.* 70/287 (EA); Tanga, Mlinga, 5°05' S, 38°45' E, 17 Aug. 1950, *Verdcourt B* 310 (EA).

18. *Pteris mkomaziensis* *Verdc.* in *Verdcourt, F.T.E.A. Pterid.* 18-20 (2002); Roux in *Strelitzia* 23: 174 (2009). **Type:** Tanzania, Same district, Mkomazi Game reserve, Maji Kununua ridge, *Abdallah R., Mboya & Vollesen* 96/91 (holotype: K!).

Etymology: Named after the type locality which is Mkomazi game reserve.

Rhizome shortly creeping, scales brown, shiny, linear lanceolate. Fronds dimorphic, tufted, sterile ones 30-37 cm long with stipe 17.5-20.5 cm long, fertile fronds up to 48 cm long, stipe 20-24 cm long with basal scales. Lamina ovate-triangular, leathery, 19-25 cm long, 18-22 cm wide, 2-3 pinnate. Rachis slightly winged on upper part by decurrent pinnae bases. Pinnae 3-4 pairs, sterile 1.2-11 cm long, fertile 11-15 cm long, 3-5 cm wide, basal pinnae in all cases 6.5-17.5 cm long, tripartite, deeply pinnatifid, in some cases the acroscopic pinnule slightly lobed. Pinnules 4-5 pairs, fertile 1-5 cm long, 3-5 mm, sterile 1.7-4 cm long, 5-14 mm wide. Terminal segment of lateral pinnae linear-lanceolate, reaching 3.0-8.5 cm long, 4-7 mm wide, sterile one as wide as 1.2 cm. Costae and costulae spinulose above, costae deeply channeled. Veins free, sori marginal, 0.5-5.8 cm long, sterile apices of lobes sharply mucronate or spinulose-serrate.

Ecology: Found in evergreen forests of *Diospyros abyssinica*, *Heywoodia lucens*, *Manilkara discolor* and *Croton megalocarpus*.

Distribution: Tanzania (endemic).

Elevation: ±1500 m.

Conservation status: Near Threatened (NT). No recent herbarium collections known.

Notes: Tanzanian endemic, only known from Mkomazi game reserve. Described by Verdcourt in 2002, unfortunately he did not provide an illustration of this species which is now provided (Fig. 5). A distinct species among free veined dimorphic group. Known from two collections only.

Representative specimens examined: Tanzania: Maji Kununua ridge, Mkomazi game reserve, 1500 m, 7 Dec. 1995, *Abdallah & Mboya* 3837 (K).

19. *Pteris albersii* *Hieron.* in *E.J.* 53: 389 (1915); Schelpe in *Contr. Bolus Herb.* 1: 63 (1969); Pichi Sermolli in *Webbia* 27: (2): 425 (1972); Johns, *Pteridophytes of Tropical East Africa*, 30 (1991); Schippers in *Fern Gaz.* 14: 185 (1993); Verdcourt in *F.T.E.A. Pterid.* 18-21, fig. 4 (2002); Roux in *Strelitzia* 23: 169 (2009). **Types:** Tanzania, Lushoto district, West Usambaras, near Kwai, *Albers* 358 (syntypes: B; BM! photo) and near Mkusu {Mkuszu}, *Busse* 365 (syntype: B; isosyntypes P!; BM!, photo.).

Etymology: This species is named after the botanist Albers who collected the type specimen.

Terrestrial species, rhizome erect, with dark brown linear-lanceolate scales. Fronds tufted 40-70 cm tall. Stipes 20-55 cm long, straw-coloured, glabrous, reddish and scaly at the base. Lamina ovate-triangular, 13-27 cm long, 7-23 cm wide, lower basal pinnae tripinnate/ tripinnatipartite. Pinnae 3-4 pairs, oblong-lanceolate, 8-13 cm long, 2.5-5 cm wide, basal and upper pinnae shortly stalked, middle one sessile. Basal pinnae with short partly winged stipicels. Pinnules oblong, subfalcate, -deltate, 6-13 pairs, 1.8-4 cm long, 3-8 mm wide. Fertile pinnule narrower than sterile, all with decurrent bases. Terminal segment long cuspidate 1.4-2.3 cm long, 3-4 mm wide. Sterile margins distinctly with spinous-mucronate teeth. Rachis not clearly distinct in the upper half of the blade, slightly winged especially in sterile fronds. Costae and costules raised and spinulose above, costae deeply channeled. Base of costae and rachis with tubercles of hairs. Veins free, simple or forked. Sori covering almost the whole length of the lobes, sterile apices with a single apical spinule or 3-11 spinous teeth on each side depending on whether it is lateral or terminal segment.

Key to the subspecies

1. Mucro and spinous teeth of ultimate segments very distinct.....subsp. *albersii*
Mucro and spinous teeth of ultimate segments not very distinct.....2
2. Rachis and stipe straw coloured.....subsp. *uaraguessensis*
Rachis and stipe dark purple-chestnut coloured.....subsp. *mufindiensis*

subsp. *albersii* Verdc. in F.T.E.A. Pterid. 19 (2002); Roux, Strelitzia 23: 169 (2009).
Mucro and spinous teeth of ultimate segments conspicuously distinct and sharp. Rachis and stipe straw-coloured, the stipe darker at the base.

Ecology: *Podocarpus- Agauria* forest on ridges.

Distribution: Tanzania (endemic).

Elevation: 1600-2100 m.

Chromosome number: Tetraploid, n=116, possibly apogamous (Walker 1962:29).

Conservation status: Least Concern (LC)

Notes: A highly restricted species occurring only in West Usambaras mountains.

Representative specimens examined: Tanzania: Arusha National Park, 3 March 1971 Richards M 26712 (EA); Lushoto/Tanga, Usambara Mountains, Highridge 1 mile NW of Kwai, West Usambaras, 12 Jun. 1953, Drummond RB and Hemsley JH 2903 (EA); Morogoro, Nguru Mountains, Northern peak of Matulumula, 6°00' S, 37°30' E, 20 Aug. 1971, Pocs T & Schlieben HJ 6440/C (EA).

subsp. *uaraguessensis* Verdc. in F.T.E.A. Pterid. 19 (2002); Roux in Strelitzia 23: 169 (2009). **Type:** Kenya, Northern frontier district, Uaraguess, *Newbould* 3037 (holotype & isotype: K!).

Mucro and spinous teeth of ultimate segments scantily distinct. Rachis and stipe straw-coloured, the stipe darker at the base and muriculate-spinulose.

Ecology: *Juniperus procera-Podocarpus* forest.

Distribution: Kenya (endemic).

Elevation: 2250-2400 m.

Conservation status: Data deficient. Found in a very remote area where botanical surveys are yet to be done.

Notes: The only endemic species of *Pteris* in Kenya and known from two specimens. The species was described by Verdcourt (2002), but failed to provide an illustration, which is provided in this account with an ultimate segment emphasizing its distinctive character from other subspecies (Fig. 3).

Representative specimens examined: Northern Frontier District, Mt. Nyiru, 2°10' N, 36°50' E, 22 Jan. 1977, *Bono G. 38* (EA).

subsp. *mufindiensis* Verdc. in FTEA Pterid. 21 (2002); Roux in Strelitzia 23: 169 (2009). **Type:** Tanzania, Iringa district, Kigogo Forest, *Vesey-FitzGerald* 3656 (holotype: former int. red locust Contr. Survey Herb. & K!).

Mucro and spinous teeth remotely well marked, rachis and stipe dark purple to chestnut.

Ecology: Streamsides in rain forest, shaded undergrowth.

Distribution: Tanzania (endemic).

Elevation: 1850-2050 m

Conservation status: Least Concern (LC)

Notes: Tanzanian endemic. An illustration of this species is provided in (Fig. 4), plus a close up of the segment apices showing mucro and spinous teeth.

Specimens examined: Udzungwa Mountain National Park, Mt Luhomero, 7°47' E, 36°33' S, 30 Sept. 2000, *Luke WRQ et al.* 6824 (EA); Udzungwa Mountain National Park, 7°45' S, 36°51' E, 1 Oct. 2001, *Luke WRQ* 8033 (EA); Iringa district, Mufindi Escarpment, next to view point on escarpment, 8°35' S, 35°15' E, 19 Nov. 1985, *Schippers* R1127 (EA).

20. *Pteris dentata* Forssk., Fl. Aegypt.-Arab: 186 (1775); Sim, Ferns S. Afr. ed. 2: 255, t. 129 (1915); Tardieu, Fl. Madag. 5 (1): 91, figs. 14/5-6 (1958); Alston, Ferns W.T.A.: 42 (1959); Runemark in Bot. Not. 115: 189, fig. 1c, 2c-d, 5 (1962); Schelpe in Contr. Bolus Herb. 1: 64-65 (1969) & Expl. Hydrobiol. Bassin L. Bangweolo & Luapula 8 (3) Pterid.: 57 (1973) & C.F.A., Pterid.: 94 (1977); Kornas, Distri. Ecol. Pterid. Zamb. 69 (1977); Schelpe & M.A. Diniz, Fl. Mozamb., Pterid.: 118 (1979); Jacobsen, Ferns S. Afr.: 239, fig. 171 (1983); Schelpe & Anthony, F.S.A., Pterid.: 109, fig. 33/1 (1986); Benl in Acta Botanica Barcinonensia 38: 11-13 (1988); Burrows, S. Afr. Ferns: 160, t. 26.2, fig. 39, 161 (1990); Johns, Pteridophytes of Tropical East Africa, 30 (1991); Faden in U.K.W.F. ed 2: 20 (1994); Roux, Consp. S. Afr. Pterid., SABONET, 13: 79 (2001); Verdcourt, F.T.E.A. Pterid. 22-23 (2002); Roux, Swazi. Ferns & Ferns All. SABONET, 19: 96 (2003); Roux in Strelitzia 23: 171-172 (2009); Crouch *et al.* Ferns. S. Afr.: 320-321, t. 1-5 (2011). **Type:** Yemen, Menacha, 2300 m, 1889, *Schweinfurth G.A.* 1402 (neotype: C; isoneotype: K!) designated by Runemark (1962: 189) after *Forsskål s.n.* was lost.

Etymology: *dentata* means toothed or dentate; referring to the dentate margin of the sterile lobes of pinnae.

Synonyms

Pteris flabellata Thunb., Prodr. Pl. Cap.: 172 (1800); Hieron. in P.O.A.C.: 80 (1895). Type: South Africa, Cape Peninsula, between Taffelberg & Leuwekopp, *Thunberg* s.n. (lectotype: UPS).

P. dentata Forssk. var. *flabellata* (Thunb.) Runemark in Bot. Not. 115: 190, fig. 1f, g, 2/e-f, 6 (1962); Schelpe in F.Z. Pterid.: 112 (1970); Schippers in Fern Gaz. 14: 185 (1993).

P. arguta Ait. Var. *flabellata* (Thunb.) Mett. ex Kuhn, Filices africanæ: 76 (Oct. 1868).

P. arguta Ait. Hort. Kew 3: 458 (1789). Type based on *P. serrulata* Forssk.; non. illegit.

P. serrulata Forssk., Fl. Aegypt-Arab.: 187 (1775), non l.f. (1782). Type: Yemen, Hadie, *P. Forsskal* s.n. (C, lost; BM! lecto.). Designated by Morton (1969a: 247-248).

P. arguta Ait. var. *typical* Peter in Feddes Repertorium, Beiheft 40, 1: 47 (1929), nom. illeg. Type: As for *Pteris arguta* Ait.

Lonchitis adscensionis G. Forst. in Comm. Soc. Reg. Sci. Gott. 9: 72 (1789). Type: Ins. Ascensionis, *G. Forster* s.n. (holotype: B-W).

P. arguta Ait. var. *minor* Mett. ex Kuhn, Filices africanæ: 77 (Oct. 1868). Type: As for *Lonchitis adscensionis* G. Forst.

P. flabellata Thunb. var. *ascensionis* (Sw.) Hook., Species filicum 2, 7/8: 185 (Jan.-Sep. 1858).

P. arguta Ait. var. *flabellate* (Thunb.) Mett. ex Kuhn

P. ascensionensis Sw., Synopsis filicum: 100, 294 (Mar.-Apr. 1806a), as 'adscensionis'. Type: Habitat in insula sterilissima Adscensionis *sine coll.* s.n.

P. arguta Ait. var. *flabellata* (Thunb.) Kuhn f. *major* Mett. ex Kuhn, Filices africanæ: 77 (Oct. 1868). Type: As for *Lonchitis adscensionis* G. Forst.

P. arguta Ait. var. *flabellata* (Thunb.) Kuhn f. *minor* Mett. ex Kuhn

P. elegans Jacq., Frag. Bot.: 74, pl. 116 (1809). Type: Cultivated at the Scho. Gard., Vienna, from spores originating from the Cape. *sine coll.* s.n.

P. semiserrata Roxb. in Tracts relative to the island of St. Helena: 319 (Jan. 1816). Type: St. Helena, Sandy Bay, *J. Roxburgh* s.n. (holotype: BM).

P. oligodictyon Baker in J.B. British and Foreign 1880, 9: 328 (1880b). Type: Madagascar, Forest Andrangaloaka, *L. Kitching* s.n. (holotype: K).

P. dentata Forssk. var. *oligodictya* (Baker) Tardieu in Flore de Madagascar et des Comores, 5e Famille-Polypodiacees (sensu lato) [5 (1) Dennstaedtiacees-(10) Apspidiacees] : 92, fig. 14, t. 7, 8 (May 1958b).

P. straminea Cordem., Flore de l'Île de la Reunion: Cryptogamae vasculares: 52, 53 (1895), nom. nud. [McNeill et al. (2006) Art. 32. 1 (d) & Art. 41. 3].

P. cordemoyi C. Chr., Index filicum: 595 (2 Jul. 1906), nom. nov. for *Pteris straminea* Cordem.

Plant terrestrial, occasionally growing on the base of tree trunk, rhizome erect or shortly creeping with black chestnut shining linear-lanceolate scales. Fronds tufted, 0.1 (juvenile)-2.8 m tall. Stipes glabrous, 0.5-1.1 m long, straw coloured, base usually purplish occasionally dark brown. Rachis glabrous, decurrent from pinnae bases. Lamina pale green, broadly ovate, 0.5-0.9 m long, (2-46)-56 cm wide. Lamina distally pinnate, basal pinnae deeply 2-pinnatifid, strongly developed basiscopically, pinnae (8-13)-16 pairs, oblong in outline, 8-37 cm long, 3.3-9 cm wide. Pinnules 9-35 pairs, linear often falcate, 0.4-7.2 cm long, 0.2-0.8 cm wide, apex acute, base unequally adnate to the costa. Sterile margin distinctly serrate-dentate; veins free; costae channeled above, with spinules on upper surface at the junctions with costulae. Sori marginal, 2.1- 6 cm long, false indusium often erose or entire.

Ecology: *Pteris dentata* is a species of submontane, lower and middle montane moist forest along tracks and roads. Common in bamboo forest and in slopy forest sides.

Distribution: Angola, Ascension Isl., Bioko, Burundi, Cameroon, Cape Verde Isl., DRC, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mauritius, Moroccoa, Mozambique, Namibia, Principe, Reunion, Rodriques Isl., Rwanda, Sao Tome, South Africa, St Helena, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe.

Elevation: 1000-3000 m

Conservation status: Least Concern (LC)

Chromosome numbers: 2n= 58 (Walker 1962: 30).

Note: *P. dentata* is a widespread and variable species which for over two centuries have undergone name changes mainly due to loss of Forsskal's type specimen. Subsequent neotype was selected by Runemarck who subdivided this species into subsp. *dentata* and subsp. *flabellata* (Thunb.) Runem, based on margins serration. However, with keen observation of the specimens, many intermediates specimens occur and no sharp distinction exist between the two subspecies to warrant recognition.

Representative specimens examined: Eritrea: 19 Aug. 1902, *Pappi A* 2765 (EA).

Kenya: Thika, Blue Post Hotel, forest remnant behind the hotel along Chania river, 28 Sept. 2010, *Kamau P* 541 (EA); Nkunga crater lake, 0°00'70" N, 37°35'00", 19 Jan. 2001, *Luke P.A.*, 7227 (EA); Taita Taveta, Taita hills, Ngangao forest, base of Ngangao, 3°22' S, 38°20' E, 7 Jul. 1969, *Faden RB* 871 (EA); Taita Taveta, Kasigau, Mt. Kasigau, path from Rukanga up the mountain, 3°50' S, 38°40' E, 5 Apr. 1969, *Faden RB* 436 (EA); Kajiado, Chyulu Hills, main north forest, 2°40' S, 37°52' E, 12 Dec. 1993, *Luke P.A. & Luke WRQ* 3881 (EA); Kakamega Forest, Malava forest, 0°27'06" N, 34°51'33" E, 23 Sept. 2008, *Kamau P*, 47; Nairobi, Thika Road, 1°17' S, 36°49' E, 22 Oct. 1950, *Verdcourt B* 366 (EA)

; **Tanzania:** Mpwapwa/Kilosa, Ukaguru Mountains, near Mandege forest station, 24 May 1972, *Pocs T* 6586 (EA); Arusha, Ngurdoto Crater National Park, Crater forest, 3°15' S, 36°53' E, 1 Dec. 1964, *Vesey-Fitzgerald D* 4445 (EA); **Uganda:** Kigezi, Maramagambo CFR, near lake Nyamusingiri, Queen Elizabeth NP, 13 May 1968, *Lock JM & Coopers* 68/100 (EA); Bunyoro, Budongo forest nature reserve, 1°43'37" N, 31°31'18" E, 11 Nov. 2009, *Kamau P* 339 (EA).

21. *Pteris linearis* Poir. in *Encycl. Meth.* 5: 723 (1804); *Fl. Madag.* 5 (1): 97, figs. 15/7-8 (1958); Alston, *Ferns W.T.A.*: 40 (1959); *Fl. Cameroun* 3: 163, t. 22/3 & 23/2-3 (1964) & *Fl. Gabon* 8: 111, t. 19/1-2 (1964); Alston, *Ferns W.T.A.*: 42 (1959); Schelpe in *Contr. Bol. Herb.* 1: 62 (1969); Benl, *Acta Botanica Barcinonensia* 38: 15 (1988); Johns, *Pteridophytes of Tropical East Africa*, 30 (1991); Schippers in *Fern Gaz.* 14: 186 (1993); Verdcourt, *F.T.E.A. Pterid.* 24 (2002); Roux in *Strelitzia* 23: 174 (2009). **Type:** Mauritius, *Commerson*, *s.n.* (holotype: P-LA).

Synonyms

Pteris biaurita L. var. *nemoralis* (Bory ex Willd.) A. chev., *Exploration botanique de l'Afrique occidentale française* 1: 770 (1920).

P. hildebrandtii sensu Tardieu in *Mem. I.F.A.N.* 28: 74, t. 12, f. 2 (1953d) & in *Fl. Cameroun* 3: 163 (1964) pro syn., non Hieron. (1915: 407).

P. nemoralis Bory ex Willd., Enumeratio Plantarum hortiregii botanici berolensis 2: 1073, 1074 (Jun. 1809b). Type: Habitat in insula mauritiï et Borboniae ad nemorum margines, sine coll. s.n.

Campteria nemoralis (Willd.) J. Sm. in Companion to the Botanical Magazine 72: 23 (1846).

Rhizome erect, becoming woody, scales linear lanceolate, margins pale. Fronds tufted, 0.4-1.2 m tall. Stipes 17-80 cm long, straw-coloured, base reddish and sparsely scaly. Lamina ovate-oblong in outline, 22-(40-60) cm long, 12-40 cm wide, pinnate. Basal pinnae bipinnate, stipicellate, upper pinnae 4-12 pairs, oblong, 10-30 cm long, 2.5-6.5 cm wide. Pinnules in 16-37 pairs, linear to narrowly oblong, falcate, 1.0-3.6 cm long, 3-8 mm wide, with a rounded entire apex. Veins joined at base of sinus to form a complete triangular or an arch below the sinus thus forming a continuous series of areoles. Costae spinulose above at junction with costulae. Sori marginal, linear 1.0-3.3 cm long, sterile margin entire.

Ecology: Ecologically diverse species, growing from lowlands to the montane zone. Common in moist shady ravines.

Distribution: Bioko, Burundi, Cameroon, Congo (Kinshasa), Gabon, Ghana, Madagascar, Mali, Mascarene Is.; Nigeria, South Africa, Sudan, Tanzania, Uganda, Zambia and tropical Asia.

Elevation: 800-1800 m

Conservation status: Least Concern (LC)

Notes: Jacobsen (1983) in Ferns S. Afr.: 242 (1983) had erroneously sunk *P. linearis* into *P. friesii* probably because of the misidentification of the *P. linearis* specimens by Tardieu. This anomaly was subsequently rectified. Specimens examined look slightly different from the type specimen especially in relation to the long caudate apex of the pinnae which is conspicuously lacking in most of the East African specimens. The presence of costal areoles and entire rounded lobes apex clearly distinguishes this species from others.

Representative specimens examined: **Burundi:** Bururi, Rumonge, 1100 m, 9 Jun. 1966, *Lewalle* J 922 (EA). **DRC:** L. Kivu, 26 Oct. 1930, *Vandieryt* 26778 (EA). **Gabon:** Bayaka forest, *Testu* GL 1963 (EA). **Ghana:** Boti, Ruhunya, near a waterfall, 6 May 1950, *Adams* 280 (EA); Eastern region, Boti falls, growing below a cliff, *Bigger* 2458 (EA). **Tanzania:** Kigoma, Gombe Stream Reserve, Lower Mkenke, 2 Apr. 1970, *Clutton-Brock* TH 575 (EA); Tanzania, Buha, Kakombe valley, 4°38' S, 29°36' E, 2 Jan. 1972, *Daniel* 2018 (EA); Kigoma district, Kungwe-Mahali Peninsula, Kakombe near Kigoma, 2600", 7 Jul. 1959, *Harley & Newbould* 4237 (EA). **Uganda:** Bunyoro, Murchison Falls National Park, Murchison falls, 15 Sept. 1969, *Faden* RB 69/1062 (EA).

22. *Pteris microlepis* Pic. Serm. in B.J.B.B. 53: 227-231, fig. 7 (1983); Roux in Strelitzia 23: 174 (2009); **Type:** Rwanda, Ruhengeri, Parc National des Volcans, selle Ngahinga-Muhavura *Van der Veken* 10600 (holotype: GENT; duplicates BR! LG, NAM, FI-PS).

Etymology: Small, little scales.

Plant terrestrial, rhizome erect, scales shiny lanceolate, with red-chestnut median area and narrow erose margin. Fronds tufted reaching 1 m tall, with 1-2 bulbil on the rachis near apex. The bud scaly, scales shiny brown with erose margin. Stipes reaching 50 cm long,

feebly muriculate, straw coloured, base reddish and scaly. Lamina ovate-triangular, reaching up to 65 cm long and 48 cm wide, basal pinnae bipinnate, upper ones pinnate. Pinnae 8-13 pairs, oblong-lanceolate, 3-18 cm long, 2.2-3.0 cm wide, pinnae deeply incised to the costa. Apical segment of pinnae long caudate 1.5-2.0 cm long, 2 mm wide, margin crenate. Pinnules 22-28 pairs, 1.2-2.3 cm long, 3-8 mm wide, linear oblong, apex entire obtuse to rounded. Costae and costulae spinulose beneath. Veins free, sori 2-7 mm long, at the middle of the lobes.

Ecology: Bamboo forest with *Pilea* and *Impatiens*.

Distribution: Kenya (Known only from Mt. Kenya, one collection), Rwanda, Uganda.

Elevation: 2350-2550 m

Conservation status: Least Concern (LC)

Notes: Scales on the costa of pinnae, free veins and bulbiferous rachis represent the most important distinctive characteristic of this species. Closely related to *Pteris preussii*, though *P. microlepis* have narrower, numerous and deeply incised pinnae.

Specimens examined: **Uganda:** Toro, Bwamba pass, 7900" *Thomas AS 1433* (EA).

23. *Pteris preussii* Hieron. in E.J. 53: 399 (1915); Alston, Ferns W.T.A.: 40 (1959); Tardieu, Fl. Cameroun 3: 160, t. 22/1-2 (1964); Schelpe, Contr. Bolus Herb. 1: 64 (1969); Kornas, Distri. Ecol. Pterid. Zambia 69 (1977); Benl, Acta Botanica Barcinonensia 38: 10 (1988); Schippers in Fern Gaz. 14: 186 (1993); Faden in U.K.W.F. ed. 2: 20 (1994); Verdcourt, F.T.E.A. Pterid. 27-28 (2002); Roux in Strelitzia 23: 175 (2009). **Type:** Cameroon, Buea, *Preuss PR 585* (holotype: B; duplicates: BML, P).

Etymology: Named after a botanical collector Preuss P.R.

Synonyms

Pteris deistelii Hieron. in E.J. 53: 400 (1915). Type: Cameroon, Buea, *Deistel*, 476, no. '456' was an error. (syntype: B; isotype: P; BML, photo).

