DIVERSITY AND DISTRIBUTION OF THE AFROALPINE FLORA OF EASTERN AFRICA WITH SPECIAL REFERENCE TO THE TAXONOMY OF THE GENUS *PENTASCHISTIS* (POACEAE)

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University or any other award.

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DEDICATION

To AL–MIGHTY ALLAH whose **Glory and Power** sustains the great diversity of life and the Universe!

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ABSTRACT

The African tropic−alpine system, consists of a number of geographically separated ‘sky−islands’ and constitutes an excellent system in which to investigate the interaction between the geographical and ecological components of differentiation. The mountain systems harbouring the Afroalpine zone act as giant water towers that are source of almost all rivers that are an important source of water for domestic, industrial and agricultural use. Due to inaccessibility caused by extreme isolation and harsh conditions little research has been done on the diversity, species richness and evenness among other aspects in the Afroalpine zone. For effective conservation of these important zones it is important to understand their ecology. and the conservation status of the species of these zones. The aim of this study was to carry out ecological analysis of Afroalpine species in general and addresses species delimitation in the genus *Pentaschistis*. The vegetation of Afroalpine zone of Mount Kenya, Elgon, Kilimanjaro, Ruwenzori, Bale and Simen were sampled for ecological analysis and taxonomic revision of the genus *Pentaschistis*. A total of 75 plots (100 × 100 m) from five vegetation types were analysed using both univariate and multivariate analyses. From the study a total of 46 families, 124 genera and 278 species were recorded from rock outcrops, bogs, grassland, *Dendrosenecio* forest/woodland and *Alchemilla* vegetation communities. Six families, namely Asteraceae, Poaceae, Caryophyllaceae, Lamiaceae, Cyperaceae and Rosaceae constitute 56% of all the species sampled. Five communities were described from the vegetation types studied: *Carex−Deschampsia* bogs, *Festuca−Pentaschistis* grassland communities, *Dendrosenecio−Alchemilla* forest/woodland, *Alchemilla* communities and *Helichrysum−Festuca−Koeleria−Pentaschistis* rock outcrop communities. The species richness and diversity is higher in older mountains such as Mt. Simen, Bale and Elgon (over 20 MYBP) compared to younger mountains such as Mt. Kenya (3.5 MYBP), Kilimanjaro and Rwenzori (less than 3 MYBP) mountains. Similarly Ethiopian Mountains were more species rich and have higher diversity than mountains of East Africa. Simen was the most species rich as well as exhibiting highest species diversity while Rwenzori was the most species poor and with the least species diversity. The East Africa Mountains were similar both in their species composition and community structure, as were the Ethiopian Mountains. Factors such as the geographical distance, age, geological history, and position of the mountains along the Rift Valley, climatic and edaphic factors are thought to be responsible for the observed patterns. The five vegetation communities were recognizable from each other though rock outcrop and grassland communities were barely separable ($R< 0.25$). The rest of the vegetation communities were overlapping but separable especially between bogs vs. *Dendrosenecio* ($R > 0.5$). The mainly southern African grass genus *Pentaschistis* was represented on all Afro−alpine mountain systems but due to the complex ecological and geographical variation patterns, the number of species recognized is widely disputed. A classification based on a well–supported evolutionary hypothesis for the genus is necessary. In order to obtain this, morphological studies of both natural populations and herbarium specimens have been conducted during this study. A total of 38 characters were used to carry out phenetic analysis of 37 specimens from nine taxa. The results from morphological observation as well as the cluster and principal component analysis produced two main groupings viz. (1) the two widely distributed species *P. borussica* and the *P. pictigluma* species complex, and (2) two narrow endemics *P. dolichochaeta* and *P. chrysurus*. Similarly, phylogenetic analysis of three gene regions (TrnL-F, rpL-16 and ITS) based on 83 sequences were done in this study to infer the phylogeographic history of this genus. The results from this study indicate two independent events of colonization each corresponding roughly to the two broadly distributed species and the two narrow endemics. The morphological, phenetic and phylogenetic analysis of this study support the current taxonomic classification of the tropical species of the genus *Pentaschistis*.

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DEFINITION OF TERMS

Abiotic: refers to the non−living components of an ecosystem, such as water, air, soil etc.

Abundance: The number of organisms in a population that show degree of density (within inhabited areas) and prevalence.

Acaulescent: With no stem or reduced stem

Afroalpine: Vegetation communities occurring above the treeline in high tropical African Mountains and dominated by relatively sparse low growing vegetation with characteristic life forms such as tussock grasses, acaulescent herbs and rosette perennials.

Afromontane: the vegetation zone below ericaceous belt dominated by tropical moist forest in African Mountains and highlands.

Alpha diversity: The number of species recorded within some standardized area e.g. a square kilimetre or some naturally delineated patch of habitat such as grassland, bog, a patch of forest etc.

Anemochory: Passive dispersal of propagules by wind.

Anthropogenic: Actions or factors attributed to humans or human induced effects.

Archipelago: A group of islands often scattered in expansive water e.g. Lamu archipelago

Arctic: Pertaining to all non−forested areas north of the coniferous forests of the Northern Hemisphere.

Beta diversity: The dissimilarity or turnover in species composition between local ecological communities.

Biotic: pertaining to the living components of an ecosystem (from the simplest to the most complex organisms).

Biogeography: The science that attempts to document and understand spatial and temporal distribution of organisms. Modern biogeography now includes studies of all patterns of geographic variation in life, from genes to entire communities and ecosystems.

Boreal: occurring in the temperate and sub–temperate zones of the Northern Hemisphere that typically contains coniferous forests and some forms of deciduous forests.

Caldera: is a cauldron-like volcanic feature usually formed by the collapse of land following a volcanic eruption. They are sometimes confused with volcanic craters. The word comes from Spanish *caldera*, and this from Latin *caldaria*, meaning "cooking pot" (Wikipedia encyclopedia).

Circumboreal: occurring in the temperate/sub temperate zones of the New and Old World parts of the Northern Hemisphere.

Clade: Any monophyletic evolutionary branch in a phylogeny, using derived characters to support genealogical relationships.

Cladogram: A line diagram derived from a cladistic analysis showing the hypothesized branching sequence of a monophyletic taxon.

Colonization: The immigration of a species into new habitat followed by successful establishment of a population.

Community: An assemblage of organisms that live in a particular habitat and interact with one another.

Diaspore: Any part or stage in the life cycle of an organism that is adapted for dispersal.

Dispersal: The movement of organisms away from their point of origin.

Ecosystem: The set of biotic and abiotic components in a given environment.

Ecology: The study of the abundance and distribution of organisms and of the relationships between organisms and their biotic and abiotic environments.

Edaphic: pertaining to soil.

Endemic: Pertaining to a taxon that is restricted to the geographic area specified e.g. a continent, a mountain, lake, island etc.

Evolution: Any irreversible change in the genetic composition of a population.

Extinct: No longer living, opposite of extant.

Gene: The small unit of a DNA molecule that codes for a specific protein to produce on of the chemical, physiological, or structural attributes of an organism.

Habitat: Place where a microorganism, plant or animal lives.

Habitat diversity: The range of habitats present in a region.

Heterogeneity: The state of being mixed in composition, as in genetic or environmental heterogeneity.

Immigration: Entry of organisms to a population from elsewhere.

In-group: The focal monophyletic group in a cladistic analysis.

Microclimate: The climate within a very small area or in a particular, often tightly defined, habitat.

Migration: The movement of individuals, and commonly whole populations from one region to another.

Miocene: A geological era lasting from approximately 25 to 5 million years ago.

Moorland is a type of habitat, in the temperate grasslands, savannas, and shrublands biome, found in upland areas, characterised by low-growing vegetation on acidic soils and heavy fog.

Oligocene a geological era in the middle of the Tertiary Period (and end of the Paleogene), from approximately 33.9 to 23 million years ago.

Orogeny: The process of mountain building resulting from the upward thrust of Earth's crust due to volcanic or tectonic activities.

Out-group: A taxon related to the in-group, used in a cladistic analysis to infer primitive and derived character states in a transformation series.

Pan tropical: Occurring in all major tropical areas around the world.

Phenetic: The study of the overall similarities of organisms.

Phylogeny: The evolutionary relationships between an ancestor and all its known descendants.

Phylogeography: An approach in biogeography that studies the geographic distributions of genealogical lineages, within species and among similar species, and attempts to differentiate between historical and ongoing processes leading to the development of observed patterns.

Pleistocene: A geological era lasting from approximately 2 million to 10 000 years ago.

Pliocene: A geological era lasting from approximately 5 to 2 million years ago.

Precambrian: The Precambrian period is that long stretch of geological time that starts from the formation of the Earth up to the beginning of the Cambrian – about 4.6 billion years ago.

Sister group: In a phylogeny, the group or clade most closely related to the focal group (in group), and therefore the most useful out-group for rooting the phylogeny.

Species diversity: An index of community diversity that takes into accounts both species richness and the relative abundance of species.

Species richness: The number of species present in a community.

Stochastic: Random, expected (statistically) by chance alone.

Sclerophyllous: Having tough, thick, evergreen leaves.

Scrubland: Any of a wide variety of vegetation types dominated by low shrubs; in exceedingly dry locations.

Taxon (plural: Taxa): A general term for any taxonomic category e.g. a species, genus, family etc.

Vicariants: two disjunct and phylogenetically related species that are assumed to have been created when the initial range of their ancestor was split by some historical event.

Xerophytes: Land plants that grow in relatively dry (“xeric”) environments.

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background Information

Any isolated habitat that is entirely separated from others of its kind can be considered as an island. For example, there are many mountains in the world surrounded by low−lying land. Just as oceanic islands are separated from one another by water, so mountain summits are separated by ‘seas’ of low−lying land. Hence, mountain species have to arrive on a mountain by some form of long−distance dispersal in much the same way as mainland species arriving on oceanic islands. Some of the most interesting isolated “sky−islands” occur in the mountains of the tropical regions where the upper zones are surrounded by montane forests or savanna. The mountains of Eastern African region are like a cluster of small “sky islands” and are mostly solitary volcanic mountains on or near the Equator surrounded by ‘sea’ of savanna or are formed by uplift e.g. Ruwenzori (Hedberg, 1970).

The high African mountains in the equatorial zone, including the unique afro-alpine ecosystem, act as major water towers and basically are essential for water supply and agriculture in many African countries. These include, but are not limited to, Kenya, Uganda, Tanzania, Burundi, Rwanda, and Ethiopia. The major mountain systems that serve as water towers include Bale, Simen, Choke, Gara Muleta (Ethiopia), Rwenzori, Virunga cluster of mountains (Uganda/Democratic Republic of Congo), Kilimanjaro, Meru (Tanzania), Aberdare ranges, Mt. Kenya and Elgon (Kenya) among others. Usually the vegetation of these mountains is divided into several distinct zones: the bamboo zone, afro-montane zone, the sub-alpine ericaceous zone and the afro-alpine zone. In three mountains, viz: Kilimanjaro, Kenya and Rwenzori, above the afroalpine zone occurs alpine desert and the mountains are clad with glittering ice caps or glaciers. The afro-alpine zone typically occurs above 3500 metres in most of the mountains and harbours unique and beautiful alpine grasslands, shrubs, and bogs and is home to many rare and endemic species. It has been shaped through a dramatic history of repeated climate changes and is ideal as a natural laboratory for the study of biodiversity dynamics. The above named mountains basically constituted the study area and greater description of the same is given in the subsequent sections.

Generally speaking biodiversity is the variation of living organisms within a defined area such as habitat, an ecosystem, biome, or for the entire Earth. The biodiversity occurring in it consists of millions of both distinct and cryptic biological species, which have evolved over a long geological period of time.

From biogeographic point of view, gradients of diversity for most organisms decrease from the Equator towards either side of the poles. This means majority of the species of organisms of all kind are concentrated along the Equator or generally around the tropics and sub−tropics. Similarly diversity along altitudinal gradient increases towards mid elevation where it reaches the peak before it gradually declines towards the mountain summit. Thus the mountain systems including those of Eastern African high mountains mimic the globe in the distribution patterns of plant and non− plant communities.

The importance of the surrounding biodiversity to man and other organisms is immense and nearly impossible to quantify since it provides essential functions and services that directly impact life on earth. Besides providing food, medicines, clothes, construction materials, dyes etc. they play direct roles in the regulation and composition of atmospheric gases, regulation of the global climate, generation and maintenance of soils and nutrient recycling.

Unfortunately anthropogenic activities including over-exploitation of species, spread of alien species to new environments, direct habitat destruction for domestic or industrial purposes, and pollution among others have caused huge losses of biodiversity and extinction of numerous species. Afroalpine species are particularly vulnerable since the impact of man's activities has been compounded by the impact of global warming. Hence detailed study of the Afroalpine species, their distribution, abundance, species richness and evenness will provide baseline information necessary to give mitigation measures for the conservation of this fragile ecosystem.

1.2 Eastern African Mountains

Mount Kenya is an extinct volcano about 3.5 million years old and straddles the Equator and is 175 km north−east of Nairobi (Kenya Wildlife Service− KWS, 1997). It covers an area of 715 km^2 and was gazetted as a National Park in 1949 transcending several administrative boundaries including Nyeri, Kirinyaga, Embu, Meru South and Meru Central districts. Its vegetation consists of bamboo forest, afromontane forest, sub−alpine ericaceous zone, Afroalpine habitats and is crowned by alpine deserts and the glittering twin peaks of Batian (5,199 m) and Nelion (5,188 m). It was declared as a World Heritage Site in 1997 for "one of the most impressive landscapes of Eastern Africa with its rugged glacier−clad summits, Afroalpine moorlands and diverse forests which illustrate outstanding ecological processes" (KWS, 1997).

The Aberdare Mountain, which is a national park, is an isolated range that forms the eastern wall of the rift valley running north to south over a distance of more than 100 km (KWS, 1997). It covers an area of 767 km^2 and includes as part of the administrative boundaries of the districts of Nyeri, Muranga, Thika, Gatundu, Laikipia West and Nyandarua. There are two main peaks, Oldoinyo Le Satima, which is the highest peak (4,001 m), and Kinangop peak (3,900), separated by a long saddle of alpine moorland that ranges over 3,000 m (KWS, 1997).

Mount Elgon is a 24 million year old extinct volcano that has eroded over time showing an expansive caldera and is located 470 km North West of Nairobi, in the Tranzoia District of the Rift Valley province. It is a national park that straddles the Kenya−Uganda border covering an area of 169 km^2 with altitudinal range of 2,100−4,301 m and is famous for its bat−filled caves (KWS map, undated).