P. prolifera Hieron. in E. J. 53: 397-398 (1915); Tardieu, Mem. I.F.A.N. 28: 72, t. 11, fig. 1-2 (1953); Alston, Ferns W.T.A.: 40 (1959); Tardieu, Fl. Cameroun 3: 158 (1964); Schelpe, Contrib. Bolus Herb. 1: 64 (1969); Pichi Sermolli in B.J.B.B. 53: 232-233 (1983); Benl, Acta Botanica Barcinonensia 38: 11 (1988); Johns, Pteridophytes of Tropical East Africa, 31 (1991). Type: Cameroon, Lolodorf, *Staudt 197* (holotype: B; isotype: P).

Rhizome woody, erect or shortly creeping with darker linear-lanceolate scales. Fronds tufted, at times shortly spaced, 0.8-1.5 m tall, with a gemmae at the base of uppermost pinna pair. Stipes 25-90 cm long, straw coloured, base dark and sparsely scaly. Lamina long and narrow, linear-oblong to ovate-oblong, 0.5-1.1 m long, 20-60 cm wide, papery, pinnate-pinnatifid. Pinnae linear-oblong, 6-21 pairs, 7.5-47.0 cm long, 1.2-6.5 cm wide, lower pinnae bifid, having as many as 50 pairs of pinnules. Pinnae sizes decreases from the base towards the apical pinnae. Pinnules narrow, falcate-oblong, 14-53 pairs, 0.4-4.2 cm long, 2-5 mm wide, apex obtuse, entire. Terminal segment reaching 6 cm long. Costa and costulae spinulose above; veins free. Sori occupying more than $\frac{3}{4}$ of the segment length, sterile margins entire.

Ecology: Common in evergreen forest, montane zone, bamboo forests, swampy places and in shady slopes.

Distribution: Bioko, Burundi, Cameroon, Congo, DRC, Equatorial Guinea, Kenya, Liberia, Rwanda, Sudan, Tanzania, Uganda.

Elevation: 500-2700 m

Conservation status: Least Concern (LC)

Notes: This species is very similar to *P. catoptera* in most of its features, except that *P. catoptera* lack gemmae. However presence or absence of gemmae may not be a discrete character worthy taxonomic recognition because it was absent in some young plants of *P. preussii* thus making it difficult to identify the young ones *P. catoptera* and *P. preussii*. However in this account, they have been treated separately, until molecular analysis is carried out. Bar coding done on the two species however showed the two are distinct species.

Representative specimens examined: **Kenya:** Kakamega Forest, Salazar 1, 0°15'53" N, 31°43'42" E, 15 Oct. 2008, *Kamau P* 89 (EA). **Tanzania:** Iringa, Mwanihana forest reserve, above Sanje village, Kilombero district, Morogoro region, 7°50' S, 36°55' E, 10 Oct. 1984, *Thomas DW* 3888 (EA); Morogoro, Uluguru Mts., along road from morning side to the summit of Bondwa, 6°54' S, 37°40' E, 3 April 1974, *Faden RB* 387 (EA). **Uganda:** Ankole, Kalinzu forest reserve, 3.5 miles, NW of saw mill, West of Rubuzigye, 19 Sept. 1969, *Faden RB* 69/1165 (EA); Bunyoro, Budongo forest, Compactment N2, Line 06, 1°43'46" N, 31°33'07" E, 9 Mar. 2009, *Kamau P* 212 (EA); Bunyoro, Budongo forest, track from Busingiro, 16 Sept. 1969, *Faden RB* 69/1074 (EA).

24. *Pteris catoptera* Kunze in Linn. 18: 119 (1844); Alston, Ferns W.T.A.: 42 (1959); Schelpe in Contr. Bolus Herb. 1: 63 (1969) & F.Z. Pterid.: 117 (1970) & C.F.A., Pterid.: 94 (1977); Kornas, Distri. Ecol. Pterid. Zamb. 70 (1977); Jacobsen, Ferns S. Afr.: 240, fig. 172 (1983); Schelpe & Anthony, F.S.A.: 109, fig. 33/2, 2a (1986); Benl in Acta Botanica Barcinonensia 38: 14 (1988); Burrows, S. Afr. Ferns: 163 (1990); Johns, Pteridophytes of Tropical East Africa, 29 (1991); Schippers in Fern Gaz. 14: 185 (1993); Faden in U.K.W.F. ed 2: 20, pt. 171 (1994); Roux, Consp. S. Afr. Pterid., SABONET, 13: 78 (2001); Verdcourt, F.T.E.A. Pterid. 24-26, fig. 2/4 (2002); Roux, Swazi. Ferns & Ferns All. SABONET, 19: 92 (2003); Roux in Strelitzia 23: 170-171 (2009); Crouch *et al.* Ferns. S. Afr.: 324-325 t. 1-6 (2011). **Type:** South Africa, Natal, between Omfondi and Tugela rivers, *Gueinzijus s.n.* (holotype: LZ; lectotype: Kl).

Synonyms

Pteris abrahamii Hieron. in E.J. 53: 409 (1915), as *abrahami*. Type: South Africa, Natal, Umvoti river area, Mapumulo, *Abraham* 27 (holotype: B; BOL, K, photo.) (intermediate with few costular spinules).

P. abyssinica Hieron. in E.J. 53: 405 (1915). Type: Ethiopia, near Amora-Gattel, *Schimper* 1468 (holotype: B; isotypes: Kl, Pl!).

P. angolensis Hieron. in E.J. 53: 395 (1915). Type: Angola, Pungo Andongo, *Soyaux* 226 (Isotype: Kl; Syntype: B).

P. biaurita sensu Sim, Ferns S.Afr.ed. 2: 257, t. 127 (1915), *non* L.

P. catoptera Kunze var *catoptera*; Schelpe, F.Z. Pterid.: 118 (1970); Jacobsen, Ferns S. Afr.: 240, fig. 172 (1983); Schelpe & Anthony, F.S.A.: 109, fig. 33/2,2a (1986); Burrows, S. Afr. Ferns: 163, t. 26.5, fig. 40/164, 164a, b (1990); Schippers in Fern Gaz. 14: 185 (1993); Verdcourt, F.T.E.A. Pterid. 24-25, fig. 2/4 (2002); Roux in Strelitzia 23: 170-171 (2009).

P. catoptera Kunze var *friesii* (Hieron.). Verdc. Comb.et stat.nov; Verdcourt, F.T.E.A. Pterid. 25-26 (2002); Type: Zambia, near Abercorn, *Fries* 1220 (holotype: UPS; fragment: B; photo: K).

P. catoptera Kunze var *horridula* Schelpe in Bol. Soc. Bot. ser. 2, 41: 216 (1967) & in Contrib. Bolus Herb. 1: 66 adnot. (1969) & F.Z. Pterid.: 118, t. 38 (1970); Jacobsen, Ferns S. Afr.: 241(1983); Burrows, S. Afr. Ferns: 164 (1990); Verdcourt, F.T.E.A. Pterid. 26 (2002). Type: Zimbabwe, Mutare (Umtali), Inyamatshira Range, *Chase* 4890 (holotype: BOL; isotypes: BM! K!, SRGH).

P. friesii Hieron. in Wiss. Ergebn. Schwed. Rhod.-Kongo Exped. 1: 5 (1914); Roux in Strelitzia 23: 172 (2009); Crouch *et al.* Ferns. S. Afr.: 324-325 t. 1-6 (2011). Type: Rhodesia bor. Orient.: Lunzua river near Abercorn, 8 Nov. 1911, *Fries* 1220 (holotype: UPS; fragment: B).

P. hildebrandtii Hieron. in E.J. 53: 407 (1915). Type: Madagascar, near Tananarive, *Hildebrandt* 3479 (holotype: B; isotype: BM!, K!).

P. kameruniensis Hieron. in E.J. 53: 393 (1915). Syntypes: Cameroon, near Kumbo, *Ledermann* 2002 (B; P!; BM, photo.) & near Babangi, *Ledermann* 5828 (B; BM, photo.) (intermediate between varieties).

P. mobasiensis Hieron. in E.J. 53: 391 (1915). Faden in U.K.W.F.: 35 (1974). Type: Rwanda, W of Lake Kivu, L. Mohasi, *Mildbraed* 438 (isotype: P!; BM, photo.).

P. paucipinnata Alston in Excell, Bull. I.F.A.N. ser. A, 21: 443 (1959). Type: Sao Tome, above Monte Café, *Monod* 11690 (holotype: BM!).

P. stolzii Hieron. in E.J. 53: 410 (1915). Type: Tanzania, Rungwe District, Kyimbila, *Stolz* 937 (isotype: K!; Syntype: B).

P. togoensis Hieron. in E.J. 53: 402 (1915); Alston, Ferns W.T.A.: 40 (1959) pro parte; Tardieu, Fl. Cameroon 3: 160, t. 14/6, t. 22/4-5 (1964). Type: Togo, Rue Mts, *Kersting* 653 (lectotype: B; isolectotype: BM!). Lectotypification done by Tardieu-Blot (1959).

P. quadriaurita sensu Sim, Ferns S. Afr.: 108, t. 44 (1892); Hieron. in P.O. A. C: 79 (1895) & V.E. 2: 45, fig. 38 c-e (1908); F.D.-O.A.: 47 (1929); Tardieu, in Mem. I.F.A.N. 28: 76, t. 12, fig. 3 (1953), *non* Retz.

P. quadriaurita Retz. subsp. *abyssinica* (Hieron.) Schelpe, Contrib. Bolus Herb.1: 66 (1969).

P. quadriaurita Retz. subsp. *catoptera* (Kunze) Schelpe, Contrib. Bolus Herb.1: 66 (1969) & C.F.A., Pterid.: 95 (1977); Schelpe & Diniz, Fl. Mocamb., Pterid.: 120 (1979).

P. quadriaurita Retz. subsp. *friesii* (Hieron.) Schelpe, Contrib. Bolus Herb.1: 66 (1969); Schippers in Fern Gaz. 14: 186 (1993).

P. quadriaurita Retz. subsp. *togoensis* (Hieron.) Schelpe, Contrib. Bolus Herb.1: 66 (1969).

A heterogenous species with rhizome erect to shortly creeping with linear-lanceolate dark scales, with pale hairy margins. Fronds tufted forming a thick stock, arching (0.4-1.5)-2.5 m tall. Stipe 0.7-1.0 m long, straw-coloured, glabrous or with sparse scales or spines at the base which is reddish. Lamina oblong or oblong ovate, 24-90 cm long, 14-64 cm wide, pinnate. Pinnae oblong, 4-23 pairs, 9-30 cm long, 2.0-5.5 cm wide, basal pinnae with 1-4 accessory pinnae as long as 37 cm long and 11 cm wide. Pinnules narrowly oblong, (16-) 22-45 (-51) pairs, 1-5.5 cm long, 2-5 mm wide. Rachis smooth or spiny, costae and costules variably spinulose above and occasionally beneath. Veins free, sori marginal,

uninterrupted, occupying most of the length of the segments, sterile apices entire and rounded.

Ecology: Widespread species of wet and dry forests, common in evergreen riverside forests, bamboo zone, along wetter fringe of the dry zone in deep shade and on continuously wet soil.

Distribution: Angola, Bioko, Burundi, Cameroon, Central Africa Republic, Comoro Isl., Ivory Coast, DRC, Ethiopia, Gabon, Ghana, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Nigeria, Rwanda, Senegal, Sierra Leone, Socotra, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe.

Elevation: 450-3050 m

Conservation status: Least Concern (LC)

Notes

The whole group has been treated as *Pteris catoptera* complex, which is free veined with entire, rounded sterile apices. This group is highly complicated and various authors have tried to group the many morphotypes into either varieties or subspecies with no success as intermediates species occur in all geographical ranges of continental Africa. Many authors have used presence or absence of costular spinules, which are however variable and highly inconsistent in many specimens observed. Morphologically, there are no distinct and constant characters of taxonomic important that can be used in separating the many superficially similar species contained in this complex. Both sexual diploids and apogamous triploids occur in this species complex (Walker 1962). What is referred to as *P. catoptera* probably are several species contained in this complex, *P. catoptera* sensu stricto is a sexual diploid species, while *P. friesii* is distinct and an apomictic triploids. In this account, the 3 varieties i.e. *P. catoptera* var *catoptera*; var *friesii* Hieron.; var *horridula* Schelpe referred to in various publications by previous authors have not been recognized due to lack of discrete taxonomic characters. They are all referred here to as *Pteris catoptera* until further and wide range investigations is carried out. It is highly recommended that, there is need to carry out cytological and molecular work (which was not part of objective in this work) incorporating geographical affinities in this complex group in order to solve its taxonomic problems.

Representative specimens examined: Kenya: Taita Taveta, Sagala hills near Voi, Eastern slope near the highest point, 1 Jan. 1971, *Faden* RB 71/02 (EA); Marsabit, Mt. Kulal, 30 Jun. 1973, *Cameron JBC* 159 (EA); Marsabit, near pump house, 2°29' N, 37°55' E, 8 Aug. 1968, *Faden* RB 496 (EA); Kirinyaga district, Castle forest station, 0°21' S, 37°19' E 19 Dec. 1972, *Gillett JB* 20103 (EA); Murang'a, Kimakia forests station-Gatare road, 1 miles from Kimakia forest station, first right hand turning, 0°44' S, 37°10' E, 14 Feb. 1970, *Faden* RB 70/56 (EA); Kericho, Kimugung river, ca. 5 km NW of Kericho, 0°20' S, 35°20' E, 10 Jun. 1972, *Faden* RB & *Cameron JBC* 72/286 (EA); Meru, Lower Imenti forest, 6 miles from Meru along Meru - Mikinduri road, 0°03' N, 37°39' E, 1 Mar. 1970, *Faden* RB 70/121 (EA); Nyandarua district, Silibwet, goodfall village, 0°03'64" S, 36°15'19" E, 29 Dec. 2010, *Kamau P* 568 (EA); Kericho, Tinderet forest, 0°03'98" S, 35°24'75" E, 23 Jul. 2010, *Kamau P* 530 (EA); Nakuru, Mau forest, SW Mau forest through Chagaik road, 0°21'87" S, 35°22'91"E, 22 Jul. 2010, *Kamau P* 525 (EA); Taita Taveta district, Mbololo forest, Mbololo hill, 0°43'66" S, 36°40'94" E, 22 Mar. 2010, *Kamau P* 389 (EA); Thika district, Blue Post Hotel,

forest remnant behind the hotel along Chania river, 28 Sep. 2010, *Kamau P* 540 (EA); Kakamega Forest, Salazar 1, 20 Sep. 2008, *Kamau P* 18 (EA). **Tanzania:** Morogoro, Uluguru Mountains, NW slopes of Lupanga above Morogoro, 14 Nov. 1970, *Pocs T & Harris* 6121/B (EA); Moshi, by river Njoro, 8 km west of Moshi amongst rocks in riverine forest, 3°21' S, 37°20' E, 3 Nov. 1955, *Milne-Redhead* 7029 (EA); Moshi, Kilimanjaro, above Mweka, 3°04' S, 37°22' E, 28 Aug. 1969 *Gilbert VC* 3565 (EA); Morogoro, Uluguru mountains, Bondwa, 7 Sept. 1969, *Pocs T* 3283 (EA); Tanga, Usambara mountains, Eastern Usambara mountains, Amani area, Derema, 30 June 1970, *Faden RB* 290 (EA); Udzungwa mountain National park, 7°43'40" S, 36°33'00" E, 28 May 2002, *Luke PA & WRQ* 8510 (EA). **Uganda:** Mengo, Bugolobi 0°19' N, 32°37' E, 10 Oct. 1969, *Rwaburindore PK* 183 (EA; MHU); Mengo, Mpanga forest reserve and research station, 5 km east of Mpigi, 0°13'12" 0° 32'18"00", 9 Sept. 1969, *Faden RB* 69/1011 (EA). **Zaire:** Affluent Kanianga, 30 Oct. 1987, *Herbier AB* 3502 (EA). **Ethiopia:** Shoa, near Bacho, Sept. 1969, *Mogk M* 194 (EA).

Unresolved *Pteris* species

Pteris repens C. Chr. Index filicum: 606 (Jul. 1906), nom. nov. for *Pteris nitida* Mett. ex Kuhn (1868: 86), non R. Br. (1810: 155); Roux, *Strelitzia* 23, 175(2009); Roux, *Consp. S. Afri. Pterid.*, SABONET, 13: 79 (2001); Type: Africa Occidentalis, Ad flumen Gabon, *G. Mann* 1047 (BM!, holo., K!, iso.) is actually not a *Pteris* species but its correct identity is *Afropteris repens*. However, this species is clearly embedded in the genus *Pteris* clade after molecular analysis done by various researchers.

Pteris quadriaurita Retz sensu lato, a species complex with species which are inseparable using morphological characters, native of Asia and does not occur in Africa continent. However African materials initially identified as *Pteris quadriaurita* are all *Pteris catoptera*. However, this species are closely related.

Pteris ekemae Benl in *Nova Hedwiga* 27, 1/2; 147, figs 1, 2 (1976). There is species which is listed to occur in tropical Africa specifically Cameroon but no materials were found. However it was established that it is not a validly published name, isotype; Cameroon, *Benl Ka* 75/49 deposited at BM, and the specimen is identified as *Pteris preussii*.

CHAPTER 6. ECOLOGY OF FERNS AND LYCOPHYTES IN TROPICAL LOWLAND RAINFORESTS OF KAKAMEGA AND BUDONGO

6.1 Introduction

Tropical lowland rainforests are complex and characterized by variety of microhabitats. They sustain a large portion of the world's biological diversity. Despite this they are vanishing more rapidly than any other biome (Laurance 1999) due to socio-economic development in regions neighboring these forests. Tropical rainforests are mainly confined to an equatorial belt of varying width and vegetation change is more strictly associated with latitude. In Africa vegetation zones roughly form a series of parallel bands across the continent that corresponds to rainfall patterns, temperature or elevation. Evergreen forests occur in a narrow band along the coasts of West Africa and central Africa, and across the Congo basin into East Africa. Because of their high biological diversity and uniqueness, African rainforests are a top global conservation priority (Olson and Dinerstein 1998). There are estimated to contain over 8000 plant species, 80% of which are endemic (White 1983). However, despite all their global importance and concerted effort dedicated to saving them, conservation challenges face great impediments caused by lack of effective management plans, recurring wars, political instability, and disease epidemics.

Ferns and lycophytes make up an important component of tropical and temperate pteridoflora, serving important functions in ecosystem processes such as source of food for caterpillars, being habitat for other organisms, providing shade, and preventing soil erosion. They also play a crucial role in vegetation structure (Paciencia and Prado 2005). Fern richness and distribution according to Moran (2002) are highly influenced by habitat diversity, rainfall, cloud cover, elevation, seasonality, temperature, exposure and soils. Other contributing factors such as dispersal capacity, genetic features and certain physiological adaptations have also been proposed (Barrington 1993; Kornás 1993). However, this ecologically important group currently faces unprecedented threat caused mainly by human disturbances such as fire or land use change (Mehltreter 2010). The highest diversity of ferns and lycophytes occur in tropical rain forests, where approximately 65% of extant fern species are found (Page 1979).

6.1.1 Patterns of ferns and lycophytes richness in African countries

Data available show that, Africa is remarkably poor in ferns and lycophytes diversity compared with other tropical areas (Tryon and Tryon 1982; Parris 1985; Tryon 1986). In southeast Asia there are approximately 4500 species of ferns, South and Central America have *ca.* 3000 species. Africa and adjacent islands including Madagascar have 1441 species (Roux 2009). The low fern diversity in Africa is mainly the result of the scarcity of the continent's rain forest flora occasioned by extinction due to Tertiary droughts which reduced the extent of Africa's moist forests and led to widespread extinctions of fern species which are moisture dependent (Parris 1985; Kornas 1993).

Most of the ferns are water-dependent plants and require continuous supply of moisture for their growth and reproduction. However much of the continental Africa is characterized by low precipitation and high temperatures (Parris 1985; Tryon 1986; Barrington 1993). African diversity of ferns is highest at the tropics which decrease in a characteristic manner towards north and south of the equator, corresponding to a complex environmental gradient of decreasing moisture and increasing temperature (Jacobsen and Jacobsen 1989; Kornas 1993; Roux 2009). However, the eastern arc mountains form an important biodiversity hotspot where ferns are highly diversified (Schelpe 1983). On the other hand, tropical mountains are hot spot of fern diversity Kessler (2010) unfortunately, such data for African tropical mountains is not comprehensive Aldasoro *et al.* (2004) or altogether missing except for Mt. Kilimanjaro (Hemp 2002).

Tanzania has the highest fern diversity with 392 species, followed by Democratic Republic of Congo (DRC) (303), Kenya (275), Cameroon (274), Uganda (259), and Angola (205). Likewise, species richness decreases with increasing latitude, Ethiopia (171), Eritrea (25), Chad (18), Sudan (170), Tunisia (38), Botswana (32), Namibia (55), and Zambia (157). It is evident from above analysis that, countries with high mountains and at close proximity to Guineo-Congolian forest belt have high species diversity, a phenomenon attributed to favorable and stable climatic conditions as well as presence of refuge areas and diverse microhabitats. Many ferns range between 2000 m in East Africa or even more (Hemp 2002). Jacobsen and Jacobsen (1989) recorded a maximum of biodiversity in East Africa between 1500 and 2000 m.

The diversity gradients are steeper toward the north than towards the south (Dzwonko and Kornaś 1978; Kornaś 1979). For instance, species diversity decreased moderately along the transect Zaire-Zambia-Botswana. In Nigeria, there is a rich rain forest flora in the south, highly impoverished in the centre, almost no ferns and lycophytes except the aquatic and amphibious ones in the northern Sahel zone (Kornaś 1983). The lower species number especially in countries with large tropical rainforests such as in Gabon (126), Rwanda (166), Angola (205), and Democratic Republic of Congo (DRC) (138) may be attributed to inadequate sampling largely due to lack of botanists, impenetrable forests, and political instability in these regions. Many forests in DRC, Gabon and Angola are unexplored, and botanical expeditions in these remote areas will probably increase number of species not only in ferns but other cryptogams groups e.g. bryophytes, fungi, lichens, and slime moulds as well as flowering plants. Unlike countries in East Africa, those in Central Africa are beautifully endowed with a 'sea' of dense tropical forests with Gabon in particular having 85% of its land covered by tropical forest, DRC 68% and Angola 46.9% (FAO 2011). Kenya's and Uganda's forest cover stand at 2.5 % and 24 % respectively.

A number of rain forest taxa exhibit range discontinuities between West Africa and East Africa. This is apparently as a result of the climatic oscillations of the Pleistocene; expansion of rain forest areas in the humid (interglacial) periods followed by their contraction during the dry (glacial) periods (Kornaś 1993). Separation of the west African and east African rain forest centres obviously stimulated the processes of speciation, which are very well-marked in the angiosperms (White 1979), but also noticeable in some few ferns. For example, *Hymenophyllum triangulare* Bak. subsp. *triangulare* in west Africa, subsp. *uluguruense* Kornaś in east Africa (Schelpe 1969); and *Vittaria guineensis* Desv. var. *guineensis* and var. *camerooniana* Schelpe in west Africa, var. *orientalis* Hieron. in East Africa. Another regional disjunction very frequent in the African rain forest elements is that between the continent and the Indian Ocean islands of Madagascar and the Mascarenes (Kornaś 1993). Exell and Wild (1973) reported that forty-four per cent (44%) of ferns and lycophytes species occurring in the Flora Zambesiaca area exhibit this type of distribution while Madagascan species account for have 36% (Christiansen 1932). Phytogeographical ties between Madagascar and continental Africa go back partly to the time of direct connection of these two land masses, until the close of the Cretaceous.

The hygromegathermic rain forest elements are distributed in Africa asymmetrically in two centres of unequal size (White 1979). The vast Western Centre in the lowlands of the Guineo-Congolian Region and the eastern centre in the mountains of East Africa, consisting of an archipelago of Afromontane forest islands scattered throughout the Sudano-Zambesian Region of savanna woodlands and savannas (White 1978; Werger 1978). However, anthropogenic forces on the existing forest have had a significant effect where half of all African rainforests have been cleared and fragmented. This is because of logging, slash-and-burn farming, hunting, forest encroachment, industrial development e.g. infrastructure projects, and mining which greatly increased access to forests.

The contemporary distribution pattern of biodiversity is a consequence of abiotic and biotic factors. Everard *et al.* (1994) argue that, for natural forests to maintain their species diversity, a certain frequency of disturbance is crucial. Watkins *et al.* (2007) found that disturbance is very important for gametophyte establishment for many species of tropical fern. From his study, majority of the undisturbed sites had no established gametophytes, indicating no subsequent recruitments to sporophytes. Studies by Eggeling (1947) and Sheil (1999) show that some African tropical forests have presented evidence suggesting an important role of disturbance in maintaining tropical forest tree diversity. Furthermore, Morgenthal & Cilliers (1999) proposed that disturbance agents are necessary to prevent a reduction in plant species diversity and the formation of a homogeneous stand of core forest communities. For instance, disturbance of the soil surface and/or destruction of established plants may provide recruitment microsites, which allow invasion of communities by new species, leading to increased species richness.

It is evident from the above analyses that spatial distribution of ferns and lycophytes in Africa is poorly understood. In many regions the ecological importance of ferns is often under estimated (Mehlreter 2010). The actual diversity of ferns remain unknown for most of tropical forests including Mt. Kenya, Aberdares, Elgon, Cherangani, Mau, Meru, Rwenzori, Mabira, Kibale, Udzungwa, Uluguru, Muhavura, and Nyungwe forests. Some of the tropical rainforests in East Africa with partial ferns inventories show high species richness (Table 7). In Kenya, there are no studies or research done on ferns and lycophytes, despite having some of the most renowned botanists in tropical Africa. The

problem could be attributed to negligence of the cryptogams groups with most botanists focusing their research effort towards flowering plants as opposed to spore bearing plants. The taxonomy of the ferns of Kenya is preliminary, and a revision would be needed for most of the species especially *Asplenium*, *Dryopteris*, and *Lonchitis* among others. This study on the taxonomic revision of genus *Pteris* and ecology of ferns of Kakamega and Budongo is a modest first step. Despite the current impediment, East Africa boasts relatively high diversity of ferns and lycophytes mainly found in the tropical rainforests and mountainous ecosystems. In particular, the two selected study sites of Kakamega and Budongo forests are rich in fern and lycophyte flora. Mt. Kenya and Aberdares forests offer diverse microhabitat and moisture regime suitable for establishment of ferns and lycophytes flora, however their fern diversity are inadequately documented. Such ecosystems provide refuges and suitable microclimatic conditions which favor establishment and growth of ferns.

Table 7. Comparison of ferns species richness for selected ecosystems in Africa

Sites	Species	Area (km ²)	Ecological zone	Location	Source
Kakamega forest	85	196	Tropical rain forest	Kenya	Author
Budongo forest	66	435	Tropical rain forest	Uganda	Author
Mt. Kilimanjaro (southern slope)	140	2000	Montane	Tanzania	Hemp 2002
Usambara & Pare Mts	246		Tropical forest	Tanzania	Schippers 1993
Uluguru Mts	213		Tropical forest	Tanzania	Schippers 1993
Mt. Cameroon	184	2700	Tropical Forest	Cameroon	Aldasaro <i>et al.</i> 2004
Aberdares	313*	285,120	Montane	Kenya	Aldasaro <i>et al.</i> 2004
Taita Hills	102		Dry forests	Kenya	Faden <i>et al.</i> 1988
Table Mts	85	820	Temperate	South Africa	Aldasaro <i>et al.</i> 2004
Cape Verde	29	4033	Temperate	South Africa	Aldasaro <i>et al.</i> 2004

*Species given are over estimated, there are 275 species of ferns and lycophytes in Kenya (Roux 2009)

6.1.2 Ferns as indicators of ecosystem health

Ferns ecology is an important component in understanding their interaction with the environment. However, this area continues to be ignored until recently (Sharpe *et al.* 2010). Some research work has found ferns to be very sensitive to both natural and anthropogenic disturbances. One question yet to be answered comprehensively is, the extent to which are

altered forest ecosystems support species originally in the primary forest? This study hypothesizes that ferns and lycophytes react in different ways to disturbance as different taxa have different strategies of responding to stresses. Some fern species are very sensitive, others can tolerate low levels of disturbance whereas, others can withstand high disturbance levels. Disturbance occurs in different forms as a result of anthropogenic activities (e.g. fire, forest clearance, grazing, plantations, forest gap creation) and natural calamities e.g. landslides, flooding and volcanic eruptions. Epiphytic plants including ferns are highly sensitive to climatic conditions and in many cases, they are more vulnerable than other plants (Hietz 1999). This makes them suitable indicators of changes in local climate, forest structure and environmental conditions, which may also affect other species or ecosystem processes. Notwithstanding, gametophytic phase of the ferns are also considered as good indicators of environmental changes in the forest due to their sensitivity to the microclimatic and edaphic parameters (Page 1979).

6.1.3 Research questions and hypothesis

Ferns form a significant part of global biodiversity. However, this group is inadequately understood and their contribution towards ecological processes is rudimentary. The problem is further complicated by the fact that, their diversity and occurrences are scantily documented. To bridge the gap and obtain more information on the distribution and ecology of ferns and lycophytes, a research is designed to assess the ecological role of this group as potential indicator of ecosystem conditions. The study was carried out in two lowland tropical rainforests of Kakamega (Kenya) and Budongo (Uganda) where data on ferns is scanty with no systematic documentation of species occurrences.

The following research question/hypothesis were formulated to guide the study.

1. How many species of ferns and lycophytes are in the study area?
2. What is the representation of the ferns and lycophytes flora in Kakamega forest as compared to the whole country and also regionally?
3. How is the species richness in different habitat types (riverine, forest edges, primary and secondary forest)?
4. Does forest fragmentation affect the ferns and lycophytes richness and distribution?
5. Which species indicate presence of mature forests and disturbed sites?

6. Are there generalists species?
7. Are there some species that their growth is suppressed?
8. Any relationship between the sample size and the species richness?
9. Is there any relationship between the diversity of different taxonomic levels?
10. Is there any geographical pattern to the ferns and lycophytes species richness?

Field studies were carried out to investigate the roles played by ferns and lycophytes as indicators of ecosystem health in tropical lowlands rainforests. Transects were placed in forests with different ecological conditions such as primary, old secondary, secondary, and forest edges.

6.2 Study Areas

6.2.1 Kakamega Forest

Kakamega forest is located 50 km north of Lake Victoria in the Western province of Kenya and lies between latitudes 00°08'30.5" N and 00°22'12.5" and longitudes 34°46'08" E and 34°57'26.5" E (Schaab 2001) (Fig. 8). It forms the easternmost relics of the equatorial forests and the only representative of a tropical rain forest of Guineo-Congolian in Kenya (Kokwaro 1988). It has a mixture of Guineo-Congolian and afro-montane floral elements as well as transitional species (Blackett 1994; Althof 2005). Due to the past anthropogenic factors, it comprises a mosaic of near-primary forests, secondary forests of different seral stages, grasslands, plantations of indigenous and exotic species, swamp and riverine forest, natural glades, selectively logged forest and clearings made to pave way for human settlement (Mutangah *et al.* 1992). The forest has a high affinity to that of the West African forests as evidenced by a high number of species that share common occurrence across the same biogeographical regime of the Guineo-Congo region (Mutangah 2002).

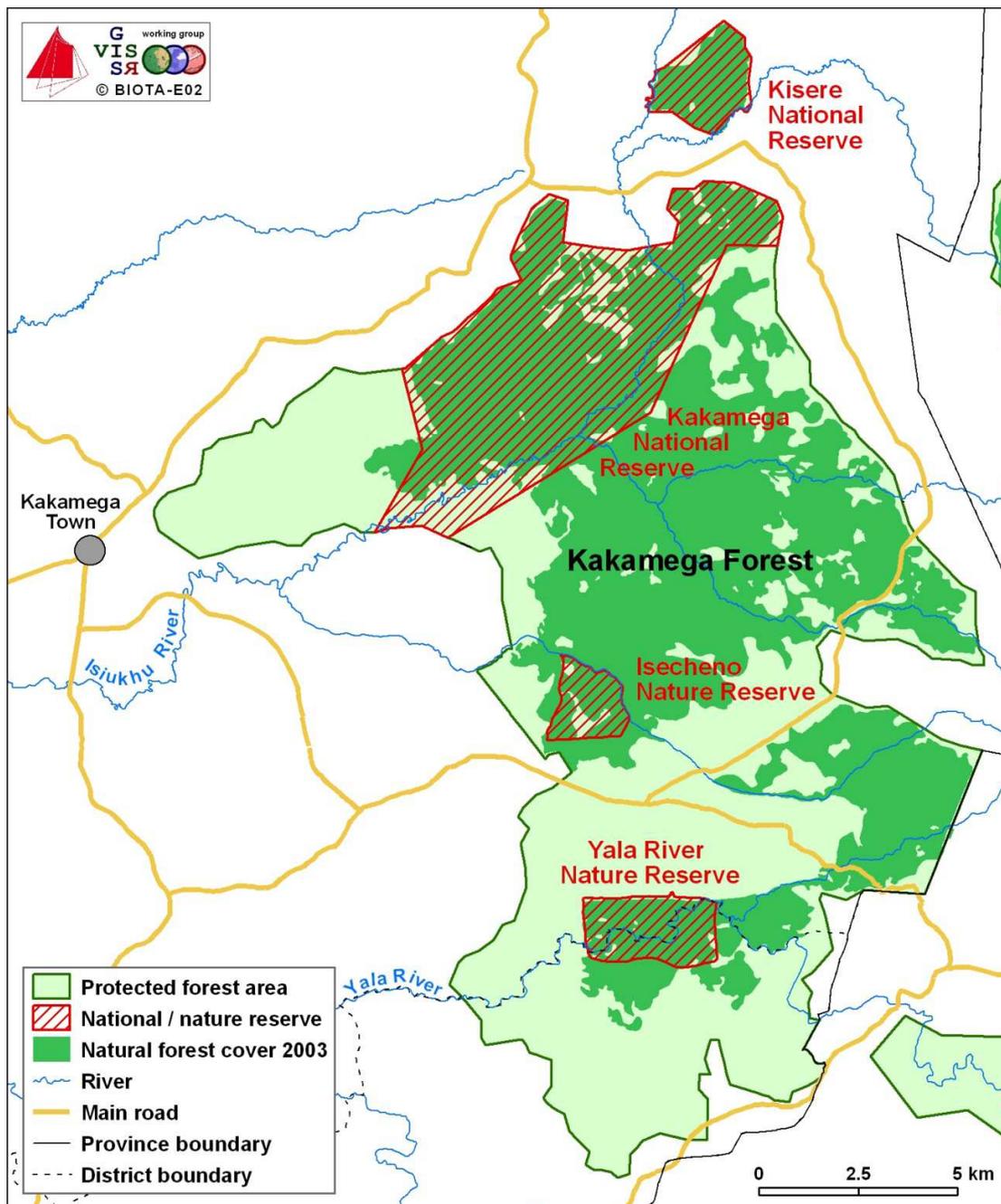


Figure 8. Map of Kakamega forest with official forest border, natural forest cover and nature reserves

[Map courtesy of BIOTA East Africa]

The forest covers an area of 19,649 ha of which 11,345 ha consist of dense indigenous vegetation. Forest plantation covers 832 ha, scattered trees and glades cover 1557 ha while cleared or cultivated areas cover 2002 ha. The forest lies between 1460 and 2060 m (Lung

and Schaab 2006) with Buyangu and Lirhanda hills being the highest. Annual rainfall ranges between 1500-2300 mm, well distributed throughout the year. Long rains are received between April to November and short dry spell occur in December and January (KIFCON 1994). The rain emanates from Intertropical Convergence Zone (ITCZ), and to certain extent influenced by the close proximity to Lake Victoria's convectional weather. The average monthly temperatures range from 11^o C and 29^oC. The forest is mainly underlain by acid and basic volcanic lava rocks of the Kavirondoian systems and Nyanzian rock formation systems, which are associated with gold-bearing quartz veins (KIFCON 1994).

Kakamega forest is rich in biodiversity of both flora and fauna. There are 986 vascular plant species (Fischer *et al.* 2010), 137 foliicolous lichens (Kumelachew 2008), 79 epiphytic bryophytes (Malombe 2007), 410 birds (Shanni and Bruijin 2006), five primates (Kirika *et al.* 2008), 243 species of bees (Gikungu 2006), 515 butterflies (Häuser 2004), 60 reptiles and 23 amphibians (Lötters *et al.* 2007). Several other previous research studies targeting specific group of plants or other areas are available e.g. Mwachala 2005; Malombe 2007; Musila 2007; Dalitz *et al.* 2011; and Rembold 2011). However, a biodiversity gap exists in relation to ferns and lycophytes of Kakamega forest due to lack of intensive inventory specifically targeting this neglected yet important group of plants.

The areas surrounding the forest are densely populated and according to Tsingalia (1990) it's an area with one of the highest human population densities in Kenya, a factor that poses great threat to the existing biodiversity. Land is intensively cultivated for sugarcane, tea and maize primarily for home consumption. The people living around the forest vicinity rely on the forest for, timber extraction, charcoal production, firewood collection, harvesting of medicinal plants, pasture for grazing, as well as illicit cultivation which put pressure on forest resources (Kokwaro 1994; Guthiga and Mburu 2006; Schaab *et al.* 2010). Big chunk of the former forest have been encroached and converted into farmland. According to Mitchell (2004), human settlement inside the forest was widespread prior gazettelement. This caused major forest disturbances in 1930's through heavy and selective logging and plantation establishment using exotic species. Some parts of the forest are,

however very well preserved, and offered ideal conditions for comparative studies of ferns and lycophytes communities in near - pristine verses disturbed environment.

Althof (2005) classified three disturbance levels in the forest (Table 8). These are characterized by young secondary forest of Campsite, Busambuli, Isecheno, Isiukhu, and Malava which experienced high disturbances. The forests of Buyangu, Colobus, Ikuywa, and Salazar classified as middle aged secondary forest had low to intermediate disturbances. Low level of disturbance was reported in Yala, an old secondary forest and Kisere, near primary forest. BIOTA (2004) document that, the forest exists in six main fragments mainly: Kakamega main forest (8537 ha), Ikuywa (1370 ha), Yala (1199 ha), Kisere (420 ha), Malava (190 ha) and Kaimosi (132 ha).

Table 8. Vegetation succession status in Kakamega Forest

Study Sites	Succession stage	Vegetation type	Disturbance level
Camp site forest, Isiukhu	Young secondary forest	<i>Rapanea melanophloeos</i> , <i>Harungana madagascariensis</i> - <i>Bridelia micrantha</i>	Disturbance high
Salazar, Buyangu, Colobus, Ikuywa	Middle aged secondary forest	<i>Celtis mildbraedii</i> - <i>Craibia brownii</i> , <i>Antiaris toxicaria</i> - <i>Funtumia africana</i> / <i>Croton sp.</i>	Disturbance low-intermediate
Busambuli, Isecheno,	Middle aged secondary forest	<i>Celtis mildbraedii</i> - <i>Craibia brownii</i> , <i>Strombosia scheffleri</i>	Disturbance high
Ghostiland, Yala	Old secondary forest	<i>Celtis mildbraedii</i> - <i>Craibia brownii</i> , <i>Ficus cyathistipula</i> , <i>Uvariopsis congensis</i>	Disturbance low
Kisere	Near primary forest	<i>Trichocladus ellipticus</i> , <i>Uvariopsis congensis</i> , <i>Antiaris toxicaria</i> - <i>Funtumia africana</i>	Disturbance low
Malava, Kaimosi	Plantation forest	Planted species e.g. <i>Deinbollia kilimandscharica</i> , <i>Markhamia lutea</i> , <i>Bischofia javanica</i> , <i>Maesopsis eminii</i> ,	Disturbance high

6.2.2 Budongo Forest

Budongo Forest Reserve (BFR) is one of the chains of forests in the Albertine rift, a semi-deciduous forest located within Masindi and Hoima Districts, in northwestern Uganda. It is situated between 1°37'-2°03'N, and 31°22'-31°46'E (Howard *et al.* 1996; Reynolds 2005) (Fig. 9). The forest was gazetted as a Central Forest Reserve (CFR) in 1932, and combined comprises 435 km² of continuous forest cover consisting of four forest blocks: Siba, Budongo, Kaniyo-Pabidi and Kitigo (Reynolds 2005). Langdale-Brown *et al.* (1964) classified Budongo forest as a medium altitude, moist, semi-deciduous tropical rain forest because most of the species are briefly deciduous.

BFR's land undulates gently, with an overall downward slope from southeast to northwest. Its rivers flow northwest, leaving the forest to run down the escarpment towards Butiaba Flats along the eastern side of the Rift Valley (Reynolds and Reynolds 1965; Reynolds 2005). Budongo forest is a catchment area for four small rivers: Sonso, Waisoke, Siba and the Kamirambwa that drain into Lake Albert (Eggeling 1947; Reynolds 2005). The altitudinal range of BFR is 700 - 1270 m, with only 0.2 km² of the area lying below 750 m, 385 km² between 750 – 1000 m, 408 km² between 1000 - 1250 m and 0.1 km² above 1250 m (Howard 1991; Poulsen 1997).

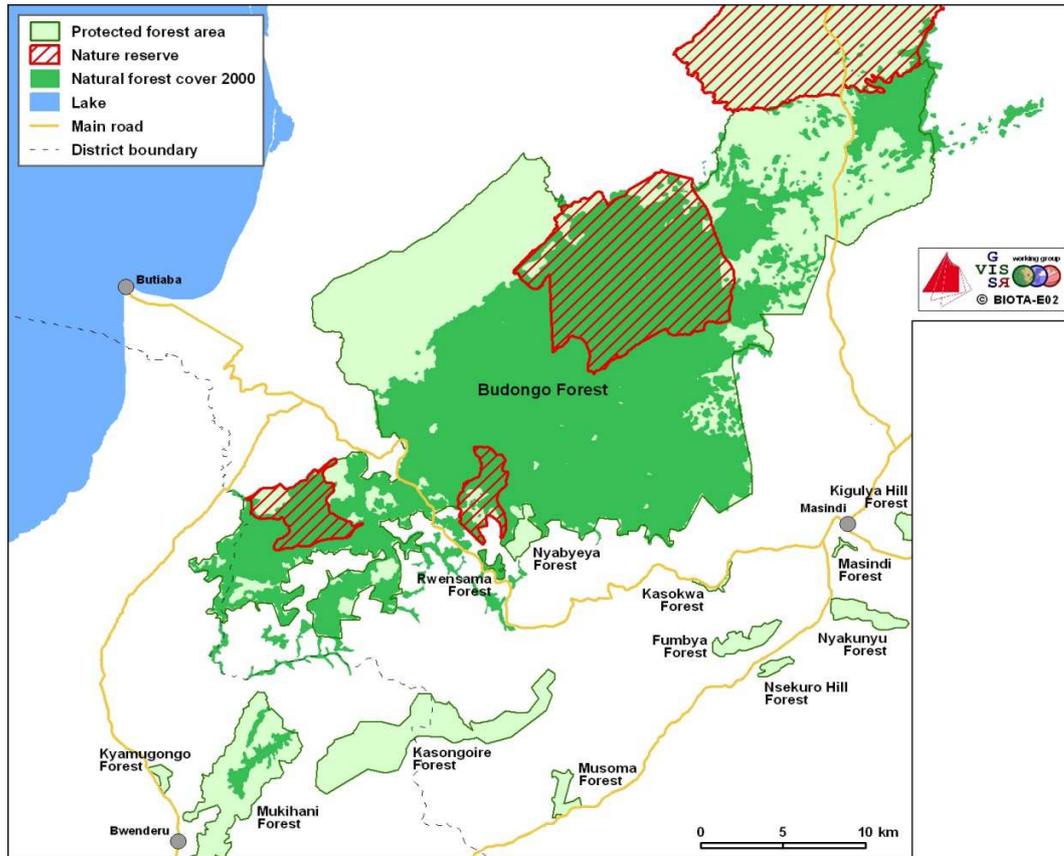


Figure 9. Map of Budongo forest (Uganda) with location of different forest types and official boundaries

[Map courtesy of BIOTA East Africa]

Generally, the average altitude of the reserve is about 1100 m (Plumptre 2001), with hills rising to just over 1200 m. Annual mean rainfall is 1600 mm, bimodal with most rain falling from March to May and from September to November (Reynolds and Reynolds 1965; Howard 1991; Owunji 1996; Reynolds 2005). One major dry season occurs between mid-December and mid-February when rainfall normally drops below 50 mm. Temperatures are generally even throughout the year with highest temperatures (32^o C) and lowest (19^oC) been recorded during dry and cold periods respectively (Reynolds 2005).

Budongo forest has three major forest types according to Eggeling (1947) and Howard *et al.* (1996). There is primary/mixed forest: dominated by *Khaya anthotheca* (mahogany), *Entandrophragma utile* and *Cynometra alexandri* (ironwood) species. The second is the swamp forest, which occur along rivers that are flooded during the wet season and waterlogged in

dry season and dominated by *Calamus sp.*, *Ficus sp.*, *Raphia farinifera* (wild palms), *Pseudospondias microcarpa* and *Mitragyna stipulosa*. Third is the old evergreen secondary forest dominated by *Cynometra alexandri*, *Chrysophyllum albidum*, *Khaya anthotbeca* and *Trichilia emetica*. The young forests of colonizing species of *Maesopsis eminii* were noted to be replaced later by fast growing species of *Cynometra alexandri*. This forest was logged between 1945 and 1947 and by pitsawing between 1990 and 2000 (Babweteera *et al.* 2000).

In the recent past, Budongo forest has been experiencing varying levels of disturbances. About 75% of the forest has experienced illegal removal of valuable tree species e.g. mahoganies (Reynolds 1993; Poulsen 1997; Reynolds and Reynolds 2005). However, the biggest single change to the composition and dynamics of the forest was the widespread use of arboricides on *Cynometra alexandri* and other species of “weed” as discussed by Bahati (1995). Apart from the nature reserve, most of the forest is classified as a secondary forest (Synnott 1985). Field surveys done in 2003-2004 by Mwavu (2007) and observation by P. Kamau (2009) revealed that illegal harvesting of trees for timber was going on negatively affecting the forest structure and composition. There were many signs of illegal pit sawing, even in the nature reserve creating forest gaps and altering ecosystem dynamics.

Budongo forest, despite its history of intensive loggings is highly diverse. There are 366 species of birds (Friedmann and Williams 1973; Owionji and Plumptre 1998), 24 species of small mammals including nine primates, 289 species of butterflies, 130 species of large moths and 465 species of trees and shrubs (Howard *et al.* 1997). From Budongo forest, 32 species of bryophytes has been recorded Malombe (2007) and 129 taxa of foliicolous lichens Kumelachew (2008). However, studies on cryptogams are inadequate or altogether lacking with no records of fungi, slime moulds, corticolous lichens, and ferns.

6.3 Field sampling

Field studies were carried out to investigate the roles played by ferns and lycophytes as indicators of ecosystem health in tropical lowlands rainforests. Actual field surveys were carried out in the two forests from September 2008 to November 2009 in two rainfall regimes i.e. dry and wet seasons. The dry season sampling in Kakamega forest was done in the month of February 2009, while the wet season sampling was carried out from

September to November 2008 and April 2009. Sampling in Budongo forest was done during the prolonged dry season of March 2009 and during October to November 2009 for wet season. Line transects ranging from 1000 m to 1500 m with sampling plots measuring 10 x 10 m (100 m²) with an interval of 20 m were established in different forest blocks and fragments with different ecological conditions. Ferns species recorded in the plots included all terrestrial species rooted in the plots, epiphytes on tree trunks and on dead logs, as well as lithophytes. Transects were established along the disturbance gradient to capture species growing in different development stages of the forests.

Data on presence/absence, growth form, and general description of the ferns were recorded in each plot, and habitat type and forest structure noted. All species encountered in the plots were recorded and voucher specimens collected in triplicates. Species were categorized according to life-forms described by Poulsen and Nielsen (1995) and Kessler (2001) with some modifications. These are, *terrestrial*: terrestrial herbs; *epiphytes*: ferns adhered to the bark of host plants; *hemiepiphytes*: climbing species rooted in the ground; *tree ferns*: terrestrial species with a well developed trunk at least 0.5 m tall at maturity; *lithophytes*: species growing on rocks or boulders with little or no soil; *terrestrial/ epiphytes*: Species growing as both terrestrials and epiphytes. Specimens were subsequently morphologically identified to species level or lower ranks where possible using reference collections at the herbaria of Makerere University (MHU) Kampala, Uganda and the East African (EA), Nairobi, Kenya. Voucher specimens were deposited and preserved at East African herbarium (EA), Kenya while duplicates were distributed to partner herbaria.

Twelve study sites were established in Kakamega forest, distributed both in north and south of the forest. Sites in the north were Busambuli, Buyangu, Campsite, Colobus, Isiukhu, Kisere, Malava, and Salazar and in the south: Ikuywa, Isecheno, Yala and Lirhanda hill. These sites had varying degree of disturbance and at different recovery stage (Table 8). In each site, 5-14 plots (10 x 10 m) were established depending on the vegetation structure, habitats and topography. In addition, 24 opportunistic plots were randomly sampled along Isiukhu and Yala rivers though not considered during analysis. This was purposely done to enrich the species list of ferns. For Budongo forest, study sites were distributed in the four forest types namely; primary forest, swamp, young secondary, and old secondary which had

20, 15, 14, 15 plots respectively. Sonso and Nyabusabo rivers were sampled intensively by walking along the river courses. The study was designed to capture as much information as possible from all possible forest types and different habitats in both forests. In total 205 plots were sampled in both forests.