The Rwenzori (also written as Ruwenzori) Mountain lies almost at the equator, rising over 4000 m above the floor of the Albertine Rift Valley and is bisected by the Uganda−Congo border, which passes through Mt. Stanley, the highest peak. The park trail head at Nyakalengija is 375 km from Kampala and can be reached through Fort Portal. The Ruwenzori Mountain is remarkable for its flora and an ascent over this mountain passes through a series of increasingly spectacular changes of vegetation zones. Above the Bakonzo farmlands occur montane forest (1500−2500 m) that changes to bamboo stands and tangles of *Mimulopsis* (2,500−3000 m). This is followed by giant tree−heathers (3000−4000 m) starting with Ericaceous species, and crowning with spectacular forms of giant *Lobelia* and *Dendrosenecio* species interspersed by thickets of *Helichrysum* species (Uganda Wildlife Authority− UWA Map, 2007).

Mount Muhavura is an extinct volcano in the Virunga Mountains on the border between Rwanda and Uganda. At 4, 127 m, Muhavura is the third highest of the eight major mountains of the mountain range, which is part of the East African Rift Valley. Muhavura lies partly in Volcanoes National Park, Rwanda and partly in Mgahinga Gorilla National

Park, Uganda where parts of this study (taxonomic sampling jointly with AFROALP II Project) was done. It is a home to the critically endangered mountain Gorilla listed on the IUCN red list of endangered species (UWA Map, 1997)

Mount Kilimanjaro with its three volcanic cones, Kibo, Mawenzi, and Shira, is an inactive volcano in northern Tanzania rising 4,600 m from its base covering an area of 388,500 ha. The highest point in Africa is on Mt. Kilimanjaro and is called Uhuru peak (5,895 m), on the volcano Kibo. Although it is inactive, Kilimanjaro has fumaroles that emit gas in the crater on the main summit of Kibo. Mt. Kilimanjaro has unique vegetation such as the water holding cabbage (*Dendrosenecio* species), *Lobelia* species, alpine grassland or tussocks and other alpine vegetation all adapted in living in alpine conditions. Subalpine *Erica* forests at 4,100 m represent the highest altitude cloud forest in Africa. In addition it has a large variety of forest species over an altitudinal ranges of 3,000 m containing more than 1,200 vascular plant species (Newmark, 1991).

Mount Meru is located east of the Great Rift Valley and about 40 km southwest of Kilimanjaro in northern Tanzania's Arusha National Park. This mountain is considered an active volcano and is the country's second highest mountain. It is the youngest volcanic mountain in tropical Africa and about 0.5 million years ago, Mount Meru erupted in a huge explosion that destroyed its cone shape and resulted in a horseshoe crater (Meru crater). In the past century, Mt. Meru had minor eruptions and the Ash Cone continues to build inside the crater (TANAPA, 2007).

The Simen Mountain is part of the Northwestern Ethiopian Mountain systems or Highlands and lies in the North Gondar Administrative Zone, approximately 110 km northeast of the town of Gondar. It consists of broad, undulating plateau, generally above 3,000 m above sea level and reaching over 4,000 m in some areas (Silki, Bwahit and Ras Dashan), part of which is a National Park (Simen Mountain National Park). The tallest peak is Ras Dashan (4,453 m) and is World Heritage site. There are two major vegetation types in the Simen Mountains. These are Afroalpine vegetation in the uplands and Afromontane vegetation in the lowlands. Ericaceous forest, scrub is a transitional, occurring both on the escarpments and in the uplands (Puff & Nemomissa, 2005).

The Bale Mountains are a range of mountains in the Oromia Region of southeast Ethiopia. They include peaks like Tullu Demtu which is the second highest point in Ethiopia (4,377 m), and Mount Batu at an altitude of 4,307 m. These mountains are part of Bale Mountain National Park and cover 2,200 km^2. Bale Mountains contains three distinct ecoregions: the northern plains, bush and woods; the central Sanetti Plateau (where the sampling was done) with an average elevation of over 4,000 m that is characterized by Afroalpine vegetation (grasslands, rocky outcrops, bogs and *Alchemilla* communities) and the southern Harenna Forest famous for its mammals, amphibians and birds including many endemic species. The central Sanetti Plateau is home to the largest population of the rare and endangered Ethiopian red wolves. (ONRS, 2008).

Gara Muleta Mountain is an isolated, rocky mountain with an elevation of 3,405 m. It is 40 km due east of the city of Harar in the Hararghe Region of Ethiopia. The vegetation of this Mountain helps in the conservation of the soil, water and biotic diversity. Previous vegetation studies documented about 361 vascular plant species (Teketay, 1996). Currently the vegetation of this mountain is increasingly being threatened by destruction caused by the surrounding population through deforestation, fire, cultivation and overgrazing.

The Choke Mountains are to the south of Lake Tana in the centre of Gojam, Ethiopia. This large mountain block rises gradually from the surrounding plateau to around 2,800 m, with the highest peak, Mt. Choke reaching an elevation of 4,070 m. The most remarkable feature of this mountain is the virtual absence of forest. The major natural habitats are moist moorland with giant *Lobelia* species, shrubby *Alchemilla* species, sedges and tussocks of *Festuca* species and other grasses (Birdlife International, 2010).

1.2.1 Diversity and Distribution of flora on Eastern African Mountains

Almost always vegetation changes in orderly manner as one climbs up a mountain from the foothill to the summit of the high mountains. Eastern African Mountains are no exception and several distinct zones of vegetation occur, viz: the savanna at the foot of the mountain followed by the bamboo zone (in most of the mountains), and the tropical rain forest zone occupies mid to high altitude (1500− 2800 m). This gradually gives way to the ericaceous zone that is dominated by the genus *Erica* L. marking the end of the tree line zone, above which occurs the distinctive afroalpine flora. Although this zone occurs in the tropical equatorial zone, it is not only isolated ecologically but has a special temperate flora and is peculiarly adapted to the extreme conditions of temperature variation.

Each mountain enclave is also isolated from seemingly neighbouring mountains and can be viewed as archipelagos− like oceanic islands− that vary in area and isolation. Speciation rates and endemicity increase with both area and isolation hence the very high endemicity of Afroalpine flora (above 80%) Hedberg (1970). The main plant communities occurring in these mountains are: *Dendrosenecio* forests/woodland, tussock grassland, *Carex* bogs and sclerophyllous scrub (*Helichrysum*/ *Alchemilla* scrub). Because of the high isolation of the Afroalpine zone, relatively few collections have been made and the area is seldom visited by researchers as it is both inhospitable and expensive to do botanical research in this zone. As such there is little or no known detailed account and comparative study of how diversity of plants species, species richness, abundance and evenness vary between the various plant communities of each mountain and between mountains. The study will also boost the herbaria collections of many taxa, which either are altogether lacking or are severely under collected.

1.2.2 Taxonomy of the genus *Pentaschistis* (Nees) Spach in the Tropical Eastern Africa

Pentaschistis (Nees) Spach consists of about 70 species, of which the majorities are indigenous to Cape Floristic Region (CFR) and other parts of South Africa. The genus is an African endemic and belongs to the tribe Danthonieae of the sub-family Danthonioideae (Poaceae). Both the generic and species delimitation of this genus have been variously described as difficult by different authors (Chippendall, 1955; Clayton & Renvoize, 1986; Linder & Ellis, 1990). Consequently the various species of *Pentaschistis*, particularly those occurring in South Africa, were placed in different genera over the years, such as in *Holcus* L., *Avena* L., *Danthonia* DC., *Eriachne* R. Brown., *Triraphis* R. Br. and *Achneria* Munro ex Benth. & Hook. f. Similarly the species circumscription of the tropical African *Pentaschistis* varied over the last 75 years and this therefore necessitated taxonomic revision. This is due to the insufficient collections and high degree of variability in the tropical African species. As a result the population on each of the various high mountain enclaves was initially treated as different species by Hubbard (1937). He recognised four species among the *Pentaschistis* with open panicles: *P. ruwenzoriensis* C.E. Hubb. from Ruwenzori, *P. meruensis* C.E. Hubb. from Mt. Meru, *P. expansa* (Pilg.) C.E. Hubb. from Mt. Kenya and *P. borussica* (K. Schum.) Pilg. from several mountains. However all these were later united under the name *P.*

borussica by Clayton (FTEA, 1970). Phillips (1994, 1995) reduced *P. minor*, *P. mannii*, *P. gracilis* to variety levels under *P. pictigluma*.

Hence this study used various methods such as phenetic and phylogenetic techniques in addition to morphology both using herbarium specimens and field observations of different populations to carry out taxonomic revision of this genus to address the question of differing species circumscription.

1.3 Economic value of Afroalpine plants in Eastern Africa

Economic botany can be defined as the exploitation of plants and plant products by humans for domestic or commercial purposes. Traditional societies including both pastoral and farming communities, particularly in Africa and Asian countries, have in-depth knowledge of the plant biological resources surrounding their environment (Timberlake, 1987) and frequently utilize them for both domestic and commercial purposes. The most commonly known uses of plants include: source of foods such as cereals, nuts, edible fruits and vegetables; source of medicine, construction materials such as timber and bamboo; fibres such as cotton for textile industry; dyes such as tannins; source of poisons such as African arrow poison; fuel such as firewood and charcoal; shade and as ornamentals among others.

Many researchers in Eastern Africa have documented traditional plant names and uses. Kokwaro (1972, 1976) has compiled numerous plant names and uses from all Kenya and East Africa. Glover *et al.* (1966; 1969) have also documented Maasai and Digo plant names and uses. The most common and significant use of plant resources is as a source of traditional medicines to treat many ailments and conditions. Many pharmaceutical drugs globally used today like artemisinin-based antimalarial drugs currently used in Kenya (from genus

Artemisia), thymol in Listerine (mouth wash) from the genus *Thymus* and atropine from the genus *Atropa* among many others have come from folk use and use of plants by indigenous cultures. As a result, numerous ethnobotanical studies aimed at identifying new pharmaceutical products have been initiated recently (Balick, 1994).

Due to the extreme isolation of Afroalpine zones of the Eastern Africa, coupled with the fact that all the mountains are protected as national parks, few of the Afroalpine plants are used for various purposes compared to other plant species from forest or lowland ecosystems by the surrounding communities. However quite a number of the Afroalpine species have uses ranging from source of medicine to cultural uses.

1.4 Problem statement

The study involves assessment of species richness, species diversity and abundance in the five vegetation types viz. rock outcrop, bog, grassland, *Dendrosenecio* forest/woodland and *Alchemilla* communities of six Eastern African mountains: Mt Kenya, Kilimanjaro, Elgon, Rwenzori, Bale and Simen. In addition the study compares the similarities of species composition between the five vegetation types and mountains as well as addressing the species circumscription of the genus *Pentaschistis* in the Afroalpine zone of Eastern Africa.

1.5 Hypotheses

- There are no significant differences in the plant species richness between rock outcrop, bog, grassland, *Dendrosenecio* and *Alchemilla* vegetation communities
- There are no significant differences in the plant species richness between Mt. Kenya, Kilimanjaro, Elgon, Ruwenzori, Bale and Simen
- There are no significant differences in terms of plant species composition between the six mountains.

- There are no significant differences in the five vegetation types (communities) of Afroalpine zone of Eastern Africa
- Phenetically and morphologically there are no significant differences between the variations of all the population of *Pentaschistis* in the mountains of Eastern Africa
- There is only single colonization event of the genus *Pentaschistis* in tropical African Mountains

1.6 Objectives of the study

1.6.1 General objective

Determine the diversity and distribution of the Afroalpine species in Eastern Africa as well evaluate the species circumscription of the tropical species of the genus *Pentaschistis*

1.6.2 Specific objectives

- Compare vascular plant species diversity between the various vegetation communities of the Afroalpine zone of each of the six mountains (alpha and beta diversity)
- Compare the similarity of plant species composition between the various vegetation communities of each mountain and between mountain systems
- Determine the species richness, abundance and evenness of Afroalpine plant species in the various vegetation communities
- Test heterogeneity (distinctness) of vegetation communities
- Establish the diagnostic features of Tropical African *Pentaschistis* and determine how many species should be recognized
- Evaluate the phenetic relationship between the species of *Pentaschistis* in the study area

- Determine the distribution and frequency of *Pentaschistis* species in the five vegetation communities of Afroalpine zone of Eastern Africa
- Revise the phylogeny of the *Pentaschistis* clade of *Danthonioideae* based on plastid and nuclear DNA sequences.

1.7 Justification and significance of the study

There is no detailed research work on the floristic composition, species diversity analysis, abundance, species richness and similarity and the conservation status of the main vegetation types of the Afroalpine zone of these mountains. Since the scope of these mountain enclaves constituting the Afroalpine zone is both limited in area and isolated detailed information on its species is urgently needed for conservation purposes because of not only high endemicity exhibited by its species but also the rarity of many Afroalpine species as well as the fragility of this peculiar ecosystem.

The genus and species of *Pentaschistis* has undergone various shifts within *Danthonioideae* and hence has been referred to as a difficult (Chippindal 1955; Clayton & Renvoize, 1986; Hilliard & Burtt, 1987; Phillips, 1994). This has been aggravated by the insufficient collections and high degree of variability in the tropical African species, and the huge geographical separation between populations in the mountain refugia. Therefore species circumscription has been a problem. Hence this study was done to assess the diversity and distribution of the vascular plants of Afroalpine species in six mountain systems of East Africa and Ethiopia as well as revise the taxonomy of the genus *Pentaschistis*. It will provide a comprehensive species checklist that will be useful in the conservation and management of this fragile ecosystem.

CHAPTER TWO: DIVERSITY AND THE DISTRIBUTION OF AFROALPINE VASCULAR PLANT SPECIES IN EASTERN AFRICA

2.1 LITERATURE REVIEW

2.1.1 Geological History

The present day landscape in Africa owes its origin to a combination of geological processes mainly operating in opposition. On the one hand, continuous weathering, erosion and deposition of the Mozambique belt have resulted in leveling of the land thereby producing extensive plains in much of the African continent (Clifford, 1970). On the other hand sporadic faulting has elevated some portions and lowered others. In some areas this faulting has been accompanied by volcanism (Clifford, 1970). From the Precambrian (>600 million years ago) until the onset of rifting during the Miocene, most part of the African continent was little affected by major earth movement (Hamilton, 1982). The middle tertiary (approximately 25 million years ago) witnessed the beginning of the doming of extensive areas of Central and Eastern Africa (Gautier, 1967; Morgan, 1973).

These geological events produced extensive plains in the eastern half of Africa sometimes stretching for hundreds of kilometres. Above these plains occur isolated hills called inselbergs as well as very high mountains, of which, three reach above the height where plants cannot survive (Mt. Kilimanjaro, Mt. Kenya and Mt. Ruwenzori). These mountains and others in this region resulted from the Recent Pleistocene−Pliocene rift tectonics and volcanism, approximately between 0.01 and 7 million years ago (Clifford, 1970). Consequently, there is a wide range of landscape features in Eastern Africa including Ethiopia as a result of these complex geological processes associated with intensive volcanic activity and faulting that gave rise to the Great Rift Valley (Nyamweru, 1980). The rift is a giant crack running through the African continent starting from the Afar depression in northern Ethiopia to almost at the mouth of river Zambezi in Mozambique covering a distance of 5,600 km. The accompanying volcanic activities are responsible for the creation of many mountains that are distributed along the faults of this great valley. This has profoundly changed the physiographic appearance of the region such that some spectacular scenery is found in countries such as Ethiopia, Kenya, Uganda, Tanzania, Burundi and Rwanda (Hedberg, 1970).