6.4 Data analysis

6.4.1 Sampling effort and species estimation

There are different estimation methods that allow estimation of the expected number of species from sample data (Colwell and Coddington 1994; Magurran 2004). This study used EstimateS version 8 (Colwell 2006), a non-parametric method used to compute the expected species accumulations and estimates of the species richness from samples and appropriate for incidence-based (presence/absence) data. The sample order was randomized 100 times to compute the mean estimator and expected species richness for each sample accumulation level. To assess sampling completeness and control for sampling effort, sample-based rarefaction curves were computed (Gotelli and Colwell 2001; Colwell *et al.* 2004) in order to compare the species richness of different study sites in Kakamega and Budongo forests.

The completeness of sampling effort for each study site was evaluated with the use of Incidence Coverage Estimator (ICE), Chao2, First order Jackknife (Jack 1), Second order Jackknife (Jack 2) and Bootstrap. These non-parametric estimators predict richness, including species not discovered in the sample (dark diversity), but likely to exist in a larger homogenous sample, from the proportional abundances of species within the total sample (Soberón and Llorente 1993; Chao *et al.* 2005). Sampling effort for each study site was calculated by dividing the actual number of species recorded by the average number of species estimated by all the five estimators except in Kakamega forest, where Jackknife 2 was excluded.

6.4.2 Beta-diversity

Beta diversity is the measure of difference in species diversity between habitats or communities. It is usually expressed in terms of a similarity index between communities or as a species turnover rate. In this study, the ferns species similarity was calculated using Sørensen index (S) of similarity for qualitative data (Sørensen 1948) calculated between

different forests types and fragments in Budongo and Kakamega forests (then transformed it into a dissimilarity index).

$$S = \frac{2C}{A + B}$$

Where S = Sørensen similarity index,
A = the total number of species in site A
B = the total number of species in site B, and
C = the number of common species between the two sites.

Species turnover was calculated using Whittaker's index for β -diversity (Whittaker 1960) as follows;

$$\beta_w = \frac{S}{\alpha}$$

Where β_w = Whittaker's similarity index,
S = the total number of species in a forest type
 α = the mean sample species number

6.5 Results

6.5.1 Estimation of species richness and sampling effort

Non-parametric species richness estimators for incidence data variously estimated species richness of the twelve study sites of Kakamega forest (Table 9). In all cases, the non-parametric richness estimators were closely similar to, but slightly higher than the observed number of species in different sites. Colobus site had 17 species recorded, whereas ICE, Chao2, Jack1, Jack2, and Bootstrap estimated a total of 19, 17, 19, 20 and 17 species respectively. At this site, recorded species richness was 94% of the estimated true richness.

Table 9. Species estimated by various estimators for study areas in Kakamega forest

Sites	Samples	Indiv.	Species recorded	ICE	Chao2	Jack1	Jack2	Boot strap	Sampling effort (%) ^a
Busambuli	10	42	15	15	15	15	8.6	16	98.4
Buyangu	7	30	15	15	15	16	12	16	96.8
Campsite	10	54	23	25	24	27	24	25	91.1
Colobus	8	24	17	19	17	19	20	17	94.4
Ikuywa	5	35	15	16	15	16	13	16	95.2
Isecheno	12	105	28	28	28	28	21	30	98.2
Isiukhu	12	92	25	31	33	33	35	30	78.7
Kisere	13	84	35	38	36	41	40	37	92.1
Lirhandanda	6	38	10	15	15	16	15	15	65.6
Malava	8	47	18	19	18	20	17	20	93.5
Salazar	12	76	28	36	35	37	40	33	79.4
Yala	14	89	45	66	61	66	72	55	72.6

^a Sampling effort was the number of species recorded divided by the mean value of estimated species of incidence-based coverage estimator (ICE), Chao2, Jackknife 1, and Bootstrap. Jackknife 2 generated low estimates values and therefore excluded from the assessment of sampling effort.

First-order Jackknife gave the highest estimates of species richness for all the the study areas except in Busambuli and Isecheno. Sampling of 10 and 12 samples registered the highest sampling effort in Busambuli and Isecheno with 98.4 % complete (15 species) and 98.2 % complete (28 species), respectively. Lirhandanda, Yala, Isiukhu and Salazar forests had the least sampling effort of 65.6, 72.6, 78.7, and 79.4 % respectively. Results showed that sampling effort was as expected low in sites with high species diversity which also turned out to be most intensively sampled e.g. Yala forest where 14 plots were sampled. Many species appear to have been missed in Salazar and Yala forests where the greatest difference between the highest and lowest species estimator were seven for Salazar and 11

species for Yala forest. The least difference was observed in Busambuli, Buyangu, Ikuywa, and Lirhanda with one species each. However, the assessment of the species data indicated that sampling effort was adequate in all sites where species observed were well above the lower recommended limit of 55 % of the estimated species richness. This suggest that a good proportion of the total species diversity were recorded in each site.

In Budongo forest, comparison of the number of species recorded and the species richness estimated by the various richness estimators showed higher values for the latter (Table 10).

Table 10. Species estimated by various estimators for study sites in Budongo forest

Forest types	Samples	Individual	Species recorded	ICE	Chao 2	Jack 1	Jack 2	Bootstrap	Sampling effort (%) ^b
Old secondary forest	15	72	27	33	33	35	37	31	79.9
Primary forest	20	89	31	40	43	42	47	36	74.5
Young secondary forest	14	64	22	25	24	27	25	25	87.3
Swamp forest	15	61	23	27	26	29	28	27	83.9

^b Sampling effort was the number of species recorded divided by the mean value of estimated species of incidence-based coverage estimator (ICE), Chao 2, Jackknife 1, Jackknife 2 and Bootstrap.

All the estimators used gave higher values of species richness than recorded. Sampling completeness was highest in young secondary and swamp forests that had 87.3 % (22 species) and 83.9 % (23 species) sampling effort respectively. Less than six species were missed in both forests. From the assessment of the data, primary forest with a sampling effort of 74.5 % had 16 species missed despite been the most intensively sampled forest with highest species richness. The differences between highest and lowest species estimators was 11 for primary forest, six for old secondary forest, three species for young secondary forest and two species for swamp forest. In all cases, sampling effort was within 55-75 % of the estimators. a clear indicator that substantial proportions of the total species diversity were recorded in all the study sites. However, more effort or field surveys are needed in primary forest whose sampling effort was least with 74.5 % complete (with 31 species).

6.5.2 Community Structure

The species richness of ferns was estimated using rarefaction, which is used to calculate the number of species expected in a sub sample selected at random from a total sample (Gotelli and Colwell 2001; Magurran 2004). The sample accumulation (rarefaction) curves for ferns recorded from different study sites of Kakamega forest were plotted (Fig. 10). The curve shows the mean number of species for each sample accumulated.

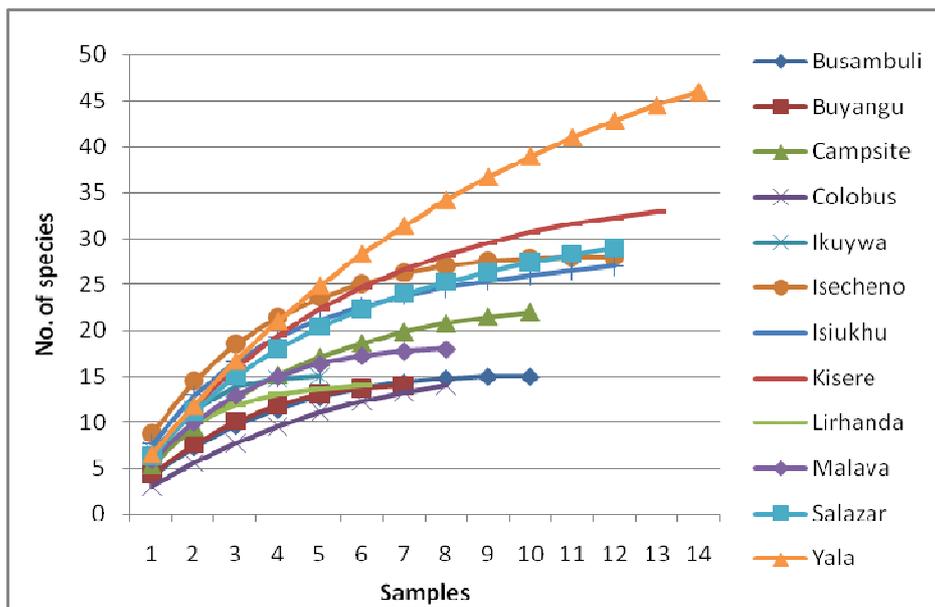


Figure 10. Sample based accumulation curve (rarefaction) of ferns in the twelve study sites of Kakamega forest

The rate of sample accumulation differed among sites. The forest of Yala was exceptionally more diverse, unique and had high species diversity compared to all the other forest types followed by Isecheno, Kisere, Isiukhu, and Salazar. Species were also evenly distributed in the sample plots. The least diverse forests were Colobus, Busambuli, Buyangu, and Lirhanda in that order. Sample-based rarefaction curve for eight of the study sites failed to saturate. The forests of Busambuli, Ikuywa, and Lirhanda reached an asymptote indicating no new species were being encountered with increased sampling effort. These sites had very low species richness compared with other sites, a factor which correlate with high level of disturbance. At the beginning, the curves are all steep which means that most of the species were accumulated rapidly in the first samples and the probability of encountering new species diminished as more samples were accumulated.

More sampling effort should be directed to Yala and Kisere forests that showed an upward trend indicating that increased sampling effort mostly likely would yield more new species. Both forests recorded the highest species number and the rate of accumulation was successively increasing as more samples were added. These forests could be having diverse microhabitats that serve as refuge for many species that would otherwise not be found in other sites. Because most of the rarefaction curves failed to reach an asymptote and different numbers of individuals were sampled at different sites, rarefied richness was compared at smallest sample size. For example, the number of species expected when the lowest sample size of five (5) samples from Ikuywa was considered was 25 species for Yala, Isecheno (24), Kisere (22), Isiukhu (21), Salazar (20), Campsite (17), Malava (16), Ikuywa (15), Lirhanda (14), Busambuli (13), Buyangu (13), and Colobus (11).

In Budongo forest, primary forest was more diverse and species rich than all the other forest types (Fig. 11) though there was an overlap with old secondary forest at low sample accumulation. The species accumulation curves for the observed species in the four forest types did not reach asymptote. This means that additional sampling effort could yield or record more species that were not recorded during the survey. The curves for young secondary and swamp forests types overlapped as sampling continued indicating the pattern of species richness and diversity in both forests were almost similar. However, as sampling increased swamp forests accumulated more species and finally ended up as a more diverse forest when compared with young secondary forest.

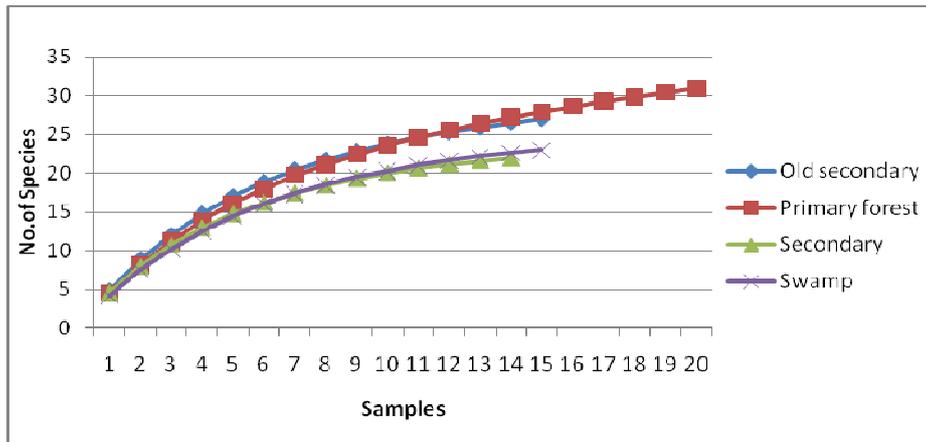


Figure 11. Species accumulation (rarefaction curves) for the four different forest types of Budongo

The number of species expected from the species accumulation curve when the lowest sample number (i.e. 14 samples from young secondary forest) were pooled was 26 species for the old secondary forest, 27 for primary forest, 22 for young secondary forest and 23 for swamp forest. The trend showed species evenness in their distribution in Budongo forest.

6.5.3 Species richness and occurrences in Kakamega and Budongo forests

A total of 85 species in 42 genera and 18 families were recorded from Kakamega forest, while Budongo forest had 66 species in 32 genera and 17 families. In Kakamega forest, the species recorded represented 37 % (23 spp.) increment from the 62 species reported by Mutangah *et al.* (2002) comprising 31% of fern species known from Kenya. Budongo forest recorded an increase of 85% from the previous record of 22 species retrieved from MHU species database.

In both forests, the most diverse families were Adiantaceae, Polypodiaceae, Dryopteridaceae and Woodsiaceae (Table 11). The most species rich genera were; Kakamega: *Asplenium* (20 species), followed by *Pteris* (6), *Cyclosorus*, *Dryopteris*, and *Pellaea* (3 each); Budongo: *Asplenium* (19 species), *Pteris* (10), *Bolbitis* (3), *Arthropteris*, *Nephrolepis* and *Cyclosorus* (2 each). Ten families; Aspleniaceae, Cyatheaceae, Cystopteridaceae, Davalliaceae, Lycopodiaceae, Lomariopsidaceae, Nephrolepidaceae, Ophioglossaceae, Selaginellaceae, and Tectariaceae were only represented by a single genus, further Aspleniaceae was the most species rich in both forests, followed by Pteridaceae. Four

families Lycopodiaceae, Lomariopsidaceae, Marattiaceae, Ophioglossaceae were represented by a single species.

Kakamega forest had interesting findings, one new species, *Diplazium* sp. E of Agnew (1993) was re-collected and *Pteris burtonii* Bak., reported as a new record for Kenya. Seventeen species belonging to 11 families were new records for Kakamega forest. These include *Cheilanthes inaequalis* (Kunze) Mett var *inaequalis*, *Pellaea doniana* Hook., *Adiantum capillus-veneris* L. (Pteridaceae); *Asplenium loxoscapoides* Baker, *Asplenium gemmiferum* Schrad., *Asplenium warneckeii* (Aspleniaceae); *Alsophila manniana* Hook. and *Alsophila dregei* (Cyatheaceae); *Dryopteris fadenii* Pic. Serm. (Dryopteridaceae), *Dicranopteris linearis* (Burm. f.) Underw. (Gleicheniaceae), *Lycopodium clavatum* L. (Lycopodiaceae), *Cyclosorus* (Thelypteridaceae), *Ptisana fraxinea* (Sm.) Murdock (Marattiaceae), *Arthropteris monocarpa* (Cordem.) C. Chr. (Tectariaceae), *Ophioglossum lancifolium* (Ophioglossaceae), *Lepisorus excavatus*, and *Plactycerium angolense* (Polypodiaceae). In Budongo forest, three species i.e. *Pteris intricata* C.H. Wright (Pteridaceae), *Bolbitis hendelotii* (Dryopteridaceae), and *Asplenium gemmascens* Alston (Aspleniaceae) were new records.

Table 11. Species richness in different families and genera

No.	Families	Kakamega		Budongo	
		Genera	Species	Genera	Species
1.	Aspleniaceae	1	20	1	19
2.	Cyatheaceae	1	2	-	-
3.	Cystopteridaceae	1	1	-	-
4.	Davalliaceae	-	-	1	1
5.	Dennstaedtiaceae	2	2	1	1
6.	Dryopteridaceae	4	6	5	7
7.	Gleicheniaceae	2	2	1	1
8.	Hymenophyllaceae	3	3	2	2
9.	Hypodematiaceae	1	1	1	1
10.	Lomariopsidaceae	1	1	-	-
11.	Lycopodiaceae	1	1	-	-
12.	Marattiaceae	1	1	1	1
13.	Tectariaceae	1	2	1	2
14.	Nephrolepidaceae	1	2	1	2
15.	Ophioglossaceae	1	1	-	-
16.	Polypodiaceae	6	6	5	5
17.	Pteridaceae	8	18	7	18
18.	Selaginellaceae	1	2	1	1
19.	Thelypteridaceae	3	5	3	3
20.	Athyriaceae	2	4	1	1
	Total	42	85	32	66

6.5.4 Species distribution and diversity in different study sites

6.5.4.1 Richness and β -diversity

Comparison of ferns in various forest blocks and fragments showed that forests with different disturbance levels were characterized by different species number (Table 12). Forest blocks and fragments with low disturbance had more species (e.g. Kisere and Yala forests) than those of moderate to high disturbance levels (e.g. Busambuli, Buyangu, Lirhandanda, and Ikuywa). Yala forest, an old secondary forest had the highest record of 45 species while Kisere a near primary forest registered 35 fern species. Lirhandanda hill, an open site with frequent fires was species poor with 10 species only. The results show that forests of the same development stage were not necessarily similar in species diversity. A good example is between middle-aged forests of Salazar and Busambuli which recorded 29 and 15 species respectively. Meanwhile, forest sites with low to moderate disturbance were species rich (e.g. Isiukhu and Salazar). Within the main forest block, Busambuli, Buyangu

and Colobus had the lowest species while Ikuywa within the forest fragment had low species richness.

Table 12. Number of species and β -diversity values in the main forest blocks and fragments of Kakamega forest

Forest type	Study site	Seral Stage	No. of species (a)	Mean species number per sample (b)	β - diversity (a/b)
Main forest block	Busambuli	Middle-aged secondary	15	4.2	3.6
	Buyangu	Middle-aged secondary	15	4.3	3.5
	Campsite	Young secondary	23	5.4	4.3
	Colobus	Middle-aged secondary	17	3.0	5.7
	Isecheno	Middle-aged secondary	28	8.8	3.2
	Isiukhu	Young secondary	25	7.7	3.2
	Salazar	Middle-aged secondary	28	6.3	4.4
Forest fragment	Lirhanda hill	Middle-aged secondary	10	6.3	1.6
	Ikuywa	Middle-aged secondary	15	7.0	2.1
	Kisere	Near primary forest	35	6.5	5.4
	Malava	Plantation	18	5.9	3.1
	Yala	Old secondary forest	45	6.4	7.0

The main forest blocks with the highest number of species were Isecheno, Salazar, Isiukhu and Campsite with a record of 28, 28, 25, and 23 species respectively. The forest fragments with the highest number of species were Yala and Kisere with 45 and 35 species respectively. Lirhanda and Ikuywa forest recorded the least species of 10 and 15 respectively. Results shows the highest species turnover was high in Yala forests (β -diversity= 7.0), followed by Colobus (β -diversity= 5.7), Kisere (β -diversity= 5.4), and

Salazar (β -diversity= 4.4). The lowest species turnover was recorded in Lirhanda (1.6) and Ikuywa (2.1).

In Budongo forest, ferns were distributed almost evenly in the four forest types with a maximum difference of nine species. However, primary forest registered the highest species number of 31, followed by old secondary forest (Table 13). Young secondary forest recorded the least species richness having 22 species. Analysis of data from Budongo forest showed that, the species turnover was highest in primary forest (β -diversity= 10.7), followed by the old secondary forest (β -diversity= 10), then swamp forest (β -diversity= 8.5) and lowest β -diversity was recorded in young secondary forest (β -diversity=7.6) which means it had low species turnover.

Table 13. Number of species and β -diversity values for the four forest types of Budongo

Forest types/Study sites	Species number (a)	Mean number of species per sample (b)	β -diversity (a/b)
Young secondary forest	22	2.9	7.6
Old secondary forest	27	2.7	10.0
Primary forest (ecological climax)	31	2.9	10.7
Swamp forest (edaphic climax)	23	2.7	8.5

6.5.4.2 Floristic dissimilarity estimates in Kakamega and Budongo forests

For β -diversity of Sørensen index of dissimilarity, results showed considerable differences between the forest sites in different stages of development and intensity of disturbance ranging from 36.51 % to 90.00 % (Table 14). Dissimilarity was highest between middle aged secondary forest of Buyangu and all other forest types. For example, the dissimilarity index of Buyangu and Yala was (S=90 %), Buyangu and Lirhanda (S=84 %), Buyangu and Kisere (S=84 %), Buyangu and Malava (S=82 %), Buyangu and Salazar (S=81.4 %), Buyangu and Colobus (S=81.25 %), Buyangu and Busambuli (S=80 %). Similarly, Busambuli forest had high dissimilarity values with most forest types except Malava and Salazar.

Table 14. Values of Sørensen index of dissimilarity among study sites in Kakamega forest

Study sites/ taxa no.	Total no. of taxa	Busambuli	Buyangu	Campsite	Colobus	Ikuywa	Isecheno	Isikuhu	Kisere	Lirhanda	Malava	Salazar
Busambuli	15	-										
Buyangu	15	80.00	-									
Campsite	23	73.68	79.49	-								
Colobus	17	75.00	81.25	75.00	-							
Ikuywa	15	66.67	73.34	57.90	68.75	-						
Isecheno	28	76.75	76.74	45.10	73.74	62.79	-					
Isiukhu	25	75.00	75.00	66.67	80.95	75.00	66.04	-				
Kisere	35	68.00	84.00	58.62	69.23	68.00	49.21	60.00	-			
Lirhanda	10	60.00	84.00	75.76	62.96	60.00	68.42	77.14	77.78	-		
Malava	18	30.30	82.00	55.00	48.57	57.58	60.87	67.44	57.69	64.29	-	
Salazar	28	32.56	81.40	49.02	64.44	48.84	42.86	54.72	36.51	68.42	52.18	-
Yala	45	69.70	90.00	75.00	74.19	66.67	58.90	65.72	42.50	81.82	65.08	39.73

The results showed that forests in different succession stages, notably middle-age forest experienced different level of disturbance and hence high dissimilarity index. Species assemblages were partly influenced by age/succession stage of the forests. The old secondary forest of Yala supported unique ferns species which were specific to this particular forest block. These species were; *Scoliosorus mannianus* (Hook.) E.H. Crane, *Asplenium africanum* Desv., *Alsophila manniana*, *Ptisana fraxinea*, *Pteris burtonii*, *Lomariopsis warneckeii*, *Diplazium* sp. E. Similarly, Kisere a near primary forest had a unique species of *Cystopteris filix-fragilis* (L.) Bernh. Likewise, Buyangu and Lirhanda forests each had two unique species of *Dicranopteris linearis* (Burm. f.) Underw and *Lycopodium clavatum* (Buyangu), *Alsophila dregei* Kunze and *Cheilanthes inaequalis* (Kunze) Mett. var *inaequalis* (Lirhanda hill). Salazar forest, a middle aged secondary forest had a unique record of *Asplenium lividum* Mett. ex Kuhn.

The Sørensen dissimilarity index between the four study sites of Budongo forest indicate that swamp forest type showed the highest dissimilarity values with all the other three forest types (Table 15). The most dissimilar were the swamp and young secondary forests (S=65.22 %), followed by swamp versus old secondary forests (S=50.95 %). The lowest was between primary and young secondary forests (S=43 %). Swamp forest had unique

species which were not found in other forests such as *Dryopteris manniana*, *Ptisana fraxinea* and *Lastreopsis currorii* (Mett.) Tindale.

Table 15. Sørensen Index values of dissimilarity of four study sites in Budongo

Sørensen Index	<i>Cynometra</i> forest (primary)	Swamp forest	Old secondary forest
Swamp forest	49.1%	-	
Old secondary forest	46.67%	50.95%	-
Young secondary forest	43%	65.22%	48%

Colonizers such as *Cyclosorus parasiticus*, *Pellaea doniana* Hook., *Pteris preussii* Hieron. and *Doryopteris concolor* var. *kirkii* (Hook.) Alston mainly dominated young secondary forest. Primary forest which was the most species rich had unique species of *Asplenium anisophyllum* Kunze, *Asplenium laurentii* J. Bommer ex H. Christ, *Pteris intricata*, and *Vittaria volkensii*.

6.5.5 Taxonomic composition

There were 85 and 66 species recorded in Kakamega and Budongo forests respectively of which 36 were shared in both forests. Indeed, 49 species were unique to Kakamega and 30 to Budongo forests. Similarly, 15 genera and three families (Cyatheaceae, Lycopodiaceae, and Ophioglossaceae) were completely missing in Budongo forest while seven genera and one family (Davalliaceae) were absent in Kakamega forest. Species-rich families of Aspleniaceae, Pteridaceae, and Polypodiaceae were well-represented in both forests. Pteridaceae and Adiantaceae were remarkably species rich with 10 and 11 species each in Budongo and Kakamega respectively. The high number of shared species in both forests in some families was probably due to habitat similarities in both forests, which support diverse species richness.

6.5.6 Life form composition

Ferns occurring in the two forests were categorized into five different life-forms / ecological guilds (Table 16). This was based on their growth habits and habitats they occupy namely; terrestrial, obligates epiphytes, lithophytes, terrestrial /epiphytes, and hemiepiphytes. There were 62 (72.9 %) and 43 (65.2 %) of terrestrial species in Kakamega and Budongo respectively. Obligates epiphytes in Kakamega were 18 species (21.1 %) that belonged to four families namely; Aspleniaceae (eight species), Hymenophyllaceae (three species), Polypodiaceae (six species) and Pteridaceae (one species). Each forest had one

lithophyte, while three species occurred as either terrestrial or as low-trunk epiphytes in Kakamega while Budongo had one. Isecheno, a middle - aged secondary forest had the highest diversity of epiphytic species mainly of Aspleniaceae (six species), Polypodiaceae (three species) and Hymenophyllaceae (one species) compared to other forests.