2.1.2 Biodiversity of the Vegetation of Eastern African Mountains

Biological diversity or simply biodiversity includes all species of plants, animals and microorganisms including their genetic material as well as the ecosystems or habitats in which they occur. It is the central axis to the study of biology (Darwin, 1872; Howard & Berlocher, 1998; Dickson & Foster, 2011) and in particular it is the core topic of ecological theory and conservation biology (Pärtel *et al.,* 2010). Biodiversity directly and indirectly affects human development (Lusweti, 2011) and is therefore crucial for the socio−economic welfare of mankind. Human induced global climate change is causing ecological communities to lose species (Wardle *et al.,* 2011) through accelerated rate of extinction especially fragile ecosystems such as Afroalpine vegetation types in mountain system. It is therefore paramount to thoroughly study species diversity, abundance, cover and distribution to pinpoint the rare, endangered and vulnerable species so that appropriate measures can be taken to conserve them. In addition this can influence policy makers towards the conservation of these vulnerable components of biodiversity. Therefore currently, biodiversity conservationists are pre−occupied with species loss from ecosystems caused by habitat destruction mostly related to anthropogenic factors (Wilson & Peter, 1988; Stuart *et al.,* 1990; Glowka *et al*., 1994; IUCN, 1994; UNEP, 2000a). Hence information on the distribution and abundance of biological species especially the rare and endangered ones are of primary importance in the planning and implementation of biodiversity conservation (Condit *et al.,* 1996; Eilu *et al.,* 2004b).

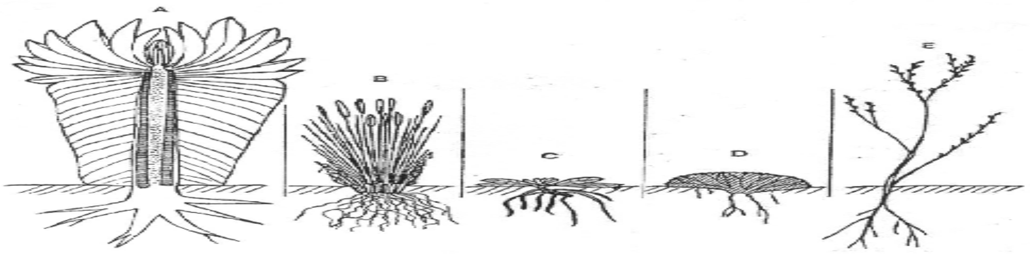
Communities including those of Afroalpine flora have distinctive ecological and physical boundaries as shown by the composition, height and growth form among others. Communities and related natural phenomena such as soil, climate and topography too, continuously co−vary (Mueller−Dombois & Ellenberg, 1974; Whittaker, 1975; Ritter, 2001). While tropical forests are well known for being the most species−rich ecosystems on earth (Gentry, 1992) Afroalpine ecosystems are thought to be species poor as is evident from the phytochorion in which they are described ("…Afroalpine archipelago−like region of extreme floristic impoverishment" (White, 1978a)).

Most of the previous studies on vegetation ecology of Afroalpine flora in Eastern Africa are based on the work of Olov Hedberg (Hedberg, 1951, 1955, 1957, 1961, 1964 and 1970) but other recent works also exist and include: accounts on Mt. Kilimanjaro (Beck *et al*., 1983), Mt. Kenya (Rehder *et al*., 1981 & 1988; Beck *et al*., 1990; Bussmann, 1994; Bussmann & Beck, 1995a), Aberdare range (Schimitt, 1991), Mt. Ruwenzori (Schimitt, 1992), Mt. Elgon (Wesche, 2002), Virunga cluster of mountains (Fischer & Hinkel, 1992), Mt. Bale (Gashaw & Fetene, 1996; Miehe & Miehe, 1993, 1994b; Bussmann, 1997), Mt. Simen (Sileshi & Puff, 2005).

2.1.3 Afroalpine zone of Eastern Africa

The vegetation of the high Mountains of East Africa and Ethiopia displays conspicuous zonation, starting with a montane forest belt, followed by an ericaceous belt and an

Afroalpine belt (Hedberg, 1951). The Afroalpine region was originally proposed by Hauman (1955) to comprise the Afroalpine calottes of the equatorial Eastern Africa, notably the Virunga volcanoes, Ruwenzori, Elgon, Mt. Kenya, Kilimanjaro and Mt. Meru. Later on Ethiopian high mountains like Simen and Bale were added to the Afroalpine regions. Despite the close proximity, the flora of the Afro−alpine is floristically distinct and ecologically isolated from the surrounding montane forest and savanna vegetation. Consequently it has been described by Hedberg as isolated temperate "Sky–islands" since the low lying montane and savanna vegetation separate the mountain enclaves from each other. The Afro−alpine parts of these mountain systems of eastern Africa are characterized by large variations of temperature during the day and night, that is, "summer every day and winter every night" (Hedberg, 1970), very high degree of endemism of flora and fauna; are species poor compared to the surrounding montane and savanna vegetation communities. The Afro−alpine zone has four major vegetation types: Bogs, rock outcrop, alpine grassland/moorland and mix scrubland (*Alchemilla* community or *Dendrosenecio* forests/woodland) and its plant community have been categorized into five distinct life forms adapted to tropical alpine conditions: giant rosette plants (giant *Lobelia* and *Dendrosenecio* species), tussock grasses, acaulescent rosette plants (*Haplocarpha* species), cushion forming plants (*Subularia monticola*) and sclerophyllous plants (*Erica* and *Alchemilla* species, Hedberg, 10) (Figure 1).



Schematic drawing of the five most important phanerogamic life-forms at the afroalpine belt. - A, *giant rosette plant*; B, *tussock grass*; C, *acaulescent rosette plant*; D, *cushion plant*; E, *sclerophyllicus shrub* [Fig. 3 aus HEDBERG (1964b)]

Figure 1: Showing the five life forms in the Afroalpine zones of the high mountains: a) giant rosette plant; b) Tussock grass; c) acaulescent rosette plant; d) cushion forming plants; and e) Sclerophyllous plants (Source: Hedberg, 1964b).

The Afroalpine flora is very interesting because of the striking ecological adaptations exhibited by many species (Hedberg, 1964) and its large amount of geographically vicarious taxa. Its giant *Dendrosenecio* and giant *Lobelias* are as renowned in this respect as the finches of the Galapagos Islands. Some 80% of the Afroalpine species of vascular plants are endemic to the high mountains of East Africa and Ethiopia (Hedberg, 1961). Vicarious taxa occur of different status. Sometimes one species occurs on all or most of the Eastern Africa with vicariad in other parts of the world e.g. *Subularia monticola* A. Br. ex Schweinf. (Afroalpine) and *S. aquatic* L. (Circumboreal). In other cases each of two species is confined to one group of mountains, as in the species pair *Lobelia wollastonii* E. G. Bak. (Virunga volcanoes and Ruwenzori) and *L. telekii* Schweinf. (Elgon, Aberdare, Mt. Kenya). Finally, there are several groups of vicarious taxa where each taxon is endemic or limited to one mountain, as in *Lobelia deckenii* (Asch.) Hemsl. group with six cognate species. The vicarious species of the Afroalpine flora have arisen as the result of geographical isolation. The massive mountains harbouring them are of unequal ages (Miocene to late Pleistocene) and have stood isolated from each other since their origin (Hedberg, 1961). Their Afroalpine enclaves are therefore markedly isolated from each other. Phytogeographically, species of Afroalpine plants are categorized into nine *flora elements* based on the supposed areas of origin of each species, that is, the areas in which they have the majority of their closest relatives (Hedberg, 1961). These floral elements are summarized in table 1.

Table 1: Flora elements of the Afro alpine zone of Eastern Africa

Group	No. of Taxa	Percentage (%)
Endemic Afroalpine element	52	19
Endemic afromontane element	35	13
South African element	17	6
Cape element	10	4
South Hemispheric temperate element	11	4
North Hemispheric temperate element	43	15
Mediterranean element	18	6
Himalayan element	5	2
Pantemperate element	87	31

Source: (Hedberg, 1961)

The endemic Afroalpine element consists of monotypic or oligotypic genera that are entirely or almost entirely confined to the Afroalpine belt e.g. *Keniochloa* Melderis, *Oreophyton* O. E. Schulz, *Haplosciadium* Hochst. and *Nannoseris* Hedb. among others. Also included within this category are members of such genera that have their main distribution in the Afroalpine belt like *Dendrosenecio* and *Alchemilla* L. species. The endemic afromontane element consists of members of genera whose distribution mainly occurs at lower levels (afromontane zone) such as giant *Lobelia* L. species. The third group, the South African element contains species that have their closest relatives in South Africa outside the Cape region e.g. *Dierama pendulum* (L.f.) Bak. The Cape element category consists of Afroalpine species that have their closest relatives in the Cape region proper e.g. *Stoebe kilimandscharica* O. Hoffm. and *Pentaschistis* (Nees) Spach species. The fifth group, the South Hemispheric temperate element includes members whose relatives occur in the Antarctic region e.g. *Nothofagus* .

The North Hemispheric, or Boreal element comprises 43 taxa whose relatives are concentrated in Europe e.g. *Cardamine hirsuta* L., *Arabis alpina* L, *Callitriche stagnalis*

Scop. among others. Members of the genera of the Mediterranean element have their relatives in the Mediterranean region and include such species as *Erica arborea* L., *Aira caryophyllea* L., *Romulea fischeri* Pax, *Trifolium multinerve* (Hochst.) A. Rich., *Anthemis tigreensis* J. Gay ex A. Rich. etc. The smallest element in the Afroalpine flora is the Himalayan element, consisting of taxa that have their nearest relatives in the mountains of Southern Asia. It contains only five taxa: *Satureja punctata* (Bth.) Briq., *S. biflora* (Buch.−Ham. ex D. Don) Briq., *Dicrocephala alpina* R. E. Fr., *Crepis scaposa* R. E. Fr. ssp. *afromontana* (R. E. Fr.) Babc., *C. suffruticosa* Babc. The ninth and the largest group is the Pan temperate element and comprises species that either occur themselves on several continents in both hemispheres, and that have their closest relatives so distributed. Examples in this category include *Deschampsia flexuosa* (L.) Trin., *Festuca kilimanjarica* Hedb., *F. pilgeri* St.–Yves ssp. *pilgeri, F. abyssinica* Hochst. ex A. Rich. etc (Hedberg 1961).

2.1.4 Value of Afroalpine flora

Plants are a major component of the biodiversity and are essential in maintaining life on our planet since they manufacture food in the form of organic compounds such as starch, fats and vitamins, among others, which are utilized by man and other animals for sustenance (Neuwinger, 1996). Consequently man is known to have been using wild plant resources since time immemorial to satisfy a wide range of basic needs of both rural and urban communities, in both tropical and sub-tropical countries (UNESCO report, 1998) including those living around the high mountains of Eastern Africa. Besides being a source of sustenance, plants also produce numerous other products, usually called secondary metabolites, that were used since ancient times for both domestic (mostly traditional medicine) and commercial purposes (for example essential oils for perfume manufacture and ingredients of pharmaceutical products). Thus the field of economic botany is one of the oldest disciplines in botanical science.

Traditional medicine in Kenya and other parts of Eastern Africa has been practiced for many centuries and still plays an important role in providing primary health care (Kokwaro, 1988; 1976) due to the inadequate health facilities and few trained health personnel available. This is evident by the fact that about 75% of the Kenyan population for example relied on traditional medicine as their primary source of health care and over 90% of the people have at one time or another resorted to the use of herbal medicine (Odera, 1997). It is for this reason that the World Health Organization (WHO) has been encouraging the use of traditional medicine, particularly in the developing countries through promoting the incorporation of its useful elements into national health care systems (Akerele, 1987).

According to WHO, up to 80% of the population in Africa uses traditional medicine for their primary health care (Hamilton, 2008). The majority of plant species used in herbal medicine treatments are harvested from the wild rather than cultivated. Therefore overexploitation especially for commercial purposes may endanger some species, particularly those endemics that have limited distribution. Herbal remedies may be prepared in various forms, as infusions, decoctions, powdery ash and instillations (Lindsay, 1978). Apart from providing spectacular scenery for tourist attraction, which boosts tourist industry, as well as playing important ecological roles, a number of the species of the Afroalpine vegetation in the Eastern Africa are used for purposes such as source of medicine for humans and livestock, firewood, food or beverage preservation and cultural/ritual activities among others.

2.2 MATERIALS AND METHODS

2.2.1 Sampling Design

Four different vegetation community types were sampled and analysed in each of the 11 mountains viz.: Simen, Choke, Bale, Gara Muleta (Ethiopia), Kenya, Aberdare, Elgon (Kenya), Meru, Kilimanjaro (Tanzania), Ruwenzori and Muhavura (Uganda) (figures 2 a–2g). These were rock outcrops, bogs, grassland, and mixed scrubland *Dendrosenecio*/*Alchemilla*). In each vegetation type in each mountain, four plots of approximately 100×100 m were sampled and analysed. Raw data (herbarium voucher specimens and silica dried leaves) were collected from the plots using the Plot and No−plot protocols developed by the Afroalp II project (NUFU project 2007/1058).

For each population of plant species, five plants were sampled, one from each of the four corners of the plot and one from the middle, that is, complete sampling of plant species was done. Leaves from these plants were put in tubes containing silica gel and the first three plants were taken as vouchers for morphological reference and verification. In case the species were not occurring within the plot, a sample of five individuals of each species was collected from outside the plots to represent the mountain (s). Plant identification was done both in the field and in the herbarium using available local floras (*Flora Tropical East Africa* and *Flora of Ethiopia and Eritrea*) as well as relevant botanical books (Beentje, 1994; Agnew & Agnew, 1994) in addition to expertise of participating taxonomists. Most of the collections were identified to species level and variety/sub−species level where applicable.