Table 16. Life form richness in Kakamega and Budongo forests

Habit	No. of species/Kakamega	%	No.of species/Budongo	%
Terrestrial	62	72.9	43	65.2
Obligates epiphytes	18	21.2	21	31.8
Lithophytes	1	1.2	1	1.5
Terrestrial /Epiphytes	3	3.5	1	1.5
Hemiepiphytes	1	1.2	-	-
Total	85	100	66	100

Budongo forest, with a well marked by dry season and receives low amount of rainfall compared to Kakamega forest had high epiphytic diversity of 21 species (31.8 %). These species were distributed in the following families; Aspleniaceae (nine species), Davalliaceae (one species), Hymenophyllaceae (two species), Tectariaceae (two species), Polypodiaceae (five species), and Pteridaceae (two species). Epiphytic ferns recorded during the dry period reduced drastically compared with the wet period in both forests. Withered ferns on the tree trunks were common in forests with high disturbance, a good indicator of a habitat deprived of water/moisture. The most affected ones were of the Aspleniaceae and Hymenophyllaceae families e.g. *Asplenium theciferum* (Kunth) Mett., *A. mannii* Hook., *A. sandersonii* Hook., *Crepidomanes melanotrichum* (Schltdl.) J.P.Roux and *C. chevalieri* (Christ) Ebihara & Dubuisson.

The composition of the fern flora varied with local microhabitat, climatic condition, anthropogenic factors and the nature of forests. A stratification of different life forms in the study sites showed varied distribution in relation to the conditions of the sites (Table 17). Terrestrial species formed the largest proportion in all the study sites with the highest species number been recorded in Yala forest 32 species, followed by Kisere (25), Salazar

(19), Isecheno (18), Primary forest (20), and Swamp forest (18). The trend showed that mature and stable forests had high diversity of terrestrial species richness. The most disturbed forests of Buyangu and Lirhanda recorded the lowest terrestrial species. Terrestrial species recorded in Budongo forest had strong similarities with respect to species number.

Table 17. Distribution of life forms in different study sites

Forests	Study sites	Life forms				
		Terrestrial	Epiphytes	T/E	HE	LI
Kakamega	Busambuli	8	5	1		
	Buyangu	6	9	-		
	Colobus	9	7	1		
	Campsite	17	6	-		
	Ikuywa	9	5	1		
	Isiukhu	15	7	3		
	Isecheno	18	10	-		
	Lirhanda	7	2	-	-	1
	Kisere	25	9	1		
	Salazar	19	7	2		
	Malava	13	4	1		
Yala	32	10	2	1	-	
Budongo	Primary forest	20	11	-	-	-
	Old secondary	16	11	-	-	1
	Swamp forest	18	5	1	-	-
	Young secondary	17	5	-	-	-

Note: T/E; Terrestrial or epiphyte, HE; Hemiepiphyte, LI; Lithophytes

The highest diversity of epiphytes was recorded in primary and old secondary forests of Budongo each having 11 species, followed by Isecheno and Yala forests each with 10 species. Interestingly, Buyangu site had high proportion of epiphytes compared to terrestrial species. Lithophytes were poorly represented in both forests. As expected, there were more epiphytes in sites with closed canopy mainly in primary and old secondary forests where humidity was high as opposed to highly disturbed sites which recorded lower species number.

6.6 Discussion

6.6.1 Sampling effort and species estimation

Total and complete inventory of species in a given community in most cases is not realistic or achievable and this calls for sufficiency of sample size. In this study, species accumulation curves and non-parametric species richness estimators were used to evaluate the sufficiency of sample size and sampling effort. Estimating species richness using various estimators help a scientistsist to know how much of the species richness estimated were observed in the sampling, i.e. degree of collection. Heck *et al.* (1975) recommend that, on average, collection of 50 % - 75 % of the total number of species known to occur in a given area as long as most common species were obtained is satisfactory.

For Kakamega forest, 65.6 %-98.4 % of ferns estimated by various richness estimators were collected in each of the twelve study sites which is rather adequate. In Yala forest, 45 species were recorded in 14 plots, but the actual species number extrapolated was 72 species meaning that only 62.5 % of the species present at that site were actually recorded. Yala was the richest site and only registered 52.9 % of the total species (85 species) recorded in Kakamega forest. This is possible as this forest site recorded the highest percentage of rare species which had localized occurrences in habitats that were unique to this particular forest type. Some species e.g. *Asplenium africanum*, *Alsophila manniana*, *Lomariopsis warneckei*, and *Diplazium* sp. E were collected from only one locality/population. Similar observations were reported by (Parris *et al.* 1992; Parris 1997 cited by Kessler 2001b). It is therefore assumed that many more species remain undiscovered in Yala until further sampling is carried out. Sites with high species diversity were observed to be characterized by species with limited distribution range hence a need for conservation concern for such sites. Lirhanda hill which had the lowest estimated species collected was highly disturbed and due to recorded low species turnover few plots were sampled as done in other studies (e.g. Kessler 2001b). The forest had rare and localized species e.g. *Alsophila dregei* and *Cheilanthes inaequalis* var. *inaequalis*. Notably, many taxa have specific ecological requirements, which would explain their patchy distribution (Kessler 2001b). Localized taxa should be of conservation concern in regard to their spore dispersal which if not dispersed to suitable habitats will be a barrier in the sustainability of those small populations.

Budongo forest had 74.4 – 87.3% of the total estimated species collected, which is within the recommended proportion of 75 %. Budongo forest is less disturbed when compared with Kakamega forest, particularly its primary forest (nature reserve) which is a pure stand of indigenous tree species and in most cases vegetation is intact with less undergrowth (Schaab 2010). Budongo forest because of its long history of on-site field research has well established, marked, and accessible routes which made intensive surveying of different sites possible, including sampling along the river courses which are ideal habitats for most of the ferns.

The estimation of the expected species richness of the study sites by rarefying all study sites down to the smallest sample size gave high species richness for forests with minimal disturbance i.e. Yala, Isecheno, and Kisere in Kakamega, the same with primary and old secondary forests of Budongo. Low species diversity was estimated for forests which had experienced high level of disturbance in the past and present e.g. Colobus, Buyangu, Busambuli, Lirhanda and Ikuywa. The curves for the disturbed forests e.g. Busambuli, Ikuywa and Lirhanda reached an asymptote after few sampling indicating sufficiency in sampling. This does not mean all the species were recorded in each study site Tuomisto and Poulsen (2000), but the likelihood of additional species with increased sampling would not yield significant results. However these sites had few species compared to sites where disturbance was minimal. Sampling at individual study sites was far from complete for most of the sites. The species accumulation curves for all the sites in Budongo and nine sites in Kakamega forest (sample-based rarefaction curve) failed to saturate, as expected in most of the species-rich tropical floras (Watkins *et al.* 2006). These curves showed an upward trend indicating that the actual number of species is higher than recorded. Increased sampling intensity in more sites would definitely yield more species.

The species diversity as depicted from all level of sample accumulation curve was highest in primary forest, followed by old secondary forest, then swamp forest and young secondary forest had the least species. These observations matches well with the health and level of disturbances in the aforementioned forest types. The absolute value of species richness as well as β diversity showed the same trend. The ability of a species accumulation curve to reach an asymptote is seen as an indicator of sampling sufficiency (Heck *et al.* 1975).

However, Heck *et al.* (1975) warns that in a very patchy environment the species accumulation curve may become asymptotic before many of the species have been sampled. This is true for the forests that were highly disturbed, their species turnover were exceptionally low and as a result few plots were sampled and the curves generated reached an asymptote.

Since the curves for Yala and Kisere showed an upward trend and did not reach a horizontal asymptote, more sampling effort should be directed in these two forests where there is a likelihood of encountering more species. These two forests had the highest species richness and are considered unique in such way that they had high and closed canopy and diverse microhabitats, which support high diversity of ferns. Though the total number of fern species in Kakamega and Budongo forests are not precisely known, recorded species richness from this study were 65.6% and 74.5% respectively of the minimum richness predicted by all the estimators for the various study sites. This showed that most of the species were sampled during the study period. However, given a chance, further sampling effort is necessary to capture rare and localized species that will help to make reliable estimates of the total species richness of both forests.

The number of species predicted by all estimators for Yala forest are exceptionally high. The highest was given by second-order Jackknife which estimated 72 species, followed by ICE with 65 species. This is because species richness estimators use the frequency of rare species to predict total sample species richness (Williams *et al.* 2007). Yala forest had many unique and rare species of ferns as compared to other study sites. Out of all the species richness estimators, ICE and Chao 2 estimators found to be the best estimators. Their estimation of species richness was not erratic and did not vary much with the recorded species richness in all the study sites.

6.6.2 Diversity patterns

The wide variation in the values of Sorensen index indicated differences in species composition in different forests. The absolute value of species richness as well as β diversity was highest in primary forest type followed closely by old secondary forest, swamp forest and finally young secondary forest type showed the least species diversity in both Kakamega and Budongo. Primary forests had high β diversity an indication of high rate of species turnover. Kornas and Dzwonko (1994); Lwanga *et al.* (1998); Jones *et al.* (2011) in their studies reported the same observations. The highest dissimilarity index was observed between Buyangu forest and all the other forests. Buyangu forest was highly disturbed, caused by human activities such as quarrying and illegal logging. This led to opening of the forest canopy and consequently, drought-resistant, colonizers and competitive species e.g. *Dicranopteris linearis* and species of Polypodiaceae family were the dominant species. Kessler (2010), propose familial traits within this phylogenetically derived family provide resistance to extreme climatic conditions.

Dissimilarity index value was high between forests in different development stages such as Yala vs. Salazar; Kisere vs Salazar; Kisere vs. Yala; Kisere vs. Isecheno; Campsite vs. Isecheno. Study sites of Budongo forests showed a similar trend where dissimilarity was highest between primary and young secondary forest. The trend observed in this study suggest that different forest types differs widely in terms of species composition and diversity they support largely influenced by local factors (Tuomisto and Poulsen 2000; Krömer *et al.* 2005) e.g. the age of the forest, level of disturbances, edaphic characteristics and niche specialization. This showed that forests which have recovered from disturbance regimes support high diversity of fern species due to availability and stability of microclimatic conditions. As a result, species composition and diversity were more influenced by forest structure, presence of microhabitats and level of disturbance. Primary and old secondary forests, which are more mature and stable with high canopy cover had diverse range of microhabitats and microsites and hence high species diversity.

6.6.3 Species richness and distribution of diversity

Previous attempts to document ferns diversity particularly in Kenya are rudimentary e.g. Mutangah *et al.* 2002; Faden *et al.* 1988 and relied mostly on the herbarium records not actual field surveys. The 85 species recorded in Kakamega forests represent a substantial percentage of ferns known from Kenya, 31% of 275 species and a paucity of continental ferns flora, only 5 % of 1441 species (Roux 2009). Apparently, 66 species from Budongo represent 25 % of 259 Ugandan ferns and 4.5 % of ferns known from Africa. This shows that ferns richness in both forests was high considering the size of the study sites. Several factors are known to have played major roles to realize this appreciable species richness though not all of them were investigated in this study. First, climatic conditions were favorable, diverse and suitable habitats for the growth and establishment of ferns were available and widely distributed in both forests. Indeed, some species were conspicuously abundant while others formed a characteristic physiognomic feature along the valleys and ravines. A relationship between species richness and higher taxon richness was clear, suggesting that genera or family richness may be a good surrogate for species richness as observed by Pausas and Saez (2000); Aldasoro *et al.* (2004). This is evident in families like Pteridaceae, Dryopteridaceae, Polypodiaceae and Thelypteridaceae. The families Aspleniaceae and Pteridaceae had the highest species number of 20 and 18 in Kakamega, then 19 and 18 in Budongo forests. These two families were similarly reported by Jacobsen and Jacobsen (1989) to be the most species rich families in South Africa.

High species diversity was recorded in Kakamega than from Budongo forest. This may be due to its privileged location with high amount of rainfall, high humidity, presence of diverse microhabitats and heterogeneity of the forest. Budongo forest receives considerably less rainfall 1150-1500 mm year⁻¹ compared to 1500-2300 mm year⁻¹ received in Kakamega forest. Favourable moisture, temperatures, diverse microhabitats and microclimate are important determinant of ferns richness in a given area as noted by other authors (e.g. Barrington 1993; Kornaś and Dzwonko 1993; Tuomisto and Poulsen 2000; Pausas and Sáez 2000; Kessler 2000; Kessler 2001a, b; Watkins *et al.* 2006; Jones *et al.* 2011). Comparable studies done in other tropical regions, some on elevation gradient reported high species richness (e.g. Central Peruvian Amazon: Young and León 1989 (61 species); Uganda: Lwanga *et al.* 1998 (147 species); Amazon: Tuomisto and Poulsen 2000

(40 species); Andean Bolivia: Kessler 2001b (755 species); Ecuador: Tuomisto *et al.* 2002, (140 species); Tuomisto *et al.* 2003 (280 species); Northeastern Peruvian Amazonia: Salovaara *et al.* 2004 (133 species); Costa Rica: Watkins *et al.* 2006 (264 species); Kluge *et al.* 2006 (484 species); Brazil: Faria *et al.* 2007 (73 species); Bolivian Andes: Jones *et al.* 2011 (95 species).

Barrington (1993), found that fern richness is highest in the wet tropics under suite of conditions that include long-term stability, wide altitudinal variations, low vapor pressure deficit and a vast array of epiphytic and terrestrial microhabitats that provide ideal conditions for ferns. Local variations in soils chemistry and topography of an area have been found to increase species diversity (Poulsen and Nielsen 1995; Tuomisto and Poulsen 2000). Accordingly, the presence of various stable heterogeneous microhabitats in Kakamega and Budongo forests provided safe refuge to several species enabling the local coexistence of species. These unique and humid microhabitats are typically high in fern richness (Richard *et al.* 2000) and include myriad of large and small pockets of wet rocky sites, ravines, valleys, bogs, swamps, caves as well as tree trunk covered by moss. Kessler (2010) attributes this pattern to proximity to water bodies, which provide high and constant humidity. However, patterns of species richness and observed patchiness may be arising from spore dispersal limitation (Jones *et al.* 2008; Kessler 2010) and gap formation which influence light intensity (Poulsen *et al.* 2006). This is much applicable in this study for some species e.g. *Alisophila manniana*, *Pteris atrovirens* that were only recorded in specific areas though microhabitat suitability was proposed to be the controlling factors. Secondly, few species were shared in both forests, which could indicate distance-limited dispersal of spores between Budongo and Kakamega forests. Both forests are 500 km apart and there could be constrain in spore dispersal in relation to distance, although Kornas (1993) predict that a distance of 700 km is not a big barrier for spore exchange. High environmental heterogeneity appears important in promoting the coexistence, through microhabitat partitioning of a diverse local flora (Jones *et al.* 2011).

Primary forest of Budongo, with stable niches provided suitable microclimatic conditions which were favourable for the growth and establishment of diverse terrestrial and epiphytic fern species. Unique species specific to this forest type were *Pteris intricata*, *Vittaria volkensii*,

Arthropteris palisotii (J.F. Gmel.) Posth. and *Asplenium laurentii*. These species are good indicators of a well preserved/managed forest and are ideal flagship species for conservation effort in other forests. Kisere forest of Kakamega is a near primary forest which had high species diversity of 33 species. In both sites, there were presence of diverse and unique microhabitats found in the forest interiors, along the rivers, streams, valleys, tree trunks and dead logs covered by bryophytes. Primary forest therefore remain a priority site for nature conservation to preserve diverse and unique fern diversity found in these forests including other plant groups such as trees, shrubs, foliicolous lichens and bryophyte. Ferns are good indicators of ecosystem health as they are susceptible to disturbance and their occurrence in high numbers indicates a forest in good health.

Old secondary forest of Budongo which is at its climax showed remarkably high species diversity though substantial high level of disturbance was noted in this forest type. The disturbance regimes include illegal charcoal making, logging, habitat destruction by sawmillers and pitsawyers, firewood collection and animal grazing (Fig. 12). In particular mahogany has been a target species for extraction from Budongo forest due to its valuable timber (Reynolds 2005). Most of the forest is on the recovery path and indigenous tree species characteristic of tropical rain forest form part of community structure. Unique fern species in this forest type include *Asplenium gemmascens*, *Bolbitis heudelotii*, and *Davallia denticulata* (Burm.f.) Kuhn.

Yala forest, another old secondary forest of Kakamega with diverse and unique microhabitats serve as a good case study of a forest which experienced intense disturbance in the past but have recovered almost to its full potential (Fischer *et al.* 2010; Schaab 2010). Species such as *Scoliosorus mannianus*, *Asplenium africanum*, *Alsophila mannianum*, *Lomariopsis warneckeii*, *Pteris burtonii* among others were only found Yala forest. Kakamega forest is a very unique ecosystem interms of ferns diversity. Four species of ferns are nationally endemic to Kakamega forest. These are *Scoliosorus mannianus*, *Pteris burtonii*, *Asplenium angolense*, *Diplazium sp.* E.

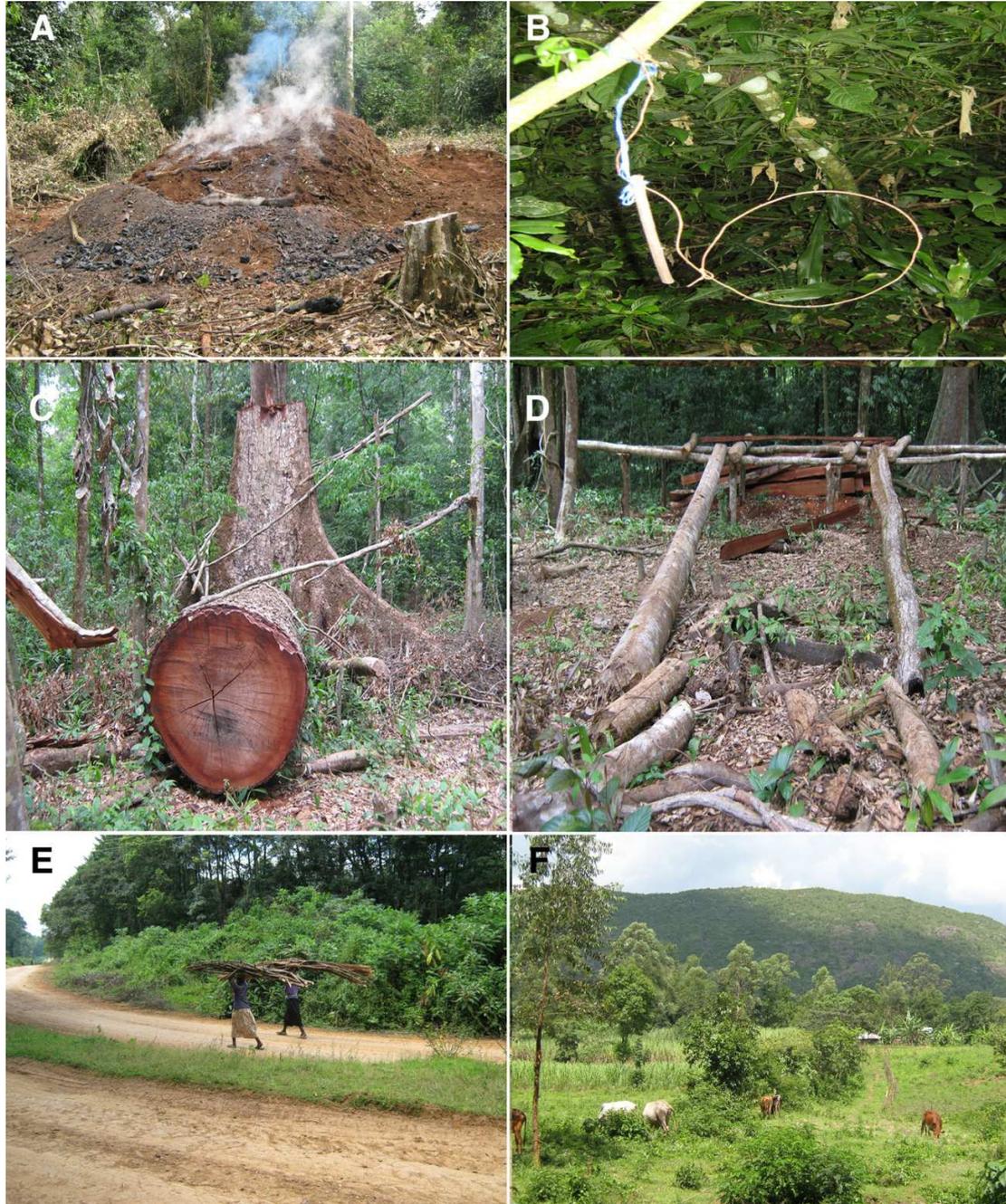


Figure 12. Different types of disturbance scenarios affecting ferns richness in Kakamega and Budongo forests

A) Charcoal making; B) Snare; C) Logging; D) Pitsawing; E) Firewood collection; F) Animal grazing.

Note. Plates A, B, C, E and F are from Kakamega forest; Plates C and D from Budongo forest.

Swamp forest type, included marshy and boggy sites that were wet most of the year. This poses a major challenge in growth of herbaceous layer such as some species of ferns which are not tolerant to soils with high water retention capacity. Moreover, spores rarely germinate successively in marshy/flooded sites because storage and viability of spore bank in such conditions would be compromised. Studies done on ferns, palms and Melastomataceae suggests that landscape-scale local soil variations are related to species distributions in both montane and lowlands forests (Tuomisto and Poulsen 1996; 2000; Tuomisto *et al.* 2002; Jones *et al.* 2011). Unique epiphytic species characteristic of this forest includes *Asplenium gemmascens* Alston, *Phymatosorus scolopendria* (Burm.f.) Pic.Serm., and *Microsorium punctatum* (L.) Copel., while terrestrial composed of *Lastreopsis currorii* (Mett.) Tindale, and *Diplazium proliferum* Bory. Poulsen (1996) suggested that water retention capacity of the soil might be used to explain observed species richness patterns in a local scale.

Low species diversity was observed in young secondary forest type, which is at intermediate succession stage, this calls for upscaling of conservation efforts to help the forest recover from the previous disturbance scenarios. It was noted that some of the gaps resulted through pitting were filled naturally with saplings of different species mainly climbers such as *Momordica foetida* and other ground vegetation leading to a bushy undergrowth that is too thick and too shady for seedlings to penetrate (Babweteera *et al.* 2000). Due to stiff completion from climbers, ferns and lycophytes were conspicuously absent in areas with history of logging. Other possible factors responsible for low species diversity include over dominance of pioneer species, which were however facilitating other species not affected by shade. *Pteridium capense*, a pioneer species in sites with high disturbance level was found to suppress establishment of other species.

The differences observed in species diversity in different sites reveal that, the level of disturbance in various forest types highly determines establishment and composition of species diversity of that particular forest. Advanced forests such as primary and old secondary which had stable environmental conditions after recovering from past disturbance regimes had high fern diversity compared to some middle and young secondary forests. Forests that experienced high disturbances had open canopies that

negatively affected and lead to a decline in fern species diversity such as in Lirhanda hill, Buyangu, and Busambuli forests. Both terrestrial and epiphytic species which are shade loving tend to be outcompeted/eliminated by species that are sun loving and thrive well in open areas. Meanwhile, some species e.g. *Asplenium inaequilaterale*, *Asplenium aethiopicum*, *Pteris catoptera*, and *Pteris dentata* were found growing in diverse habitats. This is attributed to their ability to exploit diverse microhabitats found in and outside the forests. For instance, forests with diverse niches/microhabitat had high species diversity arising from greater number of niche opportunities presented by variety of habitats.

Perhaps, absence of human pressure especially in the northern side of the forest managed by Kenya Wildlife Service (KWS) and Yala forest (nature reserve) in the southern part may be a contributing factor to high fern diversity. When compared with Budongo forest which experienced intensive logging in the past, the presence of diverse microhabitats and relatively few undisturbed sites in Kakamega forest give it privileges to harbour unique species diversity. However, Budongo forest is successively on a recovery path as management measures are well in place.

6.6.4 Taxonomic composition

Analysis of taxonomic composition showed a remarkable overlap in the fern composition at family level, low similarities at generic and specific levels which might indicate that, while both forests have a similar base stock of fern families, evolution and diversification of these families took place independently in both regions (i.e. macroevolution). A good example was provided by the family Polypodiaceae which had three and two unique genera in Kakamega and Budongo forests respectively. No genera of the families Lomariopsidaceae and Athyriaceae were shared in both forests. The results support the findings of Kessler (2001a) while comparing taxonomic composition of Mt. Kinabalu (Borneo) and Parque Nacional Carrasco (Bolivia). Apparently, the almost similar ecological ecosystems having similar ecological niches are occupied with high proportion of unrelated taxa of three families (Lomariopsidaceae, Polypodiaceae, and Athyriaceae). These indicate taxa from different phylogenetic origin share similar habitat requirements. Alternatively species composition may reflect regional differences in soils, or biogeographical differences in species distributions (Tuomisto and Poulsen 2000). Küper *et*

al. (2004) observed that floristic differences between two sites could be due to differing ecological conditions at one sites that can exclude a species from inhabiting one of them. Some terrestrial fern species depend on particular soil characteristics (Tuomisto and Poulsen 1996). Likewise, epiphytic fern may depend on characteristic of a particular host tree (Mehltreter *et al.* 2005) or microhabitat conditions (Gardette 1996).