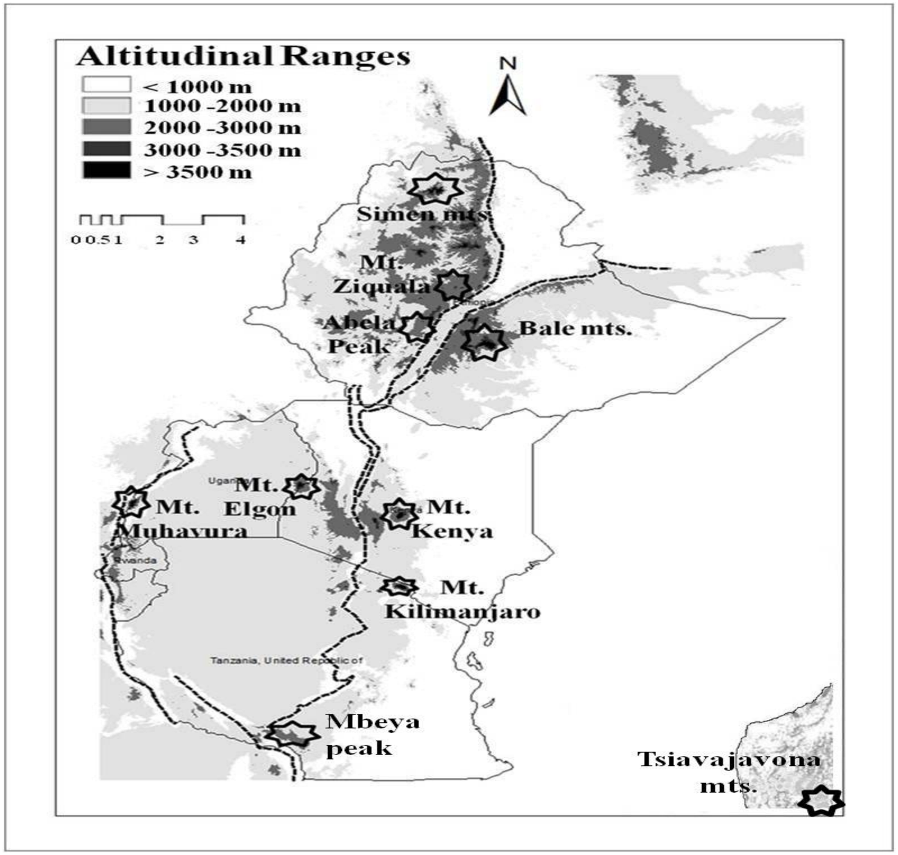


Figure 2a: Map of East Africa and Ethiopia showing major mountain systems and Rift Valley, which formed the study area (Source: AFROALP II Project)

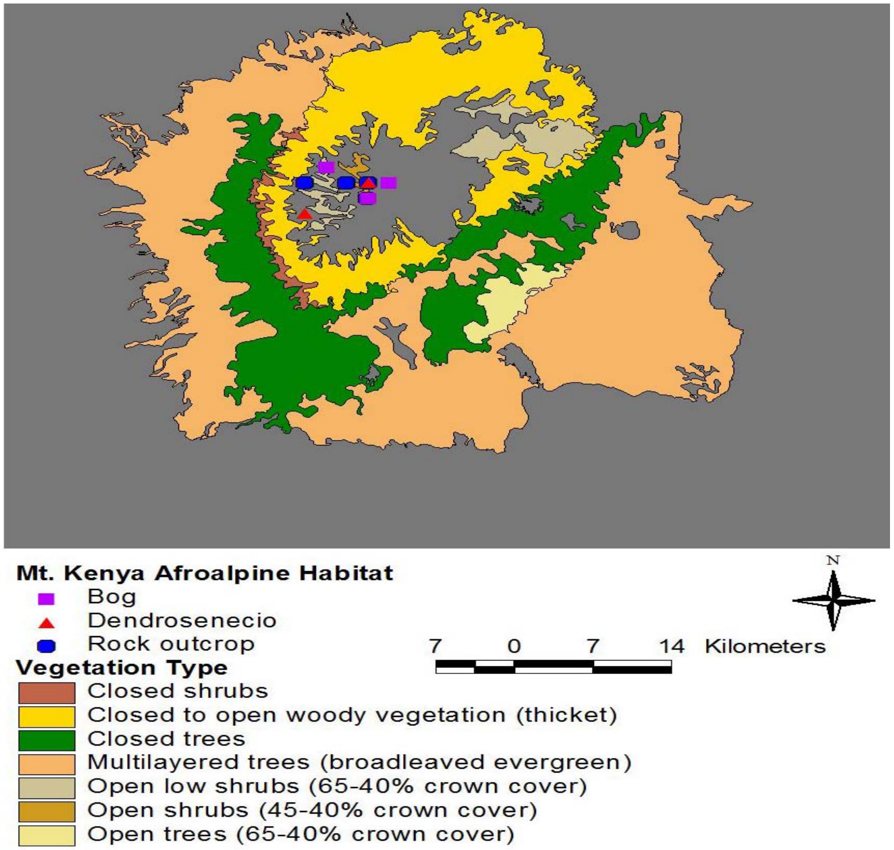


Figure 2b: Afroalpine sampling points for the bog, *Dendrosenecio* and rock outcrop plots from Mt. Kenya

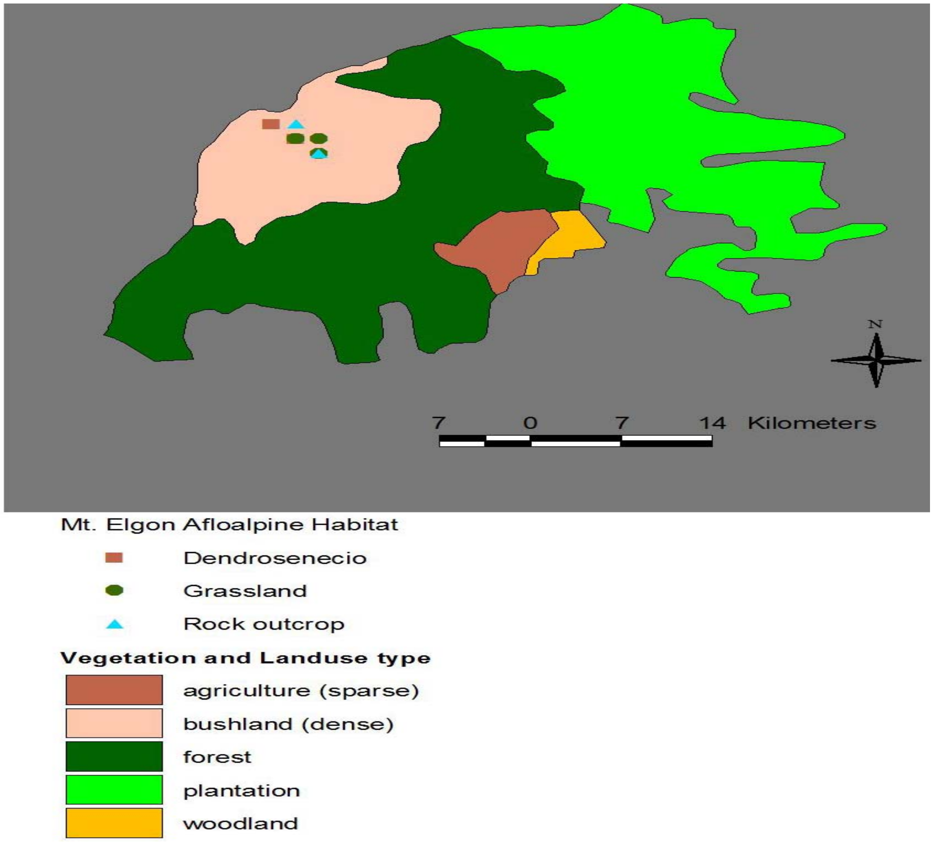


Figure 2 c: Afroalpine sampling points for the *Dendrosenecio*, grassland and rock outcrop plots from Mt. Elgon

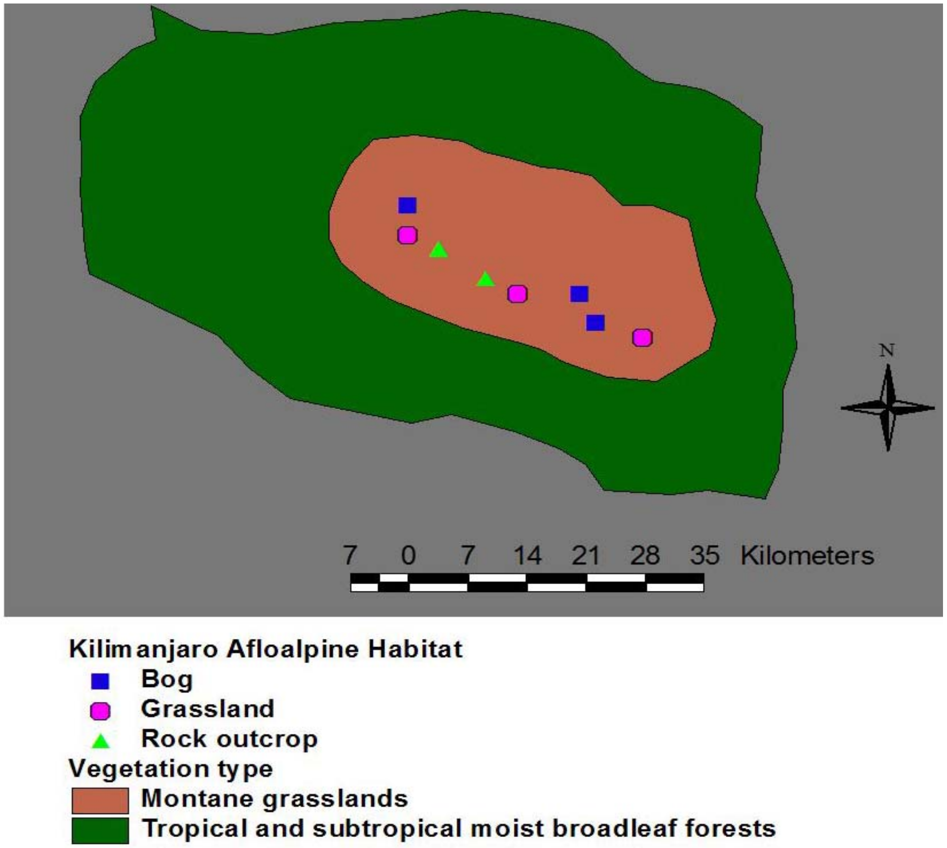


Figure 2 d: Afroalpine sampling points for the bog, grassland and rock outcrop plots in Mt. Kilimanjaro

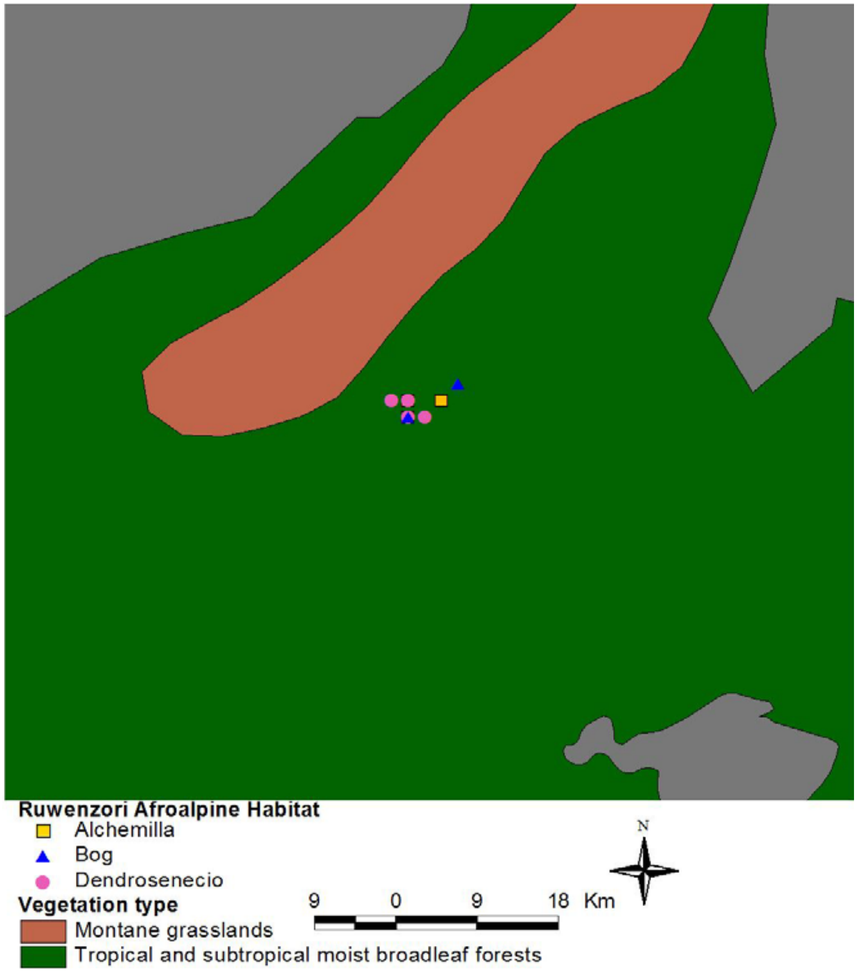


Figure 2 e: Afroalpine sampling points for *Alchemilla*, bog and *Dendrosenecio* plots of Mt. Rwenzori

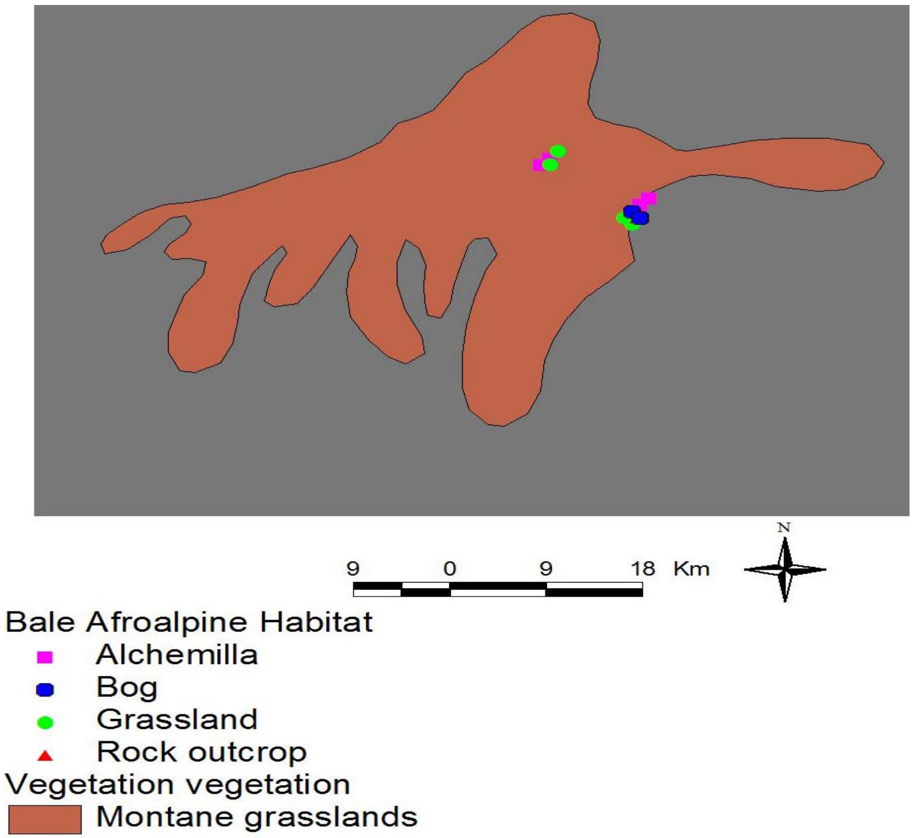


Figure 2 f: Afroalpine sampling points for *Alchemilla*, bog, grassland and rock outcrop plots of Mt. Bale