Ferns are known to disperse efficiently, however physical dispersal barriers can affect the extent to which spores are dispersed to suitable environmental conditions and their subsequent successive establishment (Tuomisto and Poulsen 2000; Jones *et al.* 2011). In this study, Mt. Elgon which is in-between the sites may have acted as a dispersal barrier between Kakamega and Budongo forests. However, variations in topographic position and soil chemistry e.g. soil phosphorus or cation concentration in tropical lowlands forests have been shown to influence floristic variation of ferns (Tuomisto *et al.* 2003; Poulsen *et al.* 2006). In general, occurrences and composition of fern species in these two forests may be as a result of different ecological processes playing a role at local scales. However, microclimatic variables were not considered in this study which form a research question for future studies. Species of highland elements e.g. *Diplazium* sp. occurred in distinct microhabitat which were highly shaded and humid.

6.6.5 Life-form composition

6.6.5.1 Terrestrial species

Most of the species recorded from both forests were terrestrial preferring wet and partially shaded areas. In Kakamega and Budongo forests, they formed the largest proportion of the fern flora with 62 (72.9%) and 42 (64.6%) species respectively. This highlights their functional importance in the ecosystem processes of tropical rainforests as reported in other rainforests such as in Bolivia Kessler (2001a), Brazil and Mexico. These species were distributed in different forest types with the highest species number recorded in Yala forest 32 species, followed by Kisere (25), Salazar (19), Isecheno (18), Primary forest (20), and Swamp forest (20). The trend was more regularly and evenly distributed and could be as a result of mature and stable forests which support growth and establishment of high diversity of terrestrial species. The most disturbed forests of Buyangu and Lirhanda recorded the lowest terrestrial species.

6.6.5.2 Epiphytic ferns

Epiphytic ferns make up an especially conspicuous component of tropical rain forests around the world (Watkins and Cardelus 2009) and they contribute greatly in ecosystems functioning as well as in species diversity. Epiphytic fern diversity in this study accounted for 18 (21.2%) and 21 (32.3%) of the entire pteridoflora in Kakamega and Budongo forests respectively (Table 16). The results shows both forests are highly impoverished in epiphytic ferns despite the high amount of annual precipitation and low seasonality experienced, which are favorable factors for ferns establishment and survival. The recorded species richness was low, when compared with other tropical rainforests, Dittrich *et al.* (2005) recorded 49 species in one hectare plot in Brazillian forests; Roberts *et al.* (2005) recorded 97 species of epiphytic ferns in Tasmanian tree ferns; and Watkins and Cardelus (2009) reported 21 species in Costa Rica. The abundance, diversity and community of vascular epiphytes are strongly influenced by local precipitation (Benzing 1983; Kreft *et al.* 2004; Dittrich *et al.* 2005; Poltz and Zotz 2011).

Epiphytes are highly sensitive to disturbance and changes in environmental factors making them good indicators of human disturbance and ecosystem health (Hietz 1999; Krömer and Gradstein 2003). In Kakamega and Budongo forests, epiphytic species richness reduced in sites with high level of disturbance e.g. Lirhanda, Malava, Busambuli, and Ikuywa, indicating they are vulnerable to anthropogenic disturbances. The low epiphytic diversity may be attributed to shifts in microclimatic conditions triggered by anthropogenic factors (Krömer and Gradstein 2003; Werner *et al.* 2005; Hietz 2005; Wolf 2005; Higuera and Wolf 2010), age of the forests, open canopy leading to increased evaporation, and low elevation of both forests. Mehltreter (2010) reported reduced tree densities and diversity of host trees which are potential habitat for epiphytes as key contributing factors to low epiphytic diversity. Reduction and loss of favorable host trees directly translates to decline of epiphytic fern species at any given site (Hietz 2005; Wolf 2005). Clearly, the survival of the epiphytes solely depends on their hosts, as they cannot get water from the soil. The species occurrences in different sites show discrete distributions between forests in different seral stages. Most of the epiphytes were recorded in primary (e.g. nature reserve and Kisere) and old secondary forests (e.g. Yala) due to presence of mature trees species that formed a closed canopy that provided the necessary microenvironment required by

epiphytic species (Fig. 13). These results are comparable with other studies e.g. Kupper *et al.* (2004); Werner *et al.* (2005); Poltz and Zotz (2011).



Figure 13. Diversity of epiphytic ferns

A) *Lepisorus excavatus*; B) *Asplenium theciferum*; C) *Scoliosorus mannianus*; D) *Pyrrosia schimperiana*; E) *Asplenium africanum*; F) *Platyserium angolense*.

Note: Plate A, B, D & E were taken in Kakamega forest; Plate C& F from Budongo forest.

Species that are shade tolerant and prefer high humidity e.g. *Asplenium africanum*, *A. mannii*, *A. ceii*, *A. theciferum*, and all Hymenophyllaceae ferns were missing in open sites. However, they occurred abundantly and were characteristically conspicuous on tree trunks in dense canopy and shaded forests. These shows that epiphytic ferns are very sensitive to habitats and atmospheric changes caused by human disturbances. Species adapted to shaded habitats disappeared at the benefit of drought tolerant “sun-epiphytes” a scenario also observed on other epiphytic taxa e.g. bryophytes (Gradstein 1992; Acebey *et al.* 2003; Holz 2003). Epiphytes sensitivity according to Padmawathe *et al.* (2004) and Werner *et al.* (2005) was related to alterations in community composition and loss of moisture via logging because of their slow process of establishment. Increased drought stress on isolated and exposed trees resulted in higher mortality among epiphytes (Werner *et al.* 2005; 2010) due to change in humidity regime.

The most common epiphytic ferns recorded in Kakamega forest were; *Asplenium theciferum* (Kunth) Mett., *A. sandersonii*, *A. ceii*, *A. mannii*, *A. aethiopicum*, *A. africanum*, *Scoliosorus mannianus*, *Crepidomanes melanotrichum*, *Trichomanes chevalieri*, *Drynaria volkensii*, *Lepisorus excavatus*, *Loxogramme abyssinica*, *Pleopeltis macrocarpa* and *Pyrrosia schimperiana*. *Asplenium*, a species-rich group, constituted the highest number of epiphytic species in both forests and was represented in all forest types. In Budongo forest, common epiphytes were *Asplenium warneckeii*, *A. africanum*, *A. anisophyllum*, *A. lividum*, *Scoliosorus mannianus*, *Loxogramme abyssinica*, *Microsorium punctatum*, *Platynerium angolense*, *Phymatosorus scolopendria*, and *Vittaria volkensii*. There were species that were facultative epiphytes e.g *Asplenium aethiopicum* and *A. paucijugum*.

However, there are epiphytic ferns that benefited from anthropogenic disturbances and flourished in disturbed habitats such as some species in the Polypodiaceae e.g. *Loxogramme africana* and *Pleopeltis macrocarpa* and in Aspleniaceae e.g *Asplenium aethiopicum*. Others are extreme specialists adapted to climatically and ecologically harsh conditions in the canopy (Biedinger and Fischer 1996; Hietz 1999) e.g *Drynaria volkensii*. These species are tolerant to drought and high light intensities and therefore preferred open tree trunks and branches as previously reported (Krömer and Gradstein 2003; Werner *et al.* 2005). Species of this kind might have developed survival strategies that enable them to cope with stressful

environments especially on reduced water. *Drynaria volkensii* was observed to have evolved a unique survival strategy whereby its big pinnae formed basket-like structure that trapped and accumulated leaf litter with water retention capacity possibly for use during the dry seasons. Such structures were also ideal habitats for small sized organisms e.g. insects, ants, butterflies, beetles, worms, spiders, birds and frogs. Species with the same strategy from other regions include *Asplenium nidus*, bird's nest fern and *Platycterium sp.*, staghorn ferns (Hietz 2010). *Asplenium aethiopicum* exhibit wide morphological variations expressed in different environmental conditions of the habitat they occupied. It 'metamorphoses' to accommodate the local habitat needs and is one of the most widespread of the fern species in Kenya inhabiting drylands to the montane forests of Mt. Kenya.

Tree species with high bryophyte cover had high composition of epiphytic fern species (Fig. 13. A & D). This phenomenon could be due to high water retention capacity, allowing a steady supply of water even during drier periods and providing mechanical support to the epiphytic ferns (ter Steege and Cornelissen 1989; Werner *et al.* 2005). Bryophyte cover tends to increase with humidity (Gradstein & Pócs 1989) so does the ferns. Four forests i.e. Kisere, Colobus, Isecheno and Yala had tree trunks with highest epiphytes richness. These forests have mature trees forming a dense canopy cover that maintain high air humidity, diverse and unique microhabitats were available with minimal human disturbances. However, substratum factors seemed to be relevant such as texture (roughness), capacity of the bark to retain water, trunk size, bryophyte mats and accumulated litter on the bark. Ter Steege and Cornelissen (1989) while working in Costa Rica tropical forests had reported similar observations.

Epiphytes recorded in the study sites did not show host preferences but trees with rough bark hosted more species which had a tendency to grow in mixed colonies. The tree host ranged from *Celtis africana* (Cannabaceae), *Ficus* spp. (Moraceae), *Harungana madagascariensis* (Hypericaceae), *Milicia excelsa* (Moraceae), *Olea capensis* (Oleaceae), *Prunus africana* (Rosaceae), etc. Tree trunks did not harbor exclusively any preferential species but *Ficus* species were observed to have more epiphytes compared to other phanerophytes. This may be attributed to their giant and curvy/twisted trunks, which by their bark characteristics exhibit diverse and favorable niches/microsites for epiphytic ferns to colonize as well as

presence of large surface areas available for colonization (Flores-Palacios and Garcia-Franco 2006). Mehltreter *et al.* (2005) found that epiphytes were more diverse and abundant on host species with favorable bark characteristics such as high water content and retention capacity. The data show that trunks of old trees played host to more epiphytes than young tree trunks.

6.6.5.3 Lithophytes

Cheilanthes inaequalis var *inaequalis* was the only obligate lithophyte occurring in forest glades in Kakamega forest while *Asplenium dregeanum* was occasionally found on rocks near streams and rivers. In Budongo forest, *Bolbitis heudelotii* found growing along the river partially submerged was the only lithophyte. Therefore, the diversity of lithophytes was exceptionally low and this could be attributed to geological situation of both forests which are generally not rocky.

6.6.6 Environmental factors and fern species richness in Kakamega and Budongo forests

The floristic dissimilarities observed in different forest sites reflected different ecological conditions. The relatively high number of ferns encountered was as a result of existence and combination of suitable microclimatic conditions that favor establishment of several species (Barrington 1993; Kluge *et al.* 2006). Fern richness is highest in the wet tropics under suit of conditions that include long-term stability, wide altitudinal variations, high humidity, low vapor pressure deficit and a vast array of epiphytic and terrestrial microhabitats that provide ideal conditions for ferns (Barrington 1993; Kluge *et al.* 2006; Kessler 2000; 2001a; 2001b; 2010). High species richness in areas with high moisture, humidity and diverse microhabitats suggests that most of these species have an affinity for damp and shady places, as one would expect (Richard *et al.* 2000; Aldasoro *et al.* 2004; Hietz 2010). Species adapted to most humid and shaded canopy sites occur abundantly and co-exist in closed canopy. Such species included *Asplenium africanum*, *A. dregeanum*, *A. ceii*, *A. macrophlebium*, *A. theciferum*, *Bolbitis auriculata*, *Pteris intricata*, *P. hamulosa*, *Selaginella versicolor*, *Vittaria volkensii*, and *Scoliosorus mannianus*. Exposure of these species to direct sunlight through conversion of the original vegetation to other arboreal vegetation leads to their disappearance. Shade loving species were highly affected by the disturbance and their

numbers declined with level of disturbance. None of these species was found in Malava forest which had highest disturbance level due to logging, firewood collection and animal grazing.

The 85 species (31 % of Kenyan ferns species) found in Kakamega forest, an area of 190 km² represent a particularly species-rich fern flora compared to the 275 fern species found in the whole country. This high diversity is attributed to habitat heterogeneity found in the forest and its proximity to the larger Guinea-Congolian forests. High environmental heterogeneity appears important in promoting the coexistence, through microhabitat partitioning, of a diverse local flora (Jones *et al.* 2011). However, 66 species recorded from Budongo forest (435 km²) an area more than double Kakamega forest in size may be explained by relatively low precipitation and uniformity in topographic complexity which resulted in paucity of suitable microhabitats necessary for establishment and growth of ferns. Nevertheless, these two forests are lowland tropical rain forest and hence their floristic heterogeneity tends to be lower. Notably, most of the species found in Kakamega forest occur in afro-montane forests of Kenya, Aberdares and Mt. Elgon except for *Scoliosorus mannianus*, *Asplenium angolense*, *Diplazium sp. E.* and *Pteris burtonii*. This shows the high afro-montane element in the lowland tropical forests.

Kakamega forest had unique species with restricted distribution. Such patchiness in the species distribution could be arising from distance-limited spore dispersal e.g. those of *Alsophila dregei*, *A. manniana* and *Scoliosorus mannianus*. The nearest known site of *A. manniana* is in Nandi hills forest, a distance of about 100 km away. Its spore dispersal to Kakamega forest could have been through water (Yala river) that have its origin in Nandi hills and passes through Yala forest. *Alsophila dregei* was previously only reported from the Kenyan coastal forests e.g. Mbololo forest of Taita hills where it occurs together with *A. manniana* and *A. humilis*. Its presence in Kakamega forest in open and isolated hills is of interest especially on its dispersal path. *Scoliosorus mannianus*, show the same trend, in Kenya it is only known to occur in the coastal forests and Kakamega where it is restricted to Yala forest. Dispersal processes are undoubtedly important, as they constrain the extent to which plants occupy suitable environmental conditions and also affect the likelihood of establishment in marginal conditions.

6.6.7 Ferns as bioindicators of forest conditions

Ferns and lycophytes served as a good indicator of forest quality and level of disturbance as documented from this study. Ferns play major ecological roles in forests processes and their occurrences are associated with different ecological conditions. Most of the species recorded show a narrow range of habitat requirement, where they are highly affected by slight alteration of their preferred local habitats. Such species have been used here as indicators of magnitude of disturbance in different habitats of Kakamega and Budongo forests. Majority of the species are clearly partitioned according to the health of the sites they occupied as found in other studies (Jones *et al.* 2011). However, some had high plasticity and occupied nearly all habitats available and occurred in various life forms e.g. *Asplenium aethiopicum*. The results showed that Kakamega and Budongo forests harbour a high diversity of ferns with 81 species in both forest of which three were lycophytes (i.e. *Selaginella kraussiana*, *S. versicolor* and *Lycopodium clavatum*) despite being lowland tropical rainforests where the highest point was 1700 m and 1200 m in Kakamega and Budongo forests respectively. The range of species recorded exhibit different habitat requirements and react differently to change in environmental factors. Species patterns in different sites is a good indicator of how species respond to different conditions/stress occasioned by human or natural disturbances. High ferns flora of these two forests was primarily due to the high amount of rainfall received and the presence of different microhabitat distributed across various habitats.

Ferns and lycophytes have also been suggested as an indicator for the tree species richness in tropical rainforests because of the difficulty in identifying tree species in these ecosystems (Raokolainen *et al.* 1997). Some studies support the idea that comprehensive biodiversity protection may be attained by targeting a subset of taxa such as ferns (Game and Peterken 1984; Ruokolainen *et al.* 1997). However, presence of different taxa giving rise to high diversity of ferns species does not necessarily mean that, the two forests are 100% in good conditions/healthy. Many species of ferns show a clear habitat differentiation in relation to light intensity/conditions, moisture availability and disturbance level making them suitable indicators of anthropogenic disturbance.

6.6.7.1 Ferns of disturbed sites

Disturbed habitats such as forests clearings and edges, logged sites, dry grassland, and roadsides habitats provided favorable conditions for ferns that are tolerant to various levels of disturbances and have evolved high adaptation mechanisms. Ferns growing in these sites are more exposed to harsh climatic conditions such as greater incidence of winds, direct sunlight, that affects fern assemblages more strongly than those in the sheltered forest interior (Grime 1985; Kluge and Kessler 2006; Hietz 2010). Gradstein (2008) states that, forest disturbances are usually associated with humidity loss resulting from a more open canopy causing drought stress to the plants. As a consequence sensitive herbaceous species are quickly replaced by the species that are drought resistant able to withstand harsh environmental conditions.

However, ferns response to human disturbances is highly variable and often species specific (Walker and Sharpe 2010). In most cases, on set of disturbances spelt doom for some species which disappeared immediately while others took advantage of the situation and proliferated in high numbers. For example, *Pteridium capense*, an invader in disturbed sites with successful survival strategies capitalizes on human disturbance of the landscape (Robinson *et al.* 2010). This species has a long creeping rhizome that spreads out easily covering sizeable areas within a short time. Disturbed sites in Kakamega and Budongo forests had low species diversity than forest interiors as also noted by other authors (e.g. Kessler 2001; Paciencia and Prado 2004; Werner *et al.* 2005; Poltz and Zotz 2011; Walker and Sharpe 2010). Decrease in number of fern species and changes in community structure in response to disturbance shows that they are highly sensitive to high amount of sunlight hence preferring shaded or partially covered sites.

Forests edges and foot paths were dominated by high abundances of invading and hardy species e.g *Pteridium capense* (bracken) and *Dicranopteris linearis* (Gleicheniaceae) as earlier observed by Sharpe and Walker (2010) while *Pellaea viridis*; *Doryopteris concolor* var. *kirkii* (Pteridaceae) and *Cyclosorus dentatus* (Thelypteridaceae) were found in areas with moderate disturbances. These species, commonly referred to as non-forest species, have extremely high recruitment rates and normally adapted to growing in highly disturbed habitats characterized by low moisture content and high light intensity. Their proliferation after

disturbances at the expense of non-tolerant species make them traditionally be classified as weeds or invasive species e.g. *Pteridium capense*. This species was particularly notorious in some study sites in Kakamega and Budongo forests due to heavy logging which changes vegetation structure, and species composition and causes habitats fragmentation (Boutin and Herbert 2002; Schmiegelow and Mönkkönen 2002). Species typical of forest interiors were not recorded in disturbed sites, and where they occurred, they were present in very low abundance as noted by Paciencia and Prado (2005). In this study, filmy ferns which are highly sensitive to environmental change were conspicuously absent in disturbed sites, as observed by others (e.g. Poltz and Zotz 2011; Werner 2005). Similarly, species characteristic of disturbed areas were absent in forests with a good canopy cover, a clear indication of niche specialization. The paucity of ferns in disturbed sites may well reflect the general inability of ferns to cope with human disturbance (Grime 1985).

Disturbance on the other hand was found to be beneficial as it helped in removal or turning of the leaf litter as well as soil thereby exposing the sporebanks in the soil which would otherwise not germinate if there were no anthropogenic processes (Hietz 2010). Hemp (2002) suggests that disturbance of natural vegetation in the transition zone between cultivated land and dense primary forest creates a wealth of different habitats giving rise to a high α diversity. Therefore, disturbances by its very nature creates safe sites, which enable species which prefer disturbed sites thrive well and give a high 'regeneration/recruitment burst' scenario.

6.6.7.2 Riverine fern species

Riverine vegetation harbored unique microhabitats with localized conditions mainly along ravines and valleys that were exceptionally rich in unique and rare ferns species (Fig. 14). Fern species of this particular habitat formed distinct species assemblages, an indication of a more stable and balanced environmental conditions. Species associated with such habitats in Kakamega forest were tree fern *Asplenium loxoscaphoides*, *Athyrium scandicinum*, *Coniogramme africana*, *Alsophila manniana*, *Deparia boryana*, *Didymochlaena truncatula*, *Diplazium* sp. E, *D. velaminosum*, *Ptisana fraxinea*, *Microlepia speluncae*, and *Cyclosorus unitus*. In Budongo forest, *Bolbitis auricululata*, *B. heudelotii*, *Diplazium proliferum*, *Pteris intricata*, *P. commutata*, *Cyclosorus afer* and *C. blastophorus* were the main riverine species. All these species occurred

in high abundance except *Alsophila manniana*, *Pteris intricata* and *Bolbitis heudelotii*, a characteristic of ideal sites with favourable microclimatic conditions. These observations and conclusions concur with studies done by Hemp (2002) and Kessler (2001a).



Figure 14. Riverine fern species from Kakamega and Budongo forests

A) *Pteris intricata*; B) *Asplenium dregeanum*; C) *Coniogramme africana*; D) *Athyrium scandicinum*.

Note: Plates A & C taken from Budongo forest; Plates B & D from Kakamega forest.

Valleys and vents, form important refuge areas for the natural flora and fauna as also noted in distribution of ferns and lycophytes of Mt. Kilimanjaro (Hemp 2002). Refuges are places that have shown climatic stability over geological time and are areas from which species spread out when climatic conditions become more favorable (Fjedsa and Lovett 1997). Lwanga *et al.* (1993) while studying ferns of Uganda found that fern diversity mostly depended on soil fertility and distance from the nearest Pleistocene refuge. In Kakamega and Budongo forests such habitats were often found along the rivers and other wet spots such as swamps and water logged areas and had high species diversity compared to other sites. Aldasoro *et al.* (2004) observes that diversity and endemism should increase towards refuges because of their isolation and maintenance of favorable climatic conditions.

6.6.7.3 Dead wood substrate species

Dead wood offered special and stable habitat for ferns species especially in the forest interiors where temperatures were low and hence decay of wood decelerated. Species composition and diversity on these substrates varied considerably with no species showing actual host preference. However, dead wood covered by bryophytes had high abundance of fern species as well as other vascular plants e.g. orchids and non-vascular species e.g. bryophytes and lichens. Moss cover forms an ideal substrates because of its efficiency in water holding capacity (ter Steege and Cornelissen (1989). Sites/logs with high abundance of moss were characterized by high number of epiphytic species. Species occurring on dead wood substrates were observed to maintain stable populations comprising of *Loxogramme abyssinica*, *Asplenium theciferum* (Kunth) Mett., and *A. paucijugum*.

6.6.7.4 Insular habitat species

Cheilanthes inaequalis var. *inaequalis*, a xerophytic fern, was found growing in rock crevices in Lirhanda hill. This was the only lithophytes in the study area with unique mechanisms that enabled it to withstand harsh environmental conditions such as low humidity and sun-exposed habitats. This was possible through desiccation tolerance. Its pinnae were rolled inward and their underside densely covered with brown rusty scales that reduces water loss through the cuticles of the pinnae. Xeric environment are insular habitat type, showing specialized communities with high degree of specificity and greater incidences of rare and endemic species (Kluge and Kessler 2006). This was true for Lirhanda hill which also had a unique tree fern, *Alsophila dregei*, first record for Kakamega forest. This species was found in abandoned pit holes dug by golder miners and only three individuals were spotted.

6.6.7.5 Competitive/invasive species

Pteridium and *Dicranopteris* are members of scrambling ferns which have a rapid growth forming a mat-like cover on the ground. They are often abundant on and characteristic of nutrient-improvised sites such as burnt fields/forests, landslides, highly weathered and forests undergoing succession stages. These species were observed to have dense growth covering forest floor soon after fire incidences becoming the dominant plant. *Pteridium* cover increased and exhibited competitive advantage over other herbaceous species after a fire incidence in Bahati forest, Kenya (P. Kamau pers. obser.). Field observation showed that this species was particularly favored by fire outbreak where it out-competes its

competitors and thus was locally abundant. This phenomenon can only be explained by rapid germination of spores which, which find optimal pH for germination in the ash on the burnt soil (Hemp 2002). Such ferns also have a subterranean and deeply buried rhizomes that is pre-adapted to surviving recurrent fires and have ability to ‘respond’ rapidly in invading burnt sites (Hietz 2010). Their sporophyte stage develops in high light exposure unlike other ferns and lycophytes that prefer shaded sites (Hemp 2002).

Ferns, over time have developed a comprehensive adaptation package, which enables them to survive harsh environmental calamities (Jones *et al.* 2010). These strategies include mechanisms to withstand severe drought and frost by becoming poikilohydric, adaptation to and surviving recurrent fires (Kornaś 1985; Jones *et al.* 2010).

6.7 Conclusions and recommendations

The high species diversity and richness recorded from both forests show that tropical rainforest support high diversity of ferns and lycophytes. The diversity of ferns recorded in this study is much higher than the previous records and forms a good baseline for future studies in these forests or other more humid forests. The most species – rich families in both forests were Aspleniaceae, Pteridaceae, Polypodiaceae, Thelypteridaceae, and Dryopteridaceae. The richest genera were *Asplenium*, *Pteris*, *Adiantum* and *Bolbitis*. *Pteris dentata*, an afro-montane species was the most dominant and abundant in Kakamega forest, confirming this forest is a heterogeneous forest. Forest interiors especially the less disturbed ones formed the most important habitats for ferns and they were clearly stratified depending on the level of disturbance.