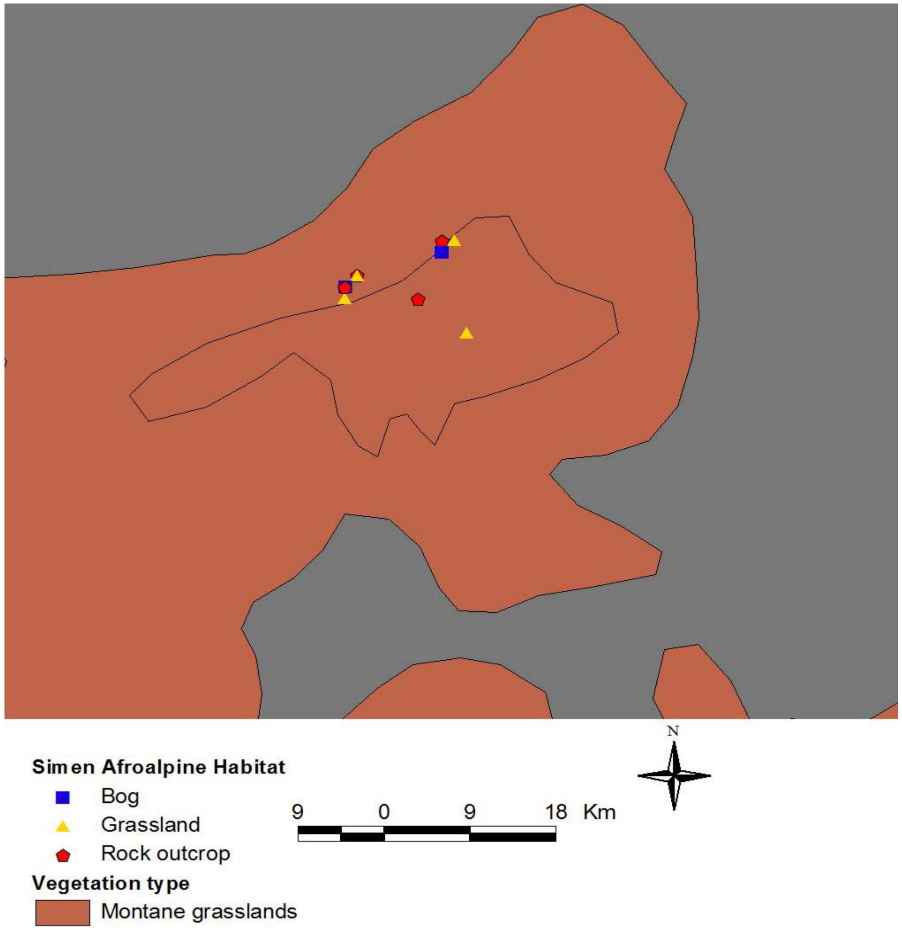


Figure 2g: Afoalpine sampling points of bog, grassland and rock outcrop plots of Mt. Simen

2.2.2 Data Analysis

The completeness of the sampling (species checklist) was assessed using the accumulative species curve computed using PRIMER version 5.0 (Clarke & Warwick, 1994; Clarke & Gorley, 2001). The software calculates species sampling data matrix by iteratively resampling the raw data 999 times and averaging the result.

2.2.3 Species Diversity Analysis

Whittaker (1972) classified diversity into alpha (α), beta (β) and gamma (γ) types. The α diversity is that of species within habitat(s) or community, β diversity is the measure of the rate and extent of change in a species along a gradient from one habitat to others while γ diversity is the richness in species of a range of habitats in a geographical area. Many diversity indices have been proposed (example reviews by Eberhardt, 1969; Peet, 1974; Magurran, 1988; Krebs, 1999; Southwood & Henderson, 2000 and Feinsinger, 2001) and there is no consensus on which one of them is the best (Lewis *et al*., 1988; Krebs, 1999).

Diversity measures are divided into species richness measure, species abundance and indices based on the proportional abundance of species (Magurran, 1988). Peet (1974) suggests that a number of concepts are lumped within the term diversity e.g. species richness, evenness (or equitability) and heterogeneity (combines species richness and evenness). There are two types of heterogeneity indices commonly referred to as type 1 and type 2 (Peet, 1974). Type 1 is the most sensitive to changes in the importance of rare species in the sample (example is Shannon−Wiener index) while type 2 are the most sensitive to changes in the most abundant species (example Simpson index). Evenness indices include Pielou's (J') index, Lloyd and Ghelardi's index (ε) [Lloyd & Ghelardi, 1964; Magurran, 1988). Importance of diversity indices include: −

1. Illustrates intrinsic diversity patterns of ecological communities and Ecosystems
2. Indicates the relative contribution of abundant and rare species to diversity
3. Shows successional trends of a community over time as affected by abundant and rare species (Lewis *et al*., 1988)

However diversity indices have limitations that can affect the accuracy of a monitoring protocol (Norris, 1999) because of their sensitivity to sample size and bias, taxonomic uncertainties and stochastic sampling.

This study used Shannon−Wiener diversity index (H') computed to base e using PRIMER version 5.0 (Clarke & Warwick, 1994; Clarke & Gorley, 2001) of the data matrix of the species sampling from the 75 plots (Appendix 1a– 1f).

$$H' = \sum_{i=1}^{n} p_i (\log_2) p_i,$$

Where n is the number of species, p_i is the proportion of the total count emanating from the ith species (Clarke & Warwick, 1994). The index is computed on the basis of what proportion of the total individuals of each species comprises. Advantages of this index are: −

- Useful in describing ecological trends because it includes both species count and evenness
- Have moderate discriminant ability
- An intermediate ease of calculation

Since it is difficult to interpret diversity indices, it is recommended to combine with other measures of diversity in giving correct interpretation and description of ecological communities. These include measures such as total number of species (species richness), abundance and evenness.

2.2.4 Species Richness

Species richness was quantified by employing Margalef's index (d) [Clifford & Stephenson, 1975) using the formula:

$d = (S-1)/\log N$ where S is the total number of species and N is the total number of individuals. The advantage of using this index is that it minimises the effect of sample sizes and the fact that S and N are simple and easy to compute. The data matrix used was the present/absent scores for all the species sampled from the 75 plots.

2.2.5 Species Evenness

In this study, Pielou's evenness index (J') was used (Pielou, 1975). It shows how evenly the individuals occurring are distributed among the different species. The data matrix used was the present/absent scores for all the species sampled from the 75 plots. The index ranges between 0 and 1 with 1 representing even distribution of individuals within all the species while lower values (towards 0) indicate dominance by one or few individual taxa (uneven distribution). The index (J') is calculated as: $J' = H'$ (observed)/H'_{max} where H'max is the maximum possible diversity achievable when all species are equally abundant (Pielou, 1975; Clarke & Warwick, 1994). Its advantage includes the fact that it reduces dependence on sample size and simplicity of its computation.

2.2.6 Pairwise comparison of intervegetation communities and intermountains using Jaccard's Similarity Index

Jaccard's Similarity Index was used to compare the degree of similarity between the five vegetation community types in the Afroalpine Mountains of Eastern Africa (Jaccard, 1901). Each time two vegetation communities were compared and the values of the common (shared) species, different and Jaccard's computed using Microsoft excel data analysis sheet.

The pooled data matrix of the scores of all species present/absent in each vegetation community from the 75 plots was used. It was computed from the equation: j/ (a+b-j)
Where: 'j' is the number of species found in both samples and 'a' is the number of species in sample a while b is the number of species in sample b.The higher the value of Jaccard's the more similar two vegetation communities are (in terms of species composition).

A total of 10 comparisons are possible between the five vegetation community types (rock outcrop Vs. bog, rock outcrop Vs. grassland, rock outcrop Vs. *Dendrosenecio*, rock outcrop Vs. *Alchemilla*, bog Vs. grassland, bog Vs. *Dendrosenecio*, bog Vs. *Alchemilla*, grassland Vs. *Dendrosenecio*, grassland Vs. *Alchemilla* and *Dendrosenecio* Vs. *Alchemilla*). Similarly the species composition among the six mountains (Mt. Kenya, Elgon, Kilimanjaro, Ruwenzori, Bale and Simen) was compared using Jaccard's similarity index. It resulted with 15 pairwise comparisons (Mt. Kenya Vs. Elgon, Kenya Vs. Kilimanjaro, Kenya Vs. Ruwenzori, Kenya Vs. Bale, Kenya Vs. Simen, Elgon Vs. Kilimanjaro, Elgon Vs. Ruwenzori, Elgon Vs. Bale, Elgon Vs. Simen, Kilimanjaro Vs. Ruwenzori, Kilimanjaro Vs. Bale, Kilimanjaro Vs. Simen, Ruwenzori Vs. Bale, Ruwenzori Vs. Simen and Bale Vs. Simen.

2.2.7 Multivariate Analysis of species composition between the vegetation communities and between mountains

2.2.7.1 Non−Parametric Multidimensional Scaling (MDS)

In order to do comparisons in the species composition of all the five vegetation communities and the six mountains at the same time, non−parametric Multidimensional scaling (MDS) was used. MDS gives a good link between the original data and the final picture and represents complex patterns correctly in low dimensional space (Clarke & Warwick, 1994). It only considers that an ordination is important representation of similarity by looking at the stress values that range from 0 to 1. The lower the stress value the better the two dimensional presentation of the data point and ideally values 0.1 or less gives the best presentation.

Similarity matrix was first generated which was used to produce graphs to discriminate sites from each other and cluster sites with similar species composition (Clarke & Warwick, 1994). In this study, ordinations were calculated using Primer version 5.0 where the original data matrix was first converted to Bray−Curtis matrix using the SIMPER module. This is the most commonly used similarity coefficient used in ecological analysis. It neutralises the effect of the rare species (common in Afroalpine flora) such that the rare a species is, the less it contributes to the overall pattern (Clarke & Warwick, 1994). Comparisons of species composition using MDS was done between the 75 plots, five vegetation communities and the six mountains. The aggregation of the various points (plots, vegetation communities or mountains) depends on the degree of similarity of species composition of the points.

2.2.7.2 Cluster Analysis

Cluster analysis of the same data (from plots, vegetation types and mountains) were performed to compare with the results of those from MDS since similar plots or vegetation types or mountains are expected to cluster together and give easily interpretable dendographs. The Bray−Curtis Algorithm was used to generate the data matrix and dendographs (Clarke & Warwick, 1994).

2.2.8 Vegetation Cover

Ecological assessment for each plot in the five sub−plots were also done that involved estimates of total vegetation cover, cover of vascular plants, bryophytes, lichens and individual species of vascular plants (percentage cover) and information recorded in the Plot protocol. In the eleven mountain systems in which raw data (percentage cover of each species in the sub–plots) was collected, it was only possible to collect plot data from six mountains viz: Mt. Bale, Simen (Ethiopia), Mt. Kenya, Elgon (Kenya side), Mt. Kilimanjaro (Tanzania) and Mt. Ruwenzori (Uganda) and therefore a total of 75 plots were sampled and data obtained for ecological assessment. The cover data was useful in the community description observed during the sampling of the plots from all the sampled mountains. Only taxonomic sampling was done in the remaining five mountains: Choke Gara Muleta (Ethiopia), Aberdares (Kenya), Mt. Meru (Tanzania) and Muhavura/Gahinga (Uganda). Hence the analysis of the data in this section only covers data obtained from plots. A reference collection of voucher specimens from each species sampled (in all the plots and non−plot samples) are deposited at EA herbarium (Kenya), national herbarium in Addis Ababa (Ethiopia), Makerere University herbarium (Uganda) , national herbarium in Arusha (Tanzania) and Oslo herbarium (Natural History Museum, University of Oslo, Norway).

2.2.9 Analysis of Variance (ANOVA) for Species richness

The data sets from vegetation communities and mountains were used to discern whether there were significant variations between them using ANOVA. First the pooled data matrices of species richness in each plot in the respective vegetation communities and mountains (Appendix 7 and 8 respectively) were rearranged to suit the STATISTICA program then Margalef's species richness (d) from the five vegetation communities and mountains was subjected to single factor (one−way) ANOVA using STATISTICA version 7 (Statsoft Inc., 1999). Tukey's multiple comparison tests were performed to find the source of variations whenever ANOVA tests were significant (Tukey, 1977).

2.2.10 Analysis of Similarities of the species composition of vegetation communities and between mountains (ANOSIM)

ANOSIM test allow a statistical test (1−way layout) of the null hypothesis that there are no assemblage differences between groups of samples, specified a priori (Clarke & Gorley, 2001). The key output is in the results log and a histogram of ANOSIM R statistic values which are obtained from 999 random permutations of the groups (mountains or vegetation communities in this study for example) between the samples and shows the likely values of R. These are distributed around zero−if there are no differences between groups than between−group and within group similarities will be roughly equal−but they are never more than 0.15 or so by chance. The data matrixes of the species present/absent of the 75 plots were used to compare assemblage differences between the vegetation communities and between mountains (Heterogeneity test).

2.2.11 Species Contribution to Similarity (SIMPER)

It is possible to identify which species primarily account for the observed assemblage differences of the various vegetation types (and mountains). This can be done by the decomposition of Bray−Curtis similarity (for within treatments e.g. within plots of any given mountain or vegetation community) (or dissimilarity) of between treatments (e.g. between 2 or more mountains or vegetation communities) index into contribution from each species. That is, by looking at the overall percentage contribution of each species makes to the average dissimilarity between two groups. Hence one list species in decreasing order of importance in discriminating the two sets of samples. This can be done using SIMPER, particularly Bray−Curtis similarity matrix (Clarke & Gorley, 2001). Here no standardization and Transformation is done and a cut−off percentage of 90% is chosen. This means that species will be listed in decreasing order of their importance, in contributing to the average dissimilarity between two groups, until the point is reached at which 90% of the dissimilarity is accounted for (Clarke & Gorley, 2001). The data matrixes of the present/absent species from the 75 plots were used to assess the contribution of each species to the overall similarities in the vegetation communities and mountains.

2.3 RESULTS

2.3.1 Diversity and Distribution of Afroalpine Plants in Eastern Africa

A total of 278 species from 124 genera belonging to 46 families were sampled from 75 plots in five vegetation community types (Appendix 4 and 9) viz: rock outcrop, bogs, grassland, *Dendrosenecio* forest/woodland and *Alchemilla* community from the four mountains of East Africa (Mt. Kenya, Elgon, Kilimanjaro and Ruwenzori) and two Ethiopian Mountains (Bale and Simen). About 58 specimens were not fully identified to species level and are excluded from this number of species in the checklist (Appendix 7). However much of the known Afroalpine species were covered in this list of (46 out of the 48 families/124 genera out of 141 genera).

Of the 46 families collected from the plots 15 families (Asteraceae, Poaceae, Caryophyllaceae, Apiaceae, Brassicaceae, Scrophulariaceae, Crassulaceae, Cyperaceae, Iridaceae, Adiantaceae, Ranunculaceae, Rubiaceae, Fabaceae, Gentianaceae and Lobeliaceae) constituted 81% of all the species recorded (figure 3) i.e. out of the 278 species, they constitute 180 species (Table 2) (Appendix 2). Asteraceae represented by 21 genera out of 124 genera(17.36%) and 69 species out of 278 species (24.82%) and Poaceae with 17 genera (14.05%) and 37 species [13.31%]) were the most dominant taxa of the Afroalpine vegetation communities in the six mountains sampled followed by Caryophyllaceae (9 genera−7.44%; 16 species−5.76%), Apiaceae (7 genera−5.79%; 9 species−3.24%), Brassicaceae (5genera−4.13%; 6 species−2.16%), Scrophulariaceae (5 genera−4.13%; 8 species−2.88%), Crassulaceae (5 genera−4.13%; 8 species−2.88%), Cyperaceae (4 genera−3.31%; 11 species−3.96%), Ranunculaceae (3 genera−2.48%; 9 species−3.24%), Adiantaceae (3 genera−2.48%; 4 species−1.44%) and Iridaceae (3 genera−2.48%; 3 species−1.08%).

Table 2: 15 dominant families of the Afroalpine plant species from Eastern Africa

No.	Family	No. of genera	Percentage (%)	No. of Species	Percentage (%)
T	**47**	**124**	**see below**	**278**	**See below**
1	Asteraceae	21	17	69	25
2	Poaceae	17	14	37	13
3	Caryophyllaceae	9	7	16	6
4	Lamiaceae	4	3	12	4
5	Cyperaceae	4	3	11	4
6	Rosaceae	2	2	10	4
7	Ranunculaceae	3	2	9	3
8	Lobeliaceae	1	1	9	3
9	Apiaceae	7	6	9	3
10	Scrophulariaceae	5	4	8	3
11	Gentianaceae	1	1	8	3
12	Fabaceae	2	2	8	3
13	Crassulaceae	5	4	8	3
14	Brassicaceae	5	4	6	2
15	Rubiaceae	1	1	4	1

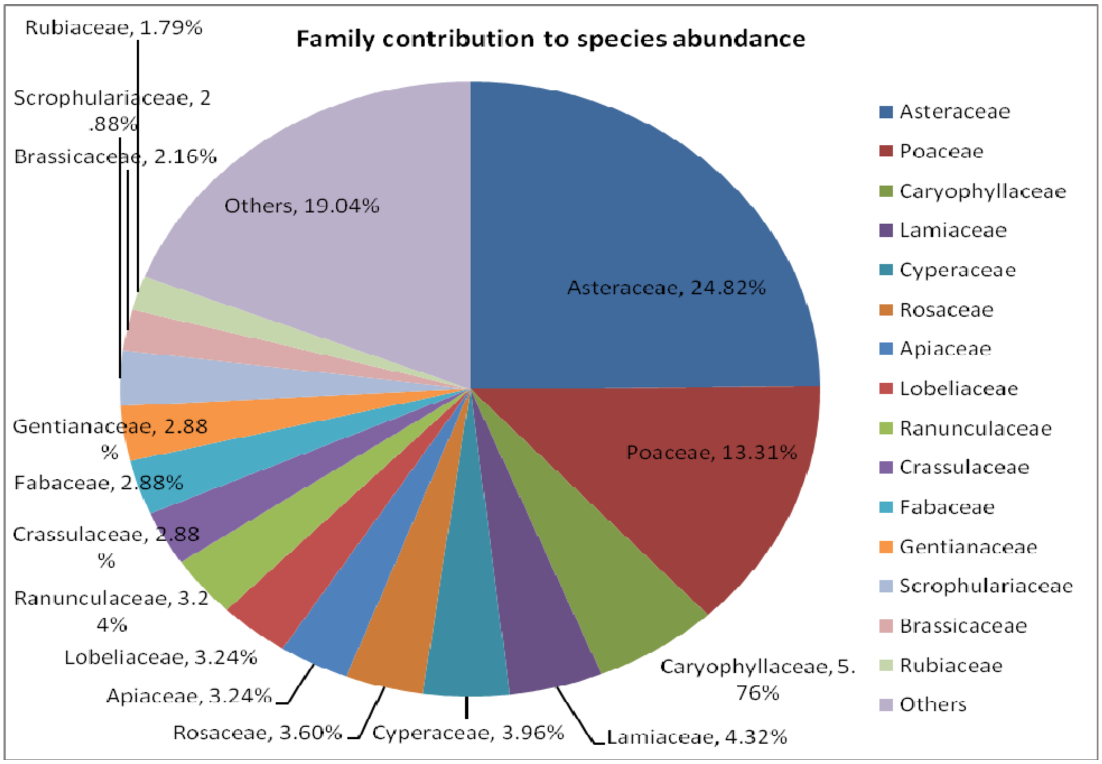


Figure 3: Percentage family contribution of Afroalpine species from Eastern Africa

Enough sampling was achieved as revealed by the average species accumulation curve for the 75 sampled plots. Here the shape of the species curve indicates the expected pattern of initial exponential increase (sharp rise) in species with increasing sampling, then gradually slowing down (as demonstrated by the curvature) as more samples are added until the curve attains almost flat curvature where more sampling hardly adds new previously unaccounted for species (Figure 4).

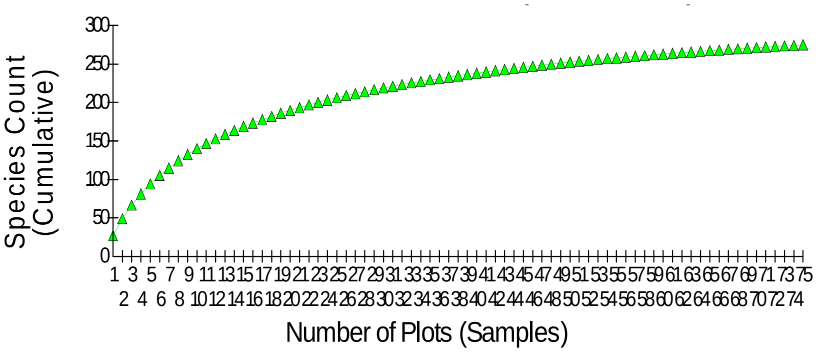


Figure 4: Species Accumulation Curve showing species sampling from 75 plots

2.3.2 Similarities between the five vegetation types

Jaccard's Similarity Index between the five vegetation community types in the Afroalpine zone of Eastern Africa showed that rock outcrop and grassland were the most similar in terms of species composition with Jaccard's similarity index of 51.98. Similarly bogs and grassland showed relatively high similarity index (44.03 Jaccards) while the most dissimilar vegetation communities were those of between grassland Vs. *Dendrosenecio* vegetation communities (21.62 Jaccards), rock outcrop verse *Alchemilla* (26.19 Jaccards) and rock outcrop Vs. *Dendrosenecio* vegetation communities (27.36 Jaccards) (figure 5).

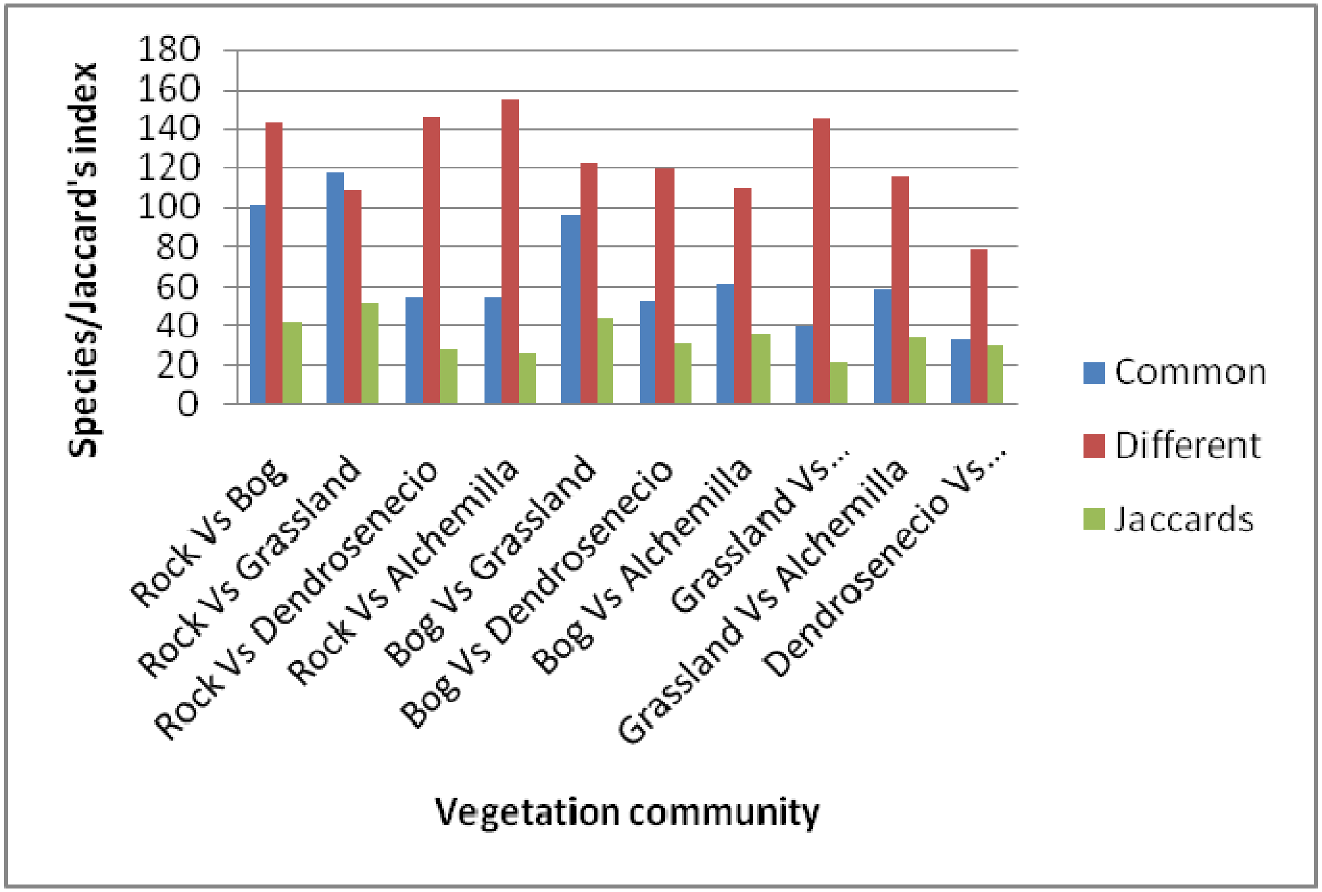


Figure 5: Similarities between five vegetation community types in Eastern Africa mountains

Multivariate analysis of the five vegetation community types using Cluster analysis (Bray−Curtis) exhibits similar patterns with that of pairwise comparison (Jaccard’s similarity index). Rock outcrop, bog and grassland cluster together (Figure 6).

Figure 6: Dendrogram showing vegetation type similarity in Afroalpine zone with respect to species composition

2.3.3 Similarity between the Afroalpine species of six Mountains of Eastern Africa

Similarity between the mountains showed that the East Africa (Kenya, Uganda and Tanzania) Mountains are more similar in terms of species composition compared with the Ethiopian Mountains (Figure 7 & 8). Similarly the Ethiopian Mountains indicate similar trend where they share more species. Among the East Africa mountains, Mt. Kenya, Kilimanjaro and Elgon are more similar while Ruwenzori appears to separate from the rest. The former two are the most similar as revealed by the relatively high Jaccard's similarity index (44.4). Similarly Bale and Simen show high degree of similarity (47.05). The most dissimilar mountains are Simen and Ruwenzori (13.22) and Bale and Rwenzori (14.93).

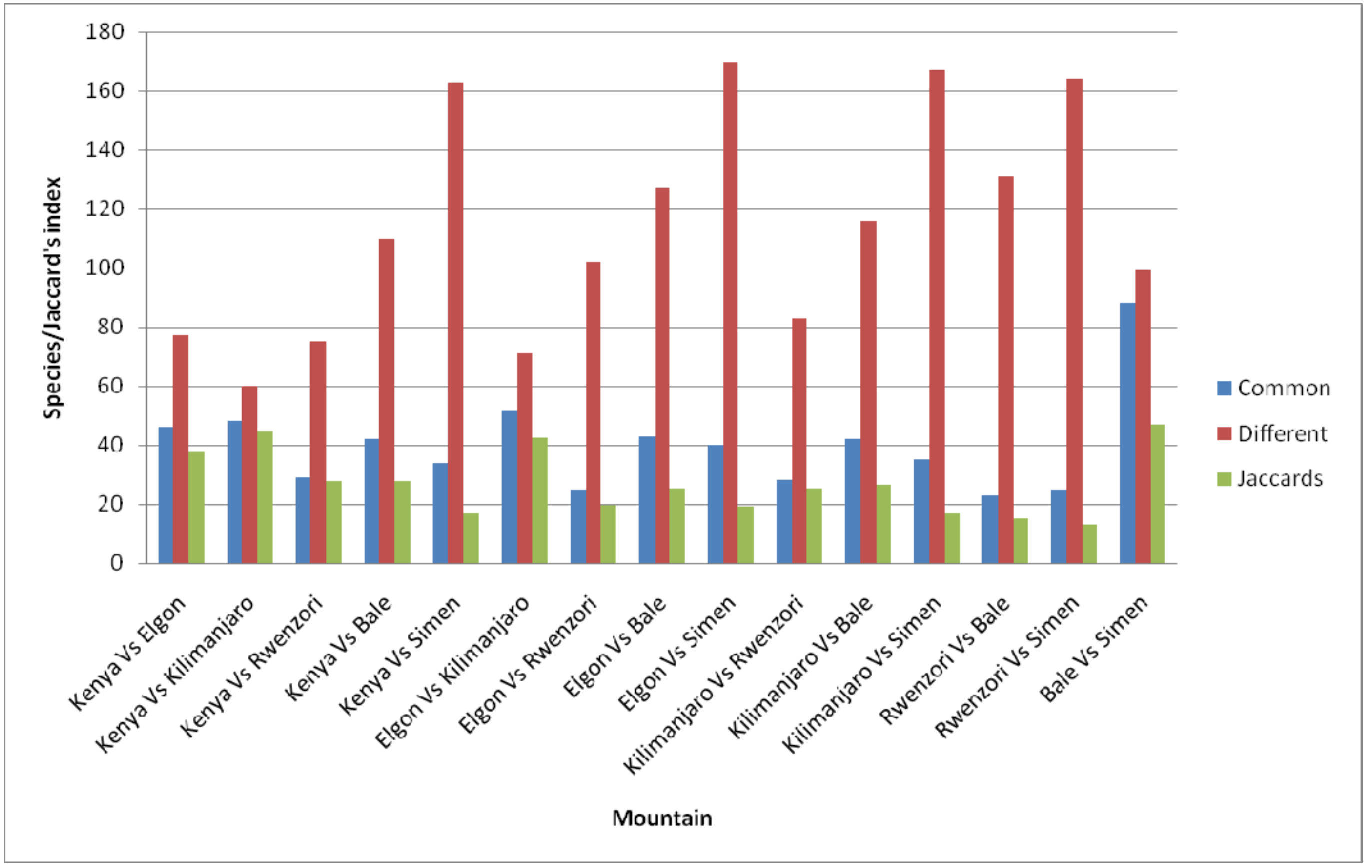


Figure 7: Similarity between the high mountains of Eastern Africa

The cluster analysis like the pairwise comparison reveals that Simen and Bale have closer affinities in terms of species composition thus clustering together (Figure 8). On the other hand, Mt. Kenya, Kilimanjaro and Elgon form a cluster indicating higher degree of similarity. Mount Ruwenzori, the only non−volcanic (Block Mountain) mountain occupies somewhat intermediate position between the Ethiopian Mountains and the remaining East Africa Mountains. The scatter plot graph from MDS exhibit same pattern of aggregation where the mountains Kenya, Tanzania and Uganda aggregate closely compared to the other mountains (Bale and Simen) of the sub–region of Ethiopia (Figure 9 and 10).