The main factor influencing the richness of ferns in different sites was the presence of diverse and stable microhabitats. These includes permanent rivers, seasonal streams, valleys, forest edges, rocky sites, dead tree trunks especially those covered by moss. It was established that microhabitat conditions largely influence species occurrences since some species are habitat specific due to conditions of the sites. High annual precipitation and humidity, low disturbance, canopy cover, and low seasonality were other important contributing factors. Importantly, forests at different development stages differed widely in terms of species composition and diversity they supported. The highest richness was in more advanced old-growth forests i.e. primary and old secondary forests, which had good canopy cover, less disturbance and hence their importance in fern conservation. Therefore, species richness was proportional to the degree of disturbance experienced in each study site.

Recent studies have shown that, the diversity of ferns, foliicolous lichens and bryophytes was highest in Kakamega than in Budongo forest (Malombe 2007; Kumelachew 2008). This largely means that, the three group of taxa are reliably good indicators of forest disturbance arguably controlled by the same environmental factors i.e. microhabitat availability, humidity, moisture, and seasonality. The major environmental factors that were observed to change with level of disturbance were the light parameters and

microclimate (moisture and temperature regime). Therefore, the occurrence of ferns in different sites/forest types was good indicator of ecological conditions in tropical forests because of their sensitivity to disturbances. High ferns species richness directly translates into forests/sites in good health. Ferns can serve as flagship species for good management of ecosystems as well as vessels of early warning systems in forest conservation (so called bio-indicators or bio-sensors). Epiphytic ferns particularly are highly vulnerable group which consequently represent a good indicator group of biodiversity that can be monitored to assess the effects of anthropogenic disturbances on the forest. They form an excellent object to study increasing external forces that affect biodiversity in general. They can be termed as 'phyto-sensors' or whistleblowers signaling slight alterations in an ecosystem and they are highly recommended as study instruments to mitigate environmental changes.

More studies should be carried out in other ecosystems especially the tropical montane forests to assess how floristic variation correlates with diverse microhabitat, microclimatic and other environmental parameters which are major determinants of species richness which peak at mid-elevations. Such studies are missing in most of the African tropical mountains particularly Mt. Kenya, Rwenzori, Elgon and Aberdares. In tropical lowland forests, the contribution of forest structure, edaphic factors, microsite and associated microclimate need further studies comparing different ecosystems.

CHAPTER 7. BIOGEOGRAPHY OF THE GENUS PTERIS

Biogeography is the science that attempt to document and understand spatial patterns of biological diversity (Lomolino *et al.* 2006). Biogeographical inferences are dependent of classification and therefore the best possible classificatory systems based on relatedness and evolutionary principles are utilized (Smith 1993). Fern produce propagules of small size, mostly 20-100µm long, that are in general more easily dispersed by wind and water than the seeds of flowering plants (Smith 1993; Wolf *et al.* 2001). They are also more biogeographically widespread than flowering plants (Tryon 1970; Smith 1972; Smith 1986; Kornaś 1993). This is probably due to their higher dispersal abilities but restricted by habitat availability Richard (2000) and their small size spores in comparison to the seeds of most angiosperms. Fern genera are older than genera of flowering plants, some of them predating continental drift events and therefore had more time to spread all over the globe before the continental drift thus facilitating intercontinental migration (Wolf *et al.* 2001).

Clearly, availability of suitable habitat, at a local scale (Tuomisto and Poulsen 1996; Richard *et al.* 2000; Wild and Gagnon 2005) and a regional scale (Guo *et al.* 2003), and not dispersal capability is responsible for fern distribution. Ferns form a suitable group of organisms for biogeographic studies due to processes pertaining to their distributional patterns and varied reasons have been used to interpret their geographical distribution (Barrington 1993; Kato 1993; Wolf *et al.* 2001). Fern flora of tropical Africa has similar biogeographical features to the phanerogam flora of the continent (Tryon 1986; Kornaś 1993).

However, tropical Africa is species depauperate as compared to Central America and Southeast Asia (Parris 1985; Tryon 1986; Kornaś 1993). Many important families and genera of rain forest ferns and lycophytes e.g. Hymenophyllaceae and Cyatheaceae are poorly represented in Africa, (Kornaś 1993). A big percentage of the fern genera that grow in tropical America and tropical Asia are completely absent in Africa (e.g. *Cyclopetis* J.Sm., *Lomagramma* J.Sm., *Paesia* St. Hil., *Plagiogyria* (Kze.) Mett. among many others). These low diversity result from poverty of the rain forest flora which offer limited chances for survival in the rain forest refugia (Kornaś 1993). Much of the Africa is characterized by

strongly seasonal or irregular rainfall whereas most ferns require a continuous supply of moisture (Parris 1985; Tryon 1985).

The historic factors responsible for this poor ferns and lycophytes diversity include shifting of climatic zones due to shifting of vegetation zones from the north to the south as a result of continental drift during the tertiary and climatic oscillations during the Quaternary (Barrington 1993; Kornaś 1993). Increasing aridity caused by continental elevation and the gradual strengthening of the cold Benguela currents as the Atlantic Ocean widened is another factor (Roux 2009). This, coupled with the erosion of the geologically stable continental plate, led to a relatively uniform landscape and a loss of microhabitats suitable for the establishment and evolution of taxa (Roux 2009). These drastically reduced the area of forest refugia and depreciated their role in Africa during the dry (glacial) periods. The significantly more diverse floras along the higher-rainfall mountainous regions of the continent and the significantly more diverse flora of Madagascar unaffected by these events, support this view (Roux 2009). Despite the poor species diversity, nine or 26.5% (the only ones in desert and xeric shrubland) of the 34 global biodiversity hotspots are found within African and Malagasy regions.

Species more widely distributed on continents are better migrators than those of limited distribution. The most important phytogeographical principles include intrinsic biological features of ferns namely their potential for wide dispersability and establishment from single propagules. Geographical proximity and environmental features such as climatological and habitat similarity are equally important. All of these factors interact to affect and ultimately determine range of a given taxon. Fern establishment after dispersal determines the future of the propagules and solely relies on the availability of suitable habitat for subsequent establishment.

7.1 Aspects of phytogeography of African ferns

Two thirds of the African ferns species are limited in their occurrence to the continent (often with the adjacent islands, including Madagascar) (Kornaś 1993). The majority of these, however, have closely related counterparts in tropical America and/or southeastern Asia. They are apparently descendants of common ancestors with wide pantropical ranges

(Kornaś 1993). Many African ferns exhibit distribution patterns similar to those of some African angiosperms (Schelpe 1983). In Africa, Kornaś (1993) classified continental fern flora into three main latitude groupings mainly tropical (paleotropical), Mediterranean, and Cape. The sub-Saharan ferns exhibit three discontinuous distribution patterns namely an Africa-American disjunction, an African-Madagascan disjunction and an Africa-Asian disjunction (Roux 2001).

Ferns are generally distributed along a latitudinal gradient with highest diversity in the tropics (Jacobsen and Jacobseb 1989; Kornaś 1993; Roux 2009). The rainforest ferns exhibit range discontinuities between West Africa and East Africa, apparently as a result of the climatic oscillations of the Pleistocene (Kornaś 1993). Eastern arc mountains exhibit high fern diversity compared with the outliers to the west (Cameroon Mountain, Fernando Po) southwards to the Natal Drakensberg in South Africa, frequently also in the mountains of Madagascar (Schelpe 1983). Fern species in Africa have not been used in biogeographic works that analyze distribution patterns of ferns and lycophytes. This is attributed to lack of studies focusing primarily on ferns as most of the biogeographical work from Africa focuses on higher plants.

7.2 Distribution of *Pteris* species in relation to major African phytochorological regions

Pteris has globally distribution mainly in Africa, Asia, and America, an expected scenario considering its rich species diversity. Most of the species ranges from tropical, subtropical and warm temperate zones. In Africa, the genus is restricted to tropics and subtropics of South Africa. The distributions of individual species are scarce, as ferns are under studied in many of the African countries Kenya included, except in South Africa where there are active pteridologists and nature enthusiastists working on ferns as evidenced in the most recently published book Crouch *et al.* 2011. In general, ferns are more strongly associated with mesic and warmer habitats than seed plants (Parris 1985; Given 1993) and hence they occur abundantly in the tropical regions. The greater dispersability of ferns can be in part demonstrated by low fern endemicity. The share of endemics in ferns is incomparably smaller among them than among the angiosperms (Kornas 1993).

Kenya has only three endemic ferns compared to 420 species of flowering plants (LEAP 2011). In Kenya, only one species of *Pteris* is endemic i.e. *Pteris albersii* subsp. *uaraguessensis* Verdc. Its closest subspecies relatives are in Tanzania where they are also endemic i.e. *P. albersii* subsp. *albersii* and subsp. *mufindiensis*. Tanzania shows the highest endemism of ferns in continental Africa with four species of *Pteris* been endemic. Kornas (1993) discovered that local centers of ferns endemism are located exactly in the same areas known as centers of endemism. There is no better way of presenting biogeography of ferns rather than using the phytochoria developed by fathers of African ecology. The regions considered in this study includes those recognized by White (1983) and later modified by Clarke (1998) as regional centre of endemism in Africa (Fig. 15).

7.3 Methodology

The phytogeography of *Pteris* was investigated by using label data from the herbarium specimens and extensive literature research. The distribution data gathered was also coded and incorporated in the phenetic analysis (Table 3). This was done to find out if the distribution ranges of *Pteris* show any adaption and correlation with the defined climatic regimes of Africa phytochoria. The reference phytochoria used are as described by White (1983) and modified by Carke (2001).

This study focuses on *Pteris* species occurring in nine phytochoria and regional centre of endemism (Fig. 15) with an objective of analyzing distribution pattern of *Pteris* in tropical Africa.

i. Guineo-Congolian region

This region covers 2,800,000 Km² and runs parallel north and south of the equator extending from the Atlantic coast eastwards through Congo Basin to the western shores of Lake Kivu. Lower and Upper Guinea forms subcentres of endemism within this region separated by the dry 'Dahomey gap'. This region has a low elevation of less than 1000 m with an annual precipitation of between 1600 and 2000 mm. More than 3000 mm of rainfall per year is received in coastal belt from Guinea republic to Liberia and a narrow coastal region of Cameroon adjacent to the Gulf of Biafra (White 1983). The region has the highest endemic plants species of which 6,400 (53 %) of 12,000 total number of species are endemic (Clarke 1998).

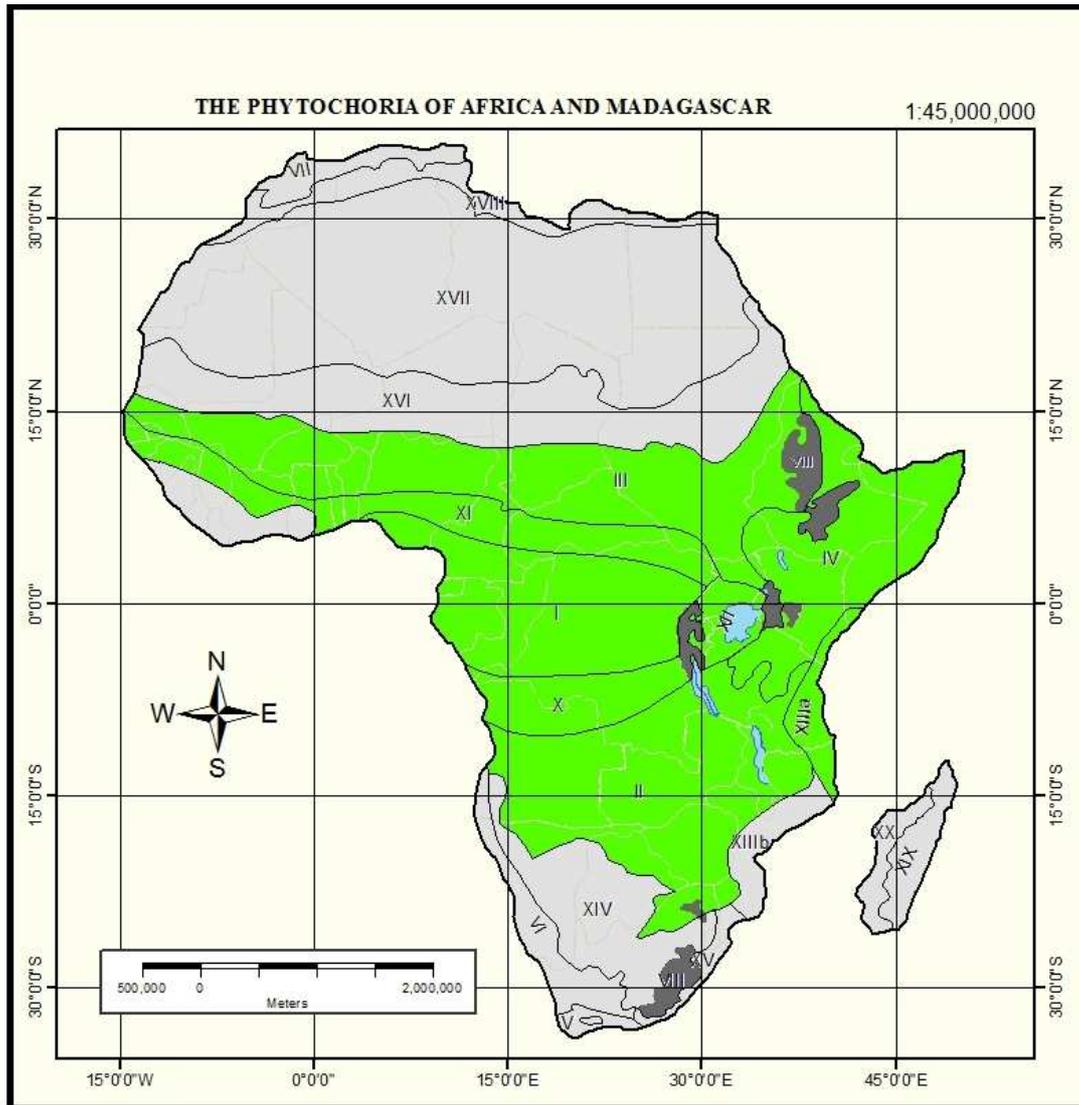


Figure 15. The major phytochoria of Africa and Madagascar

Redrawn after White 1983 and Clarke 1998. Note: Colored (green) areas indicate phytochoria considered in this study.

I. Guineo-Congolian regional centre of endemism. II. Zambezian regional centre of endemism. III. Sudanian regional centre of endemism. IV. Somalia-Masai regional centre of endemism. V. Cape regional centre of endemism. VI. Karoo-Namib regional centre of endemism. VII. Mediterranean regional centre of endemism. VIII. Afromontane archipelago-like regional centre of endemism, including IX, Afroalpine archipelago-like regional of extreme floristic impoverishment (not shown separately). X. Guineo-Congolian/Zambezia regional transition zone. XI. Guineo-Congolian/Sudania regional transition zone. XII. Lake Victoria regional mosaic. XIIIa. Swahilian regional centre of endemism. XIIIb. Swahilian/Maputaland regional transition zone. XIV. Kalahari-Highveld regional transition zone. XV. Maputaland-Pondoland regional mosaic. XVI. Sahel regional transition zone. XVII. Sahara regional transition zone. XVIII. Mediterranean/Sahara

regional transition zone. XIX. East Malagasy regional centre of endemism. XX. West Malagasy regional centre of endemism.

The vegetation here ranges from wet and dry rain forest, transitional rain forests, swamps, and glades. This region has 18 species of *Pteris* namely; *P. atrovirens* Willd., *P. auquieri* Pic. Serm., *P. burtonii* Bak., *P. catoptera* Kunze, *P. camerooniana* Kuhn, *P. cretica* L., *P. commutata* Kuhn, *P. dentata* Forssk., *P. intricata* C. H. Wright, *P. linearis* Poir., *P. hamulosa* (Christ) Christ., *P. mildbraedii* Hieron., *P. preussii* Hieron., *P. pteridioides* (Hook) Ballard, *P. similis* Kuhn, *P. tripartita* Sw., *P. vittata* L. and *P. kivuensis* C.Chr.

ii. The Zambezian region

This region extends from 3°S to 26°S from the Atlantic Ocean almost to the Indian Ocean. It includes whole of Zimbabwe, Malawi and Zambia, large parts of Tanzania, Angola and Mozambique and some small parts of Congo, Namibia, Botswana and South Africa. Most of this region which covers 3,770,000 km², lies above 900 m in elevation, rising in some areas to over 2500 m which support Afromontane communities. There are 8,500 plant species recorded from this area of which 4,590 (54 %) are endemic (Clarke 1998.). Single rain season occur with annual precipitation of between 500 and 1400 mm. This region has 17 species of *Pteris* which include; *P. albersii* Hieron. subsp. *mufindiensis*, *P. atrovirens*, *P. auquieri*, *P. buchananii* Baker ex Sim, *P. catoptera*, *P. cretica*, *P. dentata*, *P. hamulosa*, *P. intricata*, *P. linearis*, *P. mildbraedii*, *P. pteridioides*, *P. tripartita*, *P. preussii* Hieron. *P. similis*, *P. usambarensis* Hieron. and *P. vittata*.

iii. The Sudanian region

This region extends as a narrow band across Africa from the coast of Senegal to the foothills of the Ethiopian highlands (White 1983). It covers 3 731 00 km² and narrows in the west and broadens in the east with high temperatures and severe dry season. This region is highly impoverished in terms of flora with a mere 2 750 species of which 960 are endemic. *Pteris* species recorded from this region includes *P. atrovirens*, *P. commutata*, *P. similis*, *P. camerooniana*, *P. dentata*, *P. catoptera*, *P. preussii*, *P. pteridioides*, and *P. vittata*.

iv. **Somalia-Masai region**

This region occupies a large part of African mainland between 16⁰N and 9⁰S and 34⁰E and 51⁰E and the island of Socotra. It includes Eastern and Southern Ethiopia excluding the mountains, south-east Sudan, north-east Uganda (Karamoja), most of Kenya between the highlands and the coastal belt, dry lowlands of central and north Tanzania south to the Great Ruaha River valley. The area covers about 1 873 000 km² with most of the land being below 900 m descending to sea level in the north-east. The vegetation is mainly deciduous bushland and thicket covering greater part of this region. There are about 2500 species of which half are probably endemic (White 1983). *Pteris* species found in this region include *P. atrovirens*, *P. albersii* subsp. *albersii*, *P. albersii* subsp. *uaraguessensis*, *P. buchmanii*, *P. cretica*, *P. catoptera*, *P. dentata*, *P. preussii*, *P. pteridioides*, *P. mkomaziensis* Verdc. *P. usambarensis*, and *P. vittata*.

v. **Afromontane region**

This region is an archipelago-like centre of endemism extending from the Loma Mts and Tingi Hills (11⁰W) in Sierra Leone to the Ahl Mescat Mts (49⁰E) in Somalia in the east and from the Red sea Hills (17⁰N) in the Sudan Republic to the Cape Peninsula (34⁰S) covering an area of 715 000 km². In the tropics Afromontane communities are found above 2000 m though some species descend almost to sea-level. Mean annual rainfall is more than 1000 mm with at least 4000 species of which about 3000 are endemic or almost so (White 1983). *Pteris* species of this region includes; *P. bavażzanoi*, *P. buchmanii*, *P. catoptera*, *P. cretica*, *P. dentata*, *P. intricata*, *P. microlepis* Pic. Serm., *P. pteridioides*, and *P. preussii*.

vi. **The Guinea-Congolian / Zambezia Regional Transition zone**

This region separates the Guineo-Congolian and Zambebian regions and extends from the Atlantic Ocean to the high grounds surrounding northern side of Lake Tanganyika. Its maximum width is 500 km and covers an area of 705 000 km². The climate is intermediate between those of the Guineo-Congolian and Zambebian regions. The rainfall diminishes rapidly towards the Atlantic Coast to below 800 mm per year. There are about 2000 species with few endemics. *Pteris* species of this region include *P. catoptera*, *P. cretica*, and *P. dentata*.

vii. The Guinea-Congolian/Sudania regional transition zone

This transition zone which separates the Guineo-Congolian and the Sudanian regions, extends across Africa from Senegal to western Uganda and covers 1 165 000 km². Between eastern Ghana and Benin republic it reaches the coast, where the Dahomay gap separates the Guineo-Congolian rain forests into western and eastern blocks. Generally altitude is less than 750 m with some land reaching 1000 m in Guinea Highlands. There are fewer than 2000 species nearly all of which are Guineo-Congolian or Sudanian wides. *Pteris* species of this area are *P. camerooniana*, *P. hamulosa*, *P. preussii*, *P. similis*, and *P. vittata*.

viii. The Lake Victoria regional Mosaic

The region include most of Uganda, the whole of eastern Rwanda and Burundi, small parts of Zaire, Kenya, and Tanzania. Precipitation is 1500-2000 mm per year and well distributed throughout the year. There are more than 3000 species with very few endemic. Majority of the species are widespread in the Guineo-Congolian region. The region is the meeting-place of five distinct floras: Guineo-Congolian, Sudanian, Zambezian, Somalia-Masai and Afromontane. Several *Pteris* species occur in this region including *P. auquieri*, *P. buchananii*, *P. burtonii*, *P. catoptera*, *P. commutata*, *P. cretica*, *P. dentata*, *P. hamulosa*, *P. intricata*, *P. kivuensis*, *P. linearis*, *P. multifida* Poir, *P. mildbraedii*, *P. microlepis*, *P. preussii*, *P. pteridioides*, *P. similis*, *P. tripartita*, and *P. vittata*.

ix. Swahilian regional centre of endemism

This region was defined by Clarke (1998) after it was curved from the northern part of what used to be White's Zanzibar-Inhambane region centre of endemism of White (1983). The region occupies a coastal belt from Southern Somalia to the northern coast of Mozambique and covers 250 000 km². There are 4000 vascular endemic plant species, of which an estimated 1200 species are endemic. Most of the land lies below 200 m but there are scattered hills and plateau rising to high grounds such as Simba Hill in Kenya, the Pugu Hills and Rondo plateau in Tanzania and the Macondes plateau in northern Mozambique. Annual precipitation is 800 and 1200 mm with a well-defined dry season. Rainfall is comparable in amount to that of Zambezian Region, but the dry season is less severe since relative humidity is high and no month is absolutely dry (White 1983). *Pteris* species found in this region are *P. atrovirens*, *P. hamulosa*, *P. similis*, *P. tripartita*, *P. usambarensis*, and *P. vittata*.

7.4 Results

Distribution of *Pteris* species richness in different regions discussed above were summarized in Fig. 16. The distribution maps of individual species of *Pteris* are presented in Appendix I.

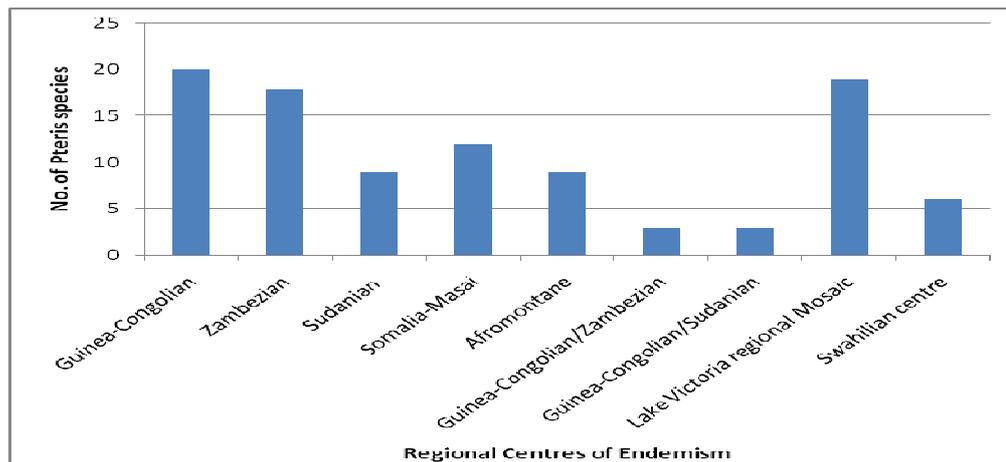


Figure 16. *Pteris* richness in different phytochoria studied

Some *Pteris* species e.g. *P. preussii* form the easternmost boundary of the Guineo-Congolian species in Kakamega forest while *P. kivuensis* has a narrow distribution ranging from eastern Congo to western Uganda. During the study *Pteris burtonii* which previously had its eastern most boundary in Uganda was found in Kakamega forest with no other record of its occurrence in Kenya. *Pteris commutata* has limited distribution extending from Guineo-Congolian to Guineo-Congolian /Sudania regional transition zone and having its range end in Lake Victoria regional mosaic. *Pteris camerooniana* is the only endemic species of this region known only from Cameroon. Ranges of ferns are usually determined by habitat availability than by their generally high, dispersal capability (Tryon 1986; 1970; Smith 1972; Smith 1993; Guo *et al.* 2003; Tuomisto *et al.* 2003). Spores without chlorophyll may survive for months to years (Lloyd and Klekowski 1970; Tryon 1970; Wolf *et al.* 2001; Mehltreter 2010). This is an advantage for long-distance dispersal as these species are not constrained to rapid acquisition of a suitable site (Wolf *et al.* 2001).