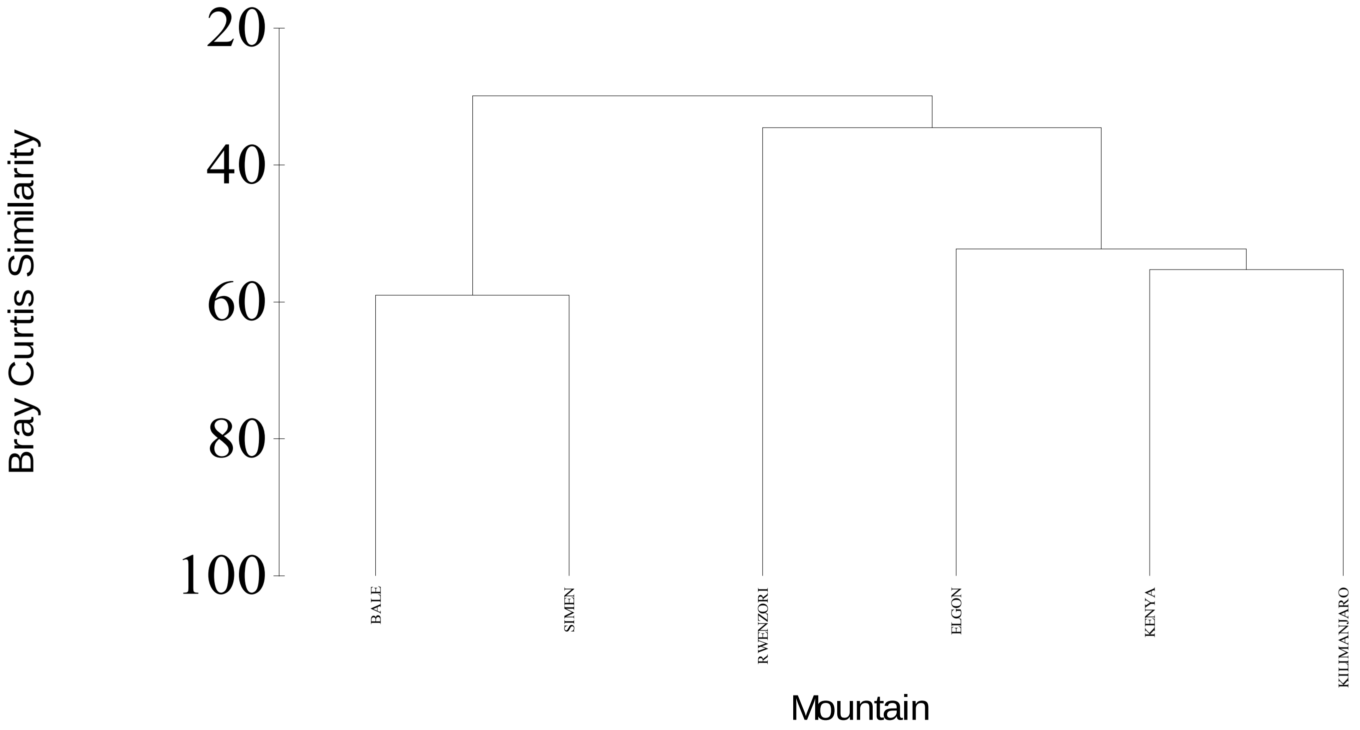


Figure 8: Species composition similarity between Eastern Africa mountains

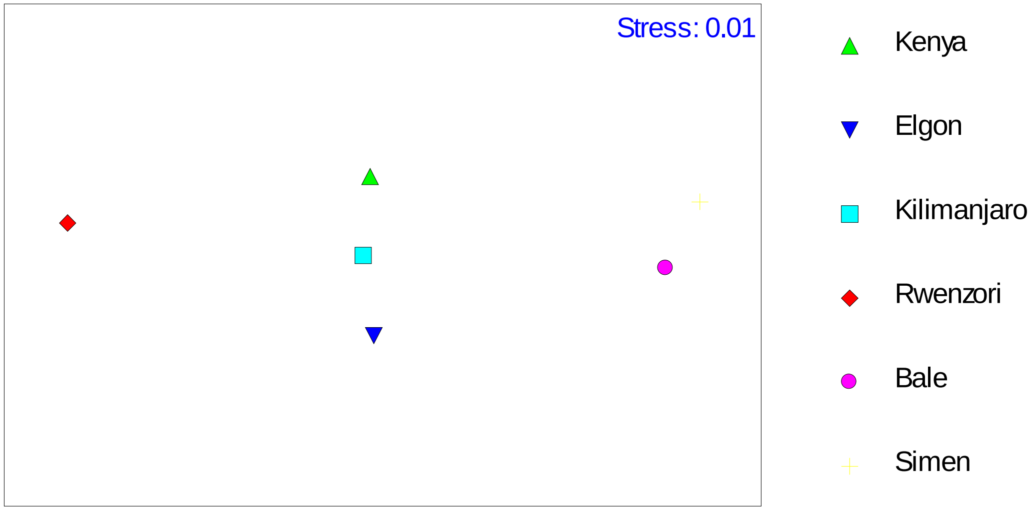


Figure 9: Multidimensional scaling graph showing species composition similarities among Eastern Africa mountains

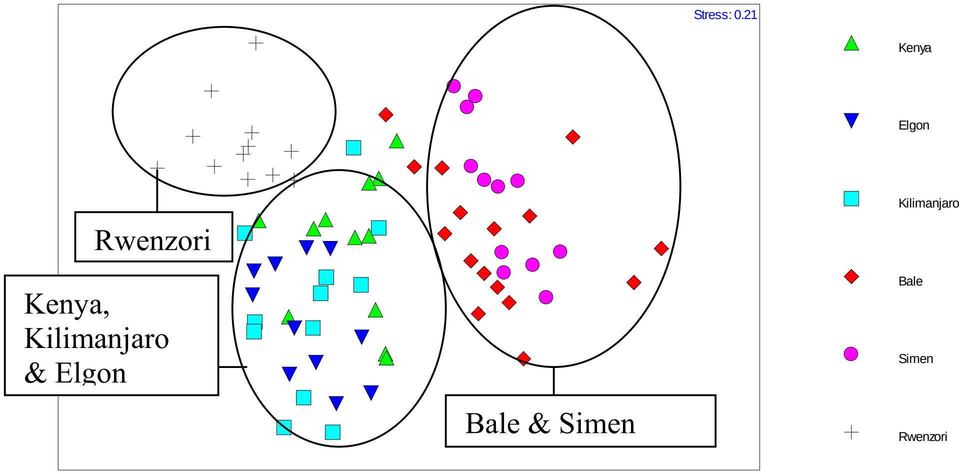


Figure 10: Multidimensional Scaling graph showing distribution of sampled plots from Eastern Africa mountains

2.3.4 Species Diversity in the Afroalpine Vegetation communities

Shannon Wiener diversity index indicate that rock outcrop had the highest species diversity (4.91 H') among the five vegetation community types followed by grassland (4.79 H') and bogs (4.68 H') while the *Dendrosenecio* vegetation community was the least species diverse in the Afroalpine zone of the East Africa and Ethiopian Mountains (Table 3). Similarly rock outcrop was the most species rich among the five vegetation communities (188 species) followed by bog and grassland communities with each 157 species. *Alchemilla* (77 species) and *Dendrosenecio* (68 species) vegetation communities were most species poor (Figure 9). Abundance too takes similar patterns with rock outcrops (660 individuals) and bogs (586 individuals) taking the lead (Figure 10).

Comparative analysis of the species richness between the five vegetation types indicates significant variation in terms of species count (richness) between the plots of the vegetation communities *Dendrosenecio* forest/woodland (68 species) vs. rock outcrop (188 species) and *Dendrosenecio* (68 species) Vs. bogs (157 species) ($p < 0.05$; F (4, 70) =6.0771; df = 70.0). Similarly there is a significant variation of species richness between rock outcrop and *Alchemilla* vegetation communities (Figure 11, 12, and table 4).

Table 3: Species diversity, richness, abundance and evenness in five vegetation types in six Eastern African mountains

Sample	Species richness (S)	Abundance (N)	Margalef's index (d)	Pielou's evenness (J')	Fisher	Shannon (H')	Simpson (1−lambda
Rock	188	660	28.8	0.9381	87.74	4.912	0.992
Bog	157	586	24.48	0.9263	70.27	4.684	0.9893
Grassland	157	436	25.67	0.9485	87.99	4.796	0.9919
Dendrosenecio	68	205	12.59	0.9509	35.58	4.012	0.9833
Alchemilla	77	160	14.97	0.971	58.35	4.218	0.9898

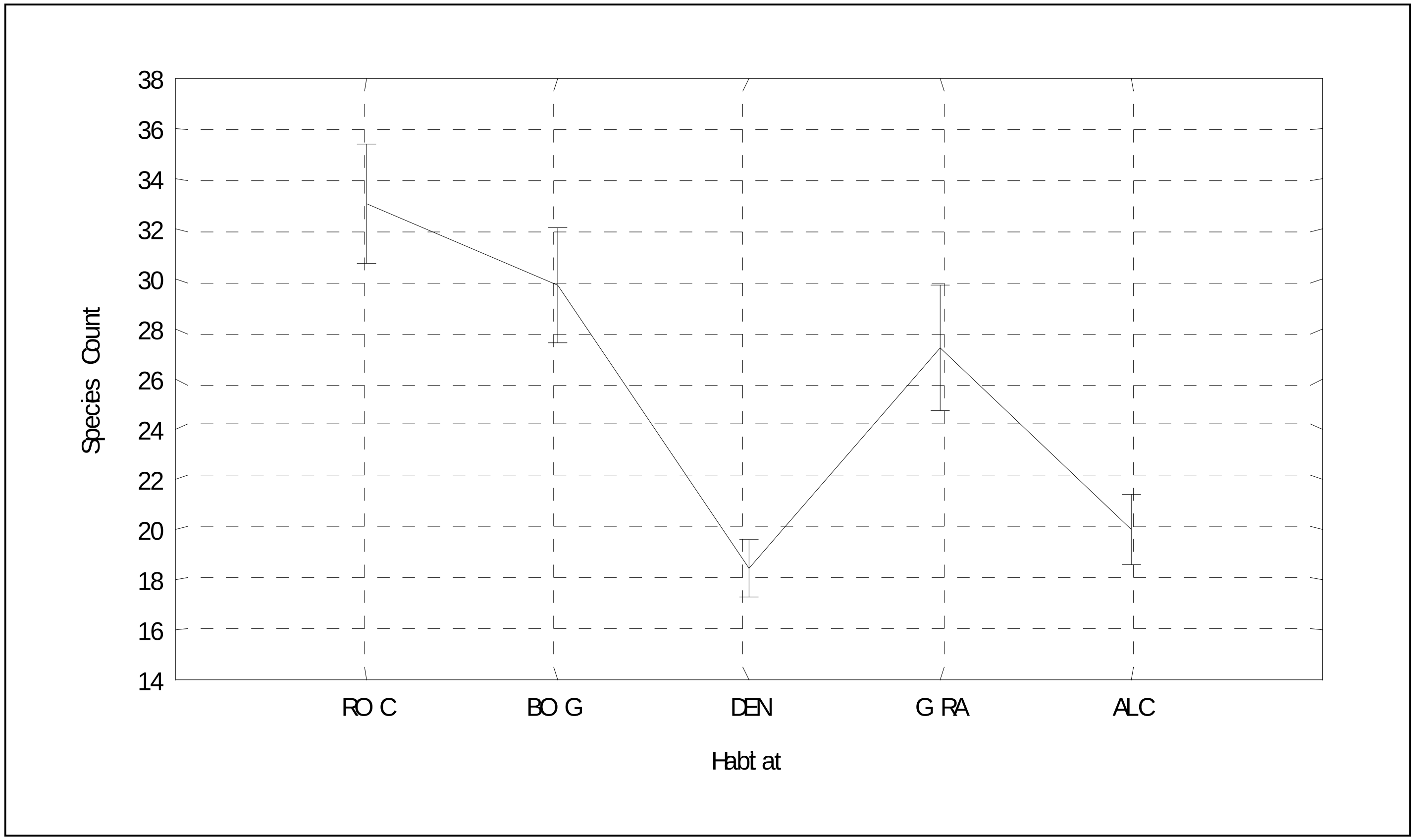


Figure 11: Variations of the species richness of the five vegetation communities as indicated by the vertical lines (Mean Standard error) (p=0.0003))

The post hoc test for the above analysis is shown in table 4 below.