Lake Victoria regional mosaic was the second species rich region with 19 species. *Pteris microlepis* and *P. multifida* were the only species endemic to this region. More than half of

the species found in Lake Victoria region were common in Guineo-Congolian region. Zambezian region had 18 species with *Pteris albersii* subsp. *mufindiensis* being a Tanzanian and Zambezian endemic. Most of the species of Somalia-Masai regional centre of endemism extend their ranges into Zambezian region. Some of them e.g. *Pteris atrovirens*, *P. auquieri*, *P. linearis*, *P. mildbraedii*, *P. similis*, and *P. usambarensis* form the southernmost boundary in this region. Somalia-Masai region, very expansive but mainly covering drylands and savannas had 12 species of *Pteris* of which three were endemic. These were *P. albersii* subsp. *albersii*, *P. albersii* subsp. *uaraguessensis* and *Pteris mkomanziensis*. The region is characterized by low precipitation, low relative humidity, absence of diverse habitats suitable for establishment of ferns and reduced forest cover.

Afromontane and Sudanian regions each had nine *Pteris* species. Two species i.e. *Pteris bavaezanoii* and *P. microlepis* are strictly high altitude species occurring only in mountains, with a minimal altitude of 2100 m above sea level. Swahilian region is the smallest region and had six *Pteris* species. There were no endemic except *Pteris usambarensis* which is near endemic restricted only in eastern Arc mountains of Taita hills and Usambaras. The Guinea-Congolian/Zambezia Regional Transition zone and Guinea-Congolian/Sudania regional transition zone were the most depauperate in species richness having three and five species respectively. Both regions are dry throughout the year with low precipitation.

7.5 Discussions and Conclusion

Pteris species are diverse and occupy different ecological niches. They occur in high numbers at higher elevations and in areas with high rainfall. Guinea-Congolian region is the most species-rich region with 20 species out of 25 species known to occur in the whole study region. This region has extensive rainforests receiving high amount of rainfall throughout the year. The presence of heterogeneous habitats and microclimate found in the different forests types from Senegal through Congo basin to Lake Kivu often offer ideal sites for establishment and growth of fern species. From the analysis, the main dispersal route for most of the *Pteris* species follow West African route. These species are dispersed to Central Africa and then to east African forests either to the afromontane forests such as Mt. Kenya, Aberdares, Kilimanjaro, Ruwenzori or to the lowland rain forests of Kakamega and Budongo. *Pteris* species of the Guineo-Congolian extend to other

regions mainly, Lake Victoria basin, Zambebian and Afromontane regions. In these regions several *Pteris* species often exist together but maintain their distinctiveness. Such co-existence is a reflection of a common evolutionary history and shared requirements.

Pteris usambarensis and *P. albersii* subsp. *albersii* are restricted to eastern Arc Mountains. These show niche specializations where the species occur abundantly in a particular habitat and are completely absent in another. *Pteris usambarensis* is the dominant *Pteris* species in Mbololo forest of Taita Hills forming a dense herbeaceous cover. *Pteris tripartita* and *P. atrovirens* show disjunct distribution occurring in west African rainforest all through to central and east African with their easternmost distribution boundary recorded at the eastern Arc mountains of Tanzania and Kenya. The most widespread species are *Pteris catoptera* and *P. dentata*, they occur in virtually all habitat types with certain degree of moisture and shade. Most of the common species of the genus *Pteris* are eurythermal and usually do not exceed their respective thresholds to a large extent e.g. *P. cretica* (East Africa 1490- 2680 m), *P. dentata* (East Africa 1000-3000 m) and *P. catoptera* (Kenya 990-3050 m), the latter two reaching the bamboo zone. *P. microlepis*, a rare relative of *P. preussii* group and probably derived as a high altitude adaptation from them, grows in Rwanda's Parc National des Volcanics at 2900 m in bamboo forest (Jacobsen and Jacobsen 1989).

Pteris mkomaziensis, *P. albersii* (all subspecies) and *P. microlepis* exhibits narrow and restricted patterns in their distribution. This may be due to specialized microclimatic requirements and probably due to competition from other species that constrained their establishments. As evidenced in this analysis it is important that distributional data of ferns be incorporated with that of vascular plants while studying diversification processes of land plants. It was observed that areas/regions with high angiosperm diversity (biodiversity hotspot) correspond to regions where high *Pteris* diversity.

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Online resources frequently accessed

- BIOTA Africa; <http://www.biota-africa.org/>
- JSTOR Plant Science; <http://www.aluka.org/>; <http://plants.jstor.org/>
- IPNI (International Plant Names Index); <http://www.ipni.org/>
- The Plantlist; <http://www.theplantlist.org/>
- Tropicos by Missouri Botanic Garden, USA; <http://www.tropicos.org/>
- Encyclopedia of life; <http://www.eol.org/>

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Koblenz-Landau University - GERMANY

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1993 - 1996 Bachelor of Science in Botany and Zoology

Jomo Kenyatta University of Agriculture and Technology(JKUAT)-Kenya

Grade: Second Class Honours, Upper Division

1988-1991 Karima Girls High School

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Employment History

Employer: National Museums of Kenya (NMK), Nairobi

Department: Botany: Section: Herbarium

Position: Research scientist; Section Head: Education and Training

2003 to date: Research Scientist with administrative responsibilities, proposal development, resource mobilization and implementation, and dissemination of scientific information to the public. My main responsibility is to research on ferns and lycophytes of tropical Africa and train two technicians to assist with fern research. Currently doing taxonomic revision of the genus *Pteris* of tropical Africa.

Responsible for curation of pteridophytes at East African herbarium (EA).

1999-2003: Research assistant – A training position in which I acquired skills on research protocols, proposals development, technical skills on plants collection, identification and preservation.

Professional Qualifications

- Trained as a fern taxonomist under a PhD programme with a special focus on ferns and lycophytes of tropical Africa
- Professionally working on systematics, biodiversity assessment, ecology and phytogeographical affinities of ferns in tropical Africa
- Successfully carried out ecological surveys in diverse ecosystems to document and map ferns species e.g. tropical rainforests of Kakamega (Kenya) and Budongo (Uganda), Taita Hills, Mt. Kenya, Aberdares, Tinderet and Nandi Hills forests. An annotated checklists for the above ecosystems produced and a field guide on ferns of Kakamega forest in preparation
- Contributed data on conservation assessment for most of the Kenyan ferns for the purposes of Red Listing process
- Compiling a profile of flagship ferns species with a comprehensive database comprising of maps and ferns images from tropical Africa
- A PhD dissertation on systematic and ecology of ferns in Kakamega and Budongo (Uganda) forests

Publications

Kamau, P. (2012). Systematic revision of *Pteris* L. (Pteridaceae) in tropical Africa and ecology of ferns in lowland rain forests. PhD dissertation, Koblenz-Landau University, Germany.

Kamau, P. (2012). A field guide to the ferns and lycophytes of Kakamega forest (Kenya). (Draft).

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Kamau, P. (2010). A rapid appraisal of ferns of Mts. Kenya and Aberdares. National Museums of Kenya. ®

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Kamau, P. (2007). Network on Medicinal Plants and Traditional Medicine. Final Project Report, IDRC. ®

Kamau, P., Mathenge, J., and Kimini, CNT (2007). Sandalwood: Its Potential for products development. Proceedings of the 5th Research Programme on Sustainable Use of Dryland Biodiversity (RPSUD) workshop, Arusha, Tanzania.

Kamau P. (2006). Exploitation of East African Sandalwood (*Osyris lanceolata*) in drylands of Kenya. The Drylander, RPSUD

Kamau, P., Kimini, CNT and Mathege, J. (2005). Preliminary survey on the unsustainable exploitation and distribution of East African Sandalwood (*Osyris lanceolata*) in Southern Kajiado district. ®

Kamau, P. (2004). Forage diversity in Kenyan rangeland ecosystem; Case of Mbeere District. Lucid, Paper No. 32

Selected workshops, symposia and training attended

- Workshop on Role of Botanicals in Agricultural Product Value Chain (APVC) analysis, Kenya Agricultural Research Institute, Nairobi, June 2011.
- Workshop on Management of Ol Donyo Sabuk ecosystem, Kenya Wildlife Service, Thika, June 2011.
- Training on Outcome Mapping, National Museums of Kenya, March 2011
- Training in use of LUCID Keys, April 2011
- Symposium on Asian Pteridology, FairyLake Botanic Garden, Shenzhen, China, November 2010.
- Regional Training workshop on IUCN Red Listing, JRS Project, Nairobi, February 2009 and April 2012.

Fellowships

2011: Shirley A. Graham fellowship in Systematic Botany and Biogeography at Missouri Botanic Garden.

Membership in Professional Societies

- American Fern Society (AFS)
- British Pteridological Society (BPS)
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APPENDICES

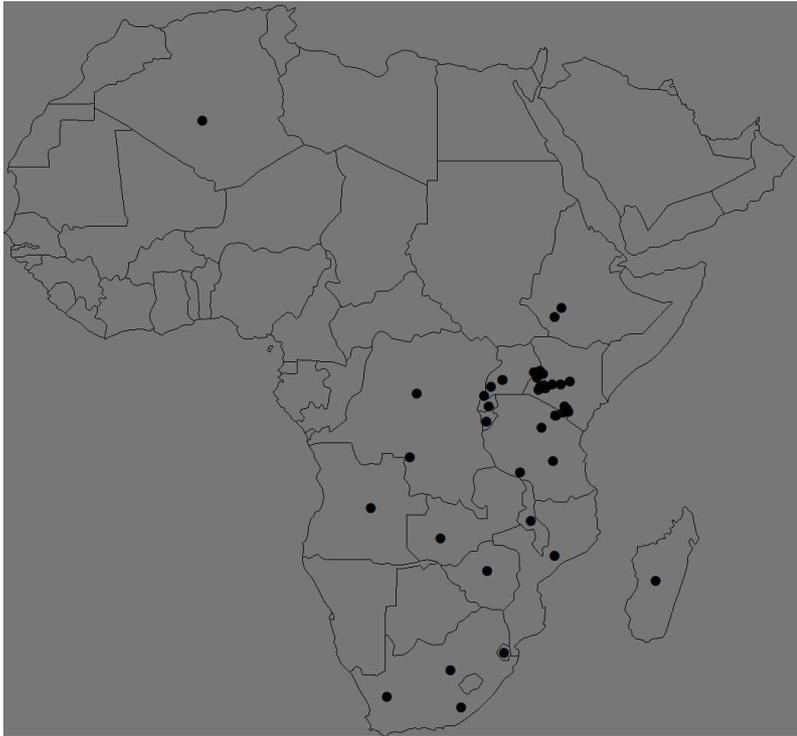
Appendix I. Distribution maps of *Pteris* species in tropical Africa



1. *Pteris vittata*



2. *Pteris multifida*



3. *Pteris cretica*



4. *Pteris camerooniana*



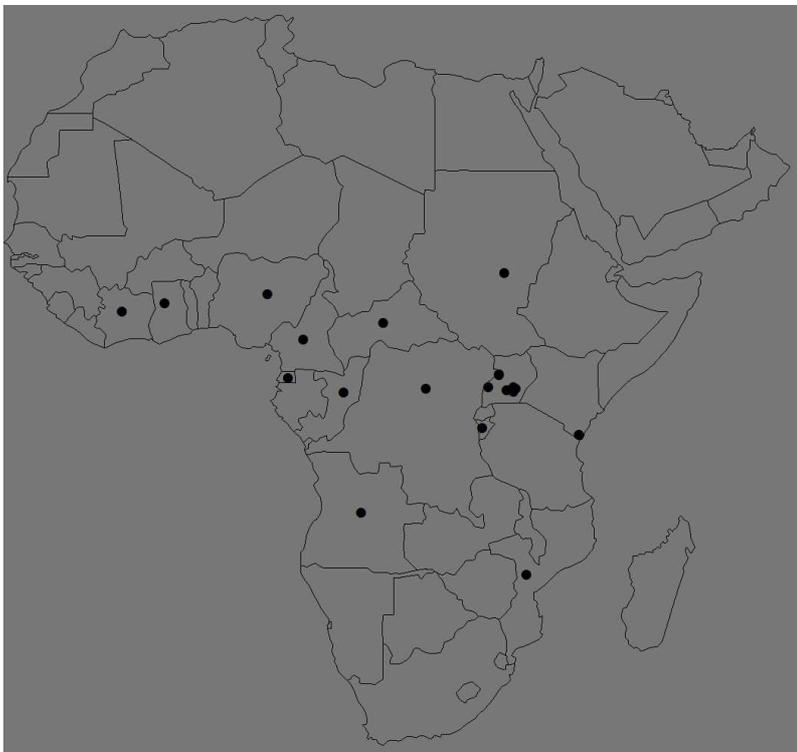
5. *Pteris commutata*



6. *Pteris atrovirens*



7. *Pteris similis*



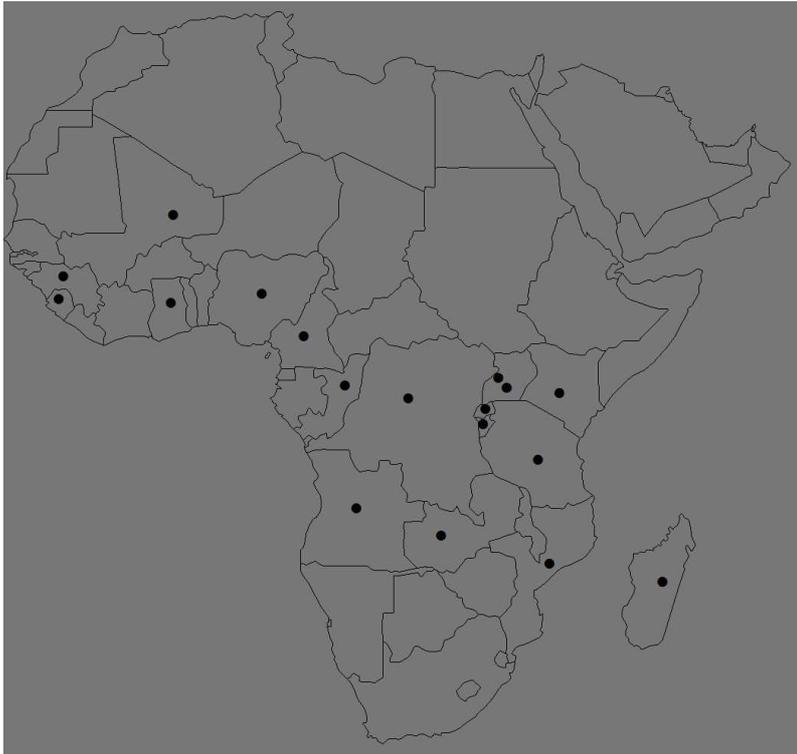
8. *Pteris hamulosa*



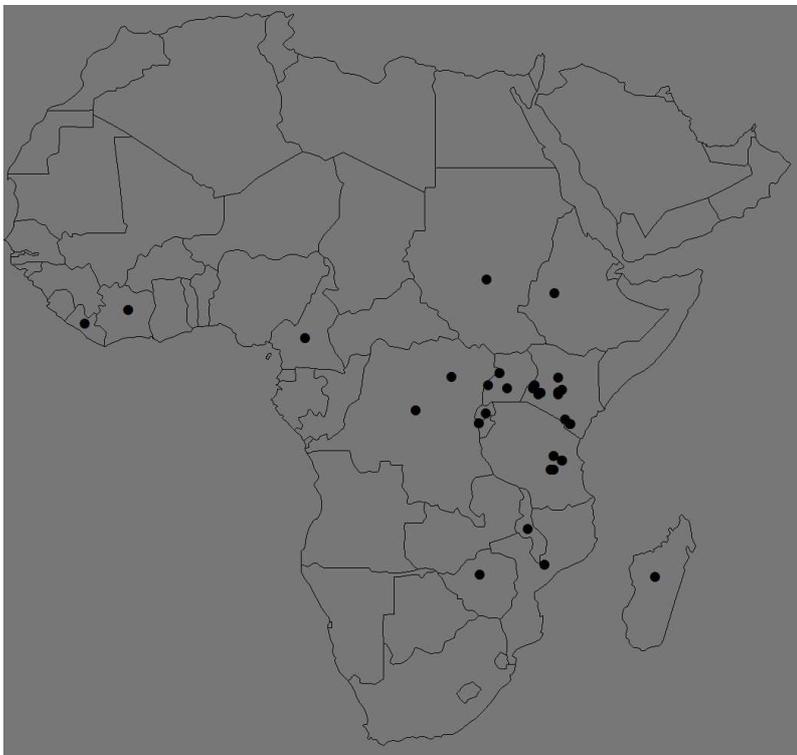
9. *Pteris mildbraedii*



10. *Pteris auquieri*



13. *Pteris intricata*



14. *Pteris pteridioides*



15. *Pteris bavazzanoi*



16. *Pteris kivuensis*



17. *Pteris usambarensis*



18. *Pteris mkomaziensis*



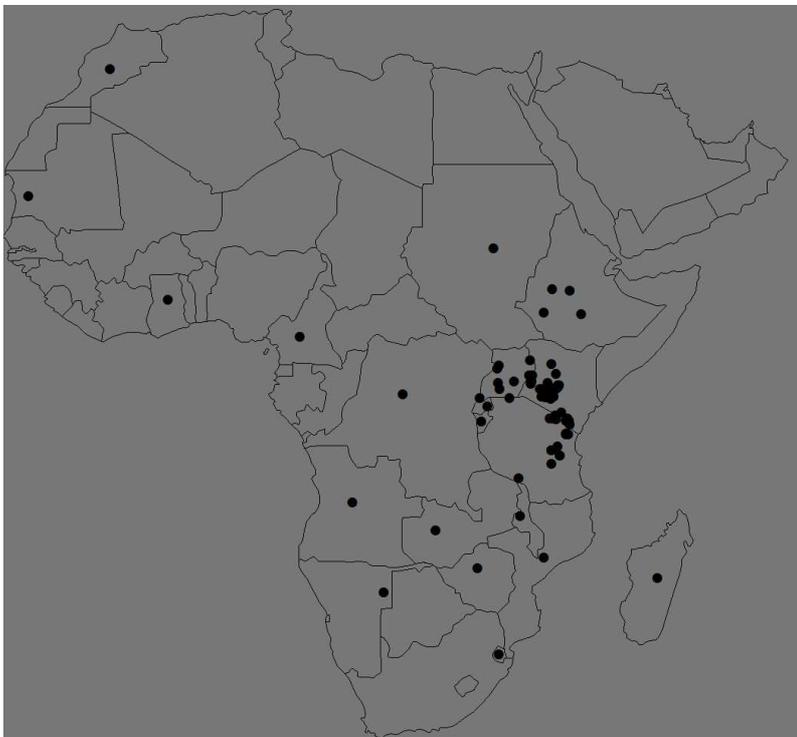
19. *Pteris albersii*
i. subsp. *albersii*



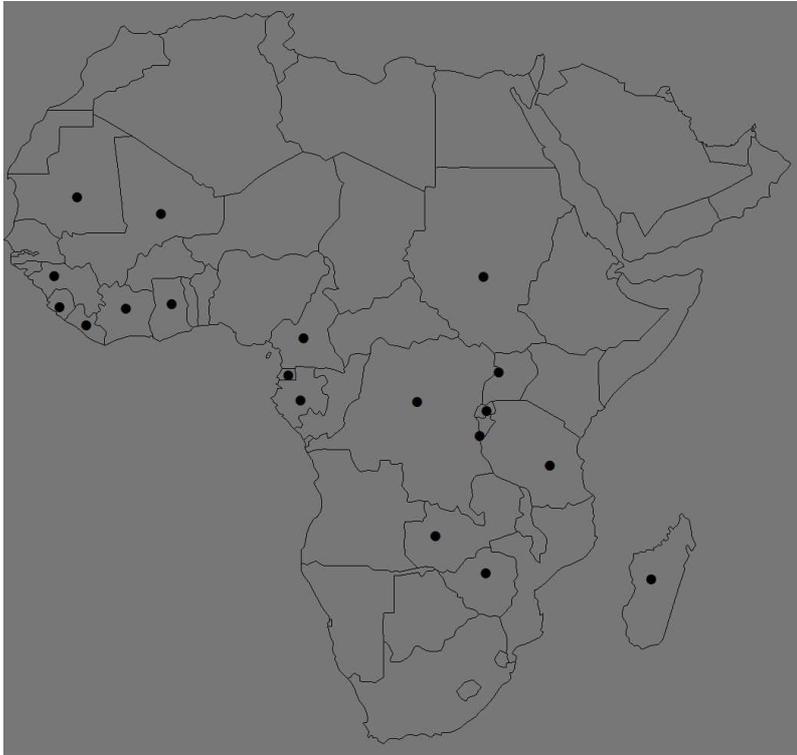
Pteris albersii
ii. subsp. *uaraguessensis*



Pteris albersii
iii. subsp. *mufindiensis*



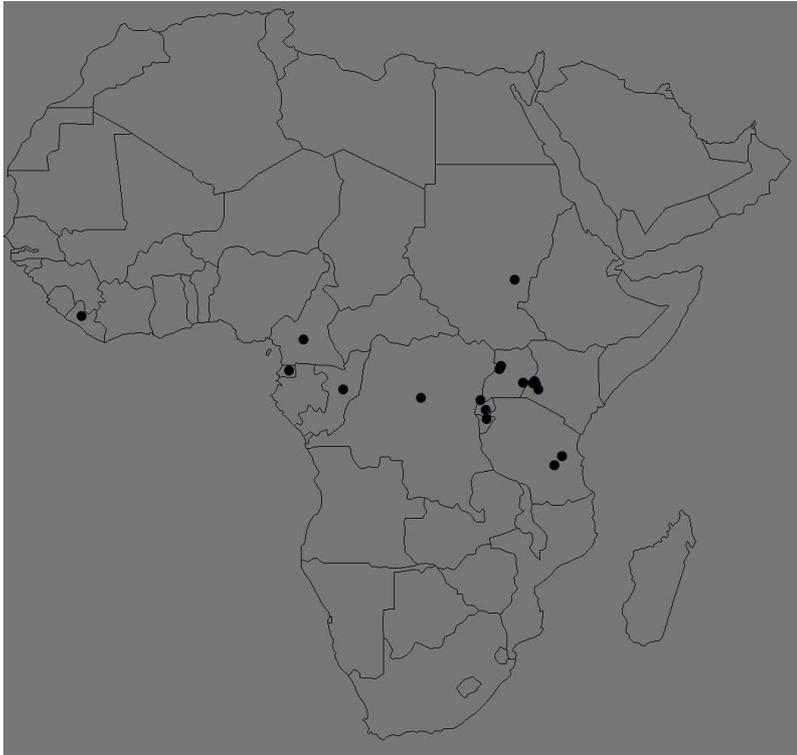
20. *Pteris dentata*



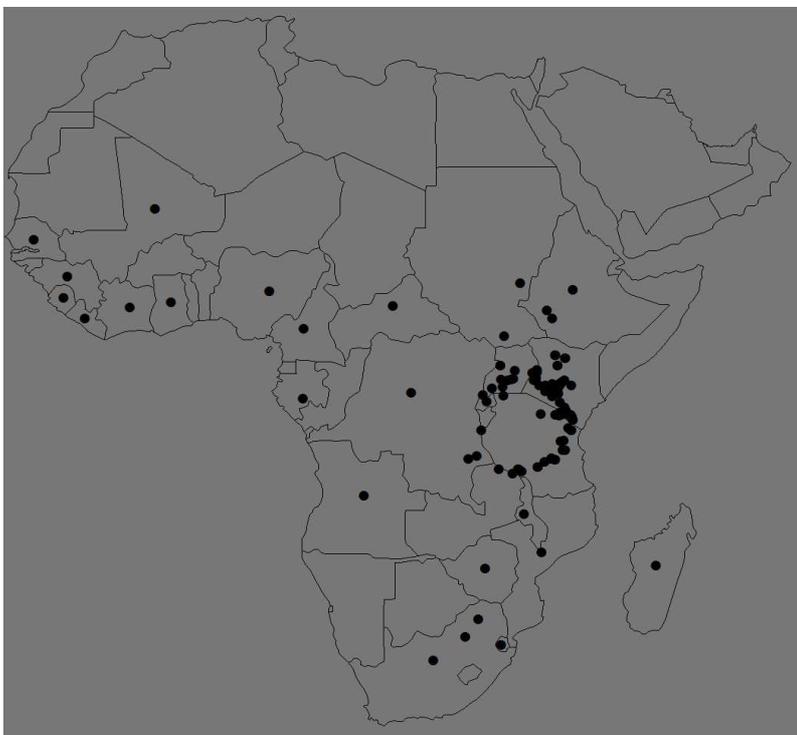
21. *Pteris linearis*



22. *Pteris microlepis*



23. *Pteris preussii*



25. *Pteris catoptera*