Table 4: Post hoc Tukey test indicating source of variation between some of the vegetation communities of the Eastern African mountains based on the species richness (Between MSE = 84.593, df = 70.000)

Habitat	Rock outcrop	Bog	*Dendrosenecio*	Grassland	*Alchemilla*
Rock outcrop		0.796897	**0.000796***	0.346359	**0.010268***
Bog	0.796897		**0.014012***	0.926656	0.094797
Dendrosenecio	**0.000796***	**0.014012***		0.116521	0.996332
Grassland	0.346359	0.926656	0.116521		0.370358
Alchemilla	**0.010268***	0.094797	0.996332	0.370358	

The table indicates the pairs of vegetation communities that have significant variations in terms of species richness ($p < 0.05$). The numbers with asterix show the p-values of the pairs of vegetation communities with significant variations ($p < 0.05$) and includes rock vs. *Dendrosenecio*, rock vs. *Alchemilla* and bog vs. *Dendrosenecio* (Figure 12).

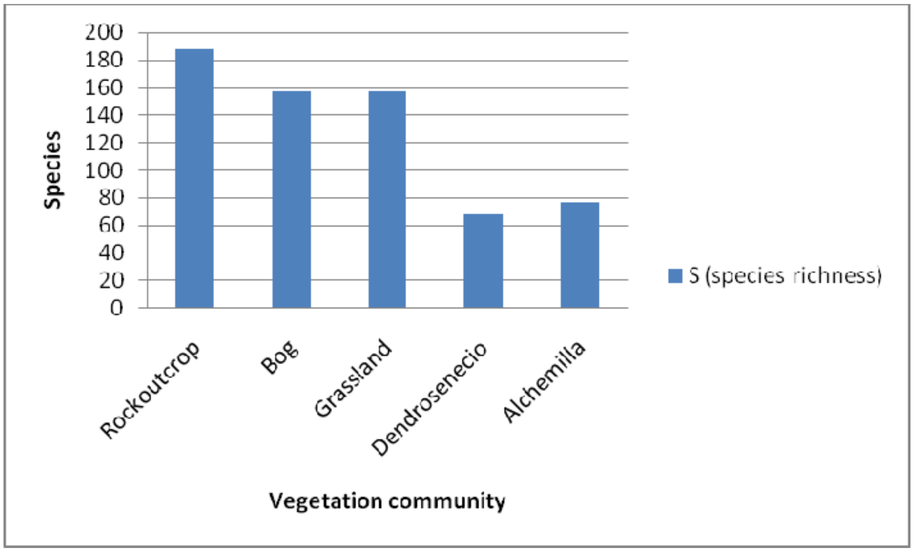


Figure 12: Species richness in five vegetation types in Afroalpine Zone of Eastern Africa

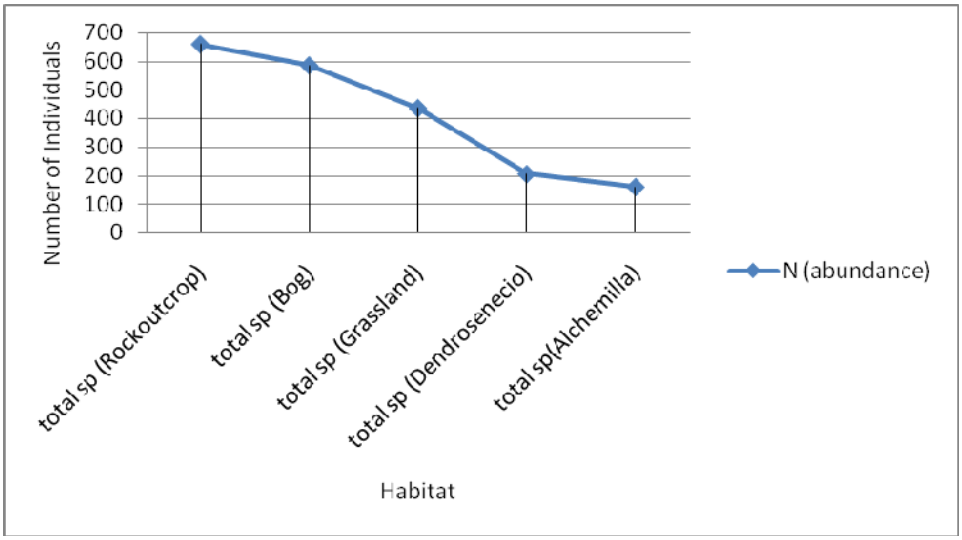


Figure 13: Line graph showing species abundance among the Afroalpine vegetation communities

Plant species abundance similarly exhibited similar trend with species richness where rock outcrop, bog and grassland vegetation communities respectively showing the highest abundance. *Alchemilla* community showed the least abundance (figure 13).

2.3.5 Comparison of Species Diversity, richness and Abundance in the Afroalpine zone of Eastern Africa

Among the six mountains analysed for species diversity, Simen (4.83 H') and Bale (4.47 H') [Ethiopian Mountains] had the highest diversity as revealed by the Shannon Wiener's diversity index (parenthesis) compared to other East Africa Mountains (Mt. Kenya, Kilimanjaro and Elgon). Mount Elgon (4.31 H') has the highest species diversity among the four East Africa Mountains followed by Mt. Kilimanjaro (4.12 H') and Mt. Kenya (4.06 H') while Mt. Ruwenzori, the only wet mountain among the six was the least species diverse (3.77 H'). The same trend was observed in terms of species richness where Simen was the most species rich among the six mountains (156 species) followed by Bale (119 species) and Elgon (93 species). Mount Ruwenzori was the most species poor (57 species) (Table 5; Figure 15). Abundance too exhibited similar trend with Simen (515 individuals) and Ruwenzori (239 individuals) having the most and least abundance level respectively (Figure 14 and table 5).

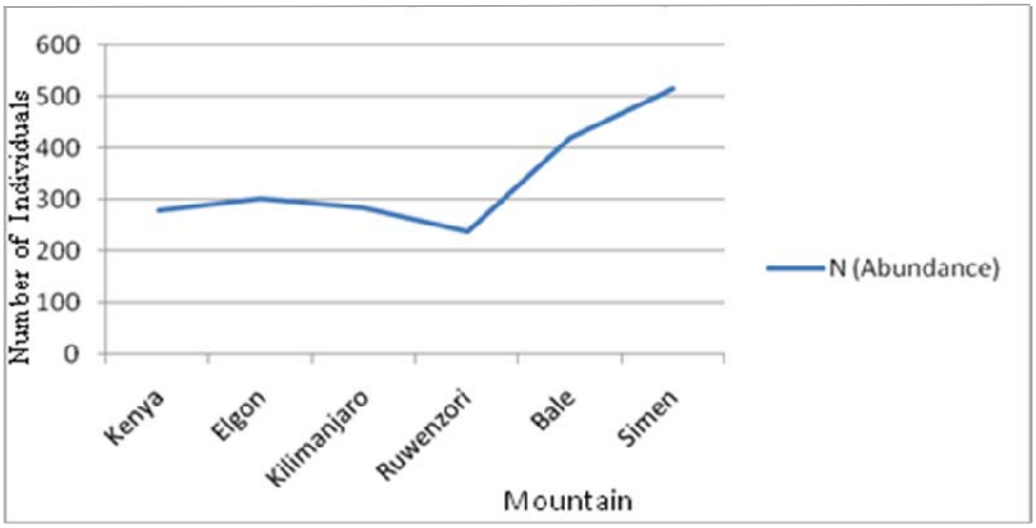


Figure 14: Line graph showing Abundance between the six Eastern African mountains

One way ANOVA (single factor) analysis between the six mountains of East Africa and Ethiopia indicate (table 5) that species count (species richness) for Mt. Simen (156 species) is significantly higher than the rest of the mountains (Figure 15), that is $P< 0.05$ (F (5, 69) =15.794; df= df = 69.0) for all other mountains and Mt. Simen while there is no significant differences between the species richness of other mountains ($P>0.05$). The post hoc test for the above analysis is shown in table 6.

Table 5: Intermountain Species Diversity, richness, Abundance and evenness

Mountain	S	N	d	J'	H'	1−Lambda'
Kenya	75	280	13.13	0.94	4.06	0.98
Elgon	93	304	16.09	0.95	4.30	0.99
Kilimanjaro	81	285	14.15	0.94	4.12	0.98
Rwenzori	57	239	10.23	0.93	3.76	0.98
Bale	119	421	19.53	0.94	4.49	0.99
Simen	156	515	24.82	0.96	4.8	0.99

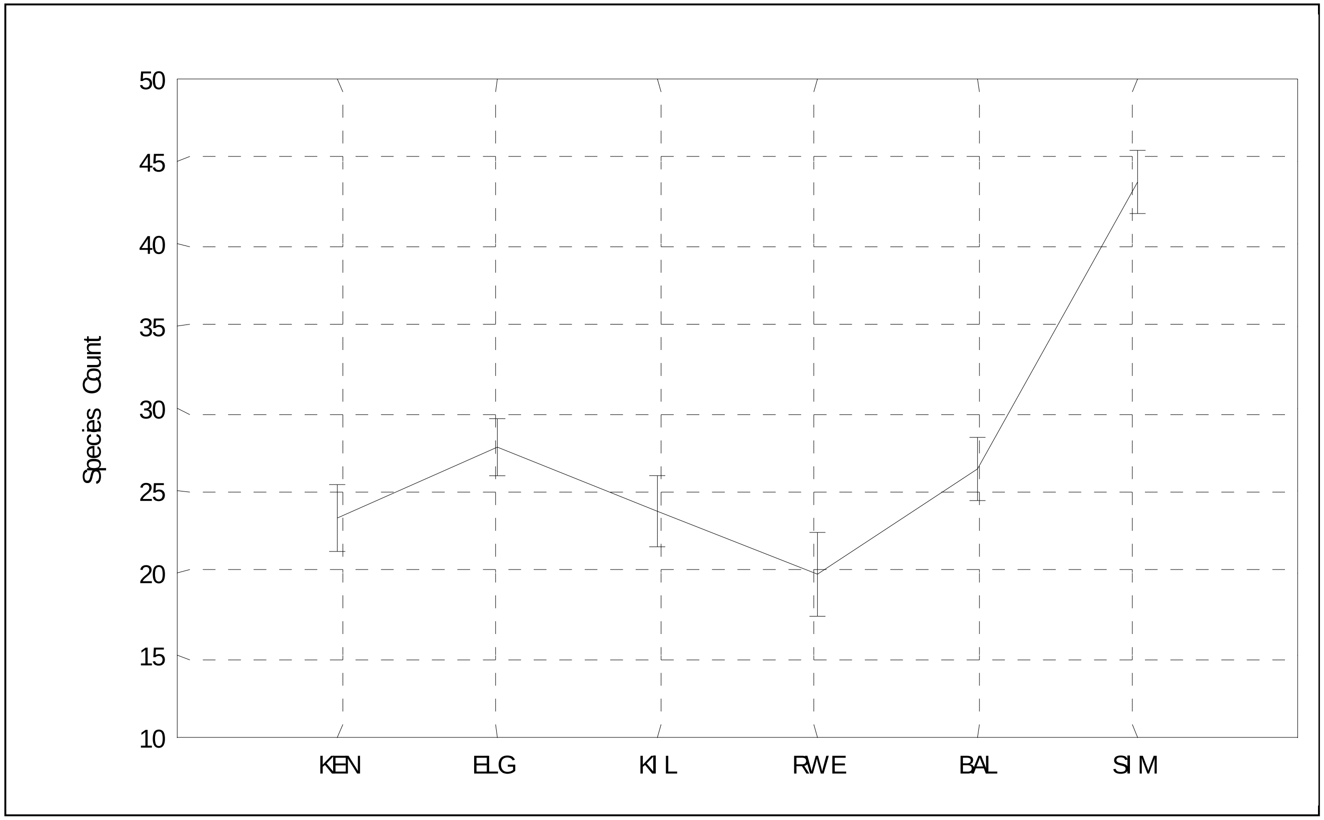


Figure 15: Variations of the species richness of the six mountains of Eastern Africa as indicated by the vertical lines (Mean Standard error) (F (5, 69) =15.794, p=.0.001; df= 69.00)

Table 6: Tukey test outcome indicating source of variation between Eastern African Mountains based on the species richness

(F[5, 69]=15.794; df = 69.000; p= 0.001)

MOUNTAIN	Kenya	Elgon	Kilimanjaro	Ruwenzori	Mt. Bale	Simen
Kenya		0.724574	0.999993	0.863016	0.894466	**0.000129**
Elgon	0.724574		0.801219	0.132988	0.997352	**0.000146**
Kilimanjaro	0.999993	0.801219		0.795506	0.941730	**0.000129**
Rwenzori	0.863016	0.132988	0.795506		0.216009	**0.000129**
Bale	0.894466	0.997352	0.941730	0.216009		**0.000129**
Simen	**0.000129**	**0.000146**	**0.000129**	**0.000129**	**0.000129**	

The p− values in bold format indicate significant variations. Here it reveals that the species count or richness in Simen Mountain is significantly higher than all other mountains. However the species richness between any other pair of mountain is not significantly different from each other ($p>0.05$).

2.3.5.1 Analysis of Similarities (ANOSIM) and Species Contribution

Analysis of similarities (ANOSIM) was performed on Primer to compare the five vegetation types (rock outcrop, bog, grassland, *Dendrosenecio* and *Alchemilla*). The automatically generated table summarizing the computations and Global test summary statistic is given in table 7 below.

Global Test

Sample statistic (Global R): 0.386

Significance level of sample statistic: 0.1%

Number of permutations: 999 (Random sample from a large number)

Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Table 7: Pairwise comparison of five vegetation communities using ANOSIM (R: 0.386; significance level: 0.1%; No. of permutations 999)

Groups	**R Statistic**	**Significance level (%)**	**Possible permutations**	**Actual Permutations**	**Number observed**
Rock outcrop and Bog	0.469	0.1	Too many	999	0
Rock outcrop and Grassland	0.204	0.3	Too many	999	2
Rock outcrop and *Dendrosenecio*	0.369	0.1	84672315	999	0
Rock outcrop and *Alchemilla*	0.418	0.1	3108105	999	0
Bog and Grassland	0.43	0.1	Too many	999	0
Bog and *Dendrosenecio*	0.509	0.1	84672315	999	0

Bog and *Alchemilla*	0.394	0.1	3108105	999	0
Grassland and *Dendrosenecio*	0.474	0.1	13037895	999	0
Grassland and *Alchemilla*	0.259	0.9	735471	999	8
Dendrosenecio and *Alchemilla*	0.257	1.8	75582	999	17

The pair wise tests comparisons of ANOSIM assessment between the five vegetation types reveal significant difference between the pairs (vegetation communities are recognizable or are heterogeneous), with significance level less than 5% in all the vegetation types (0.1 to 1.8 %) (Table 7). However the R values which gives an absolute measure of how separated the groups are (Figure16), on a scale of 0 (indistinguishable) to 1 (all similarities within vegetation types are less than any similarities between vegetation types) show various levels of separation.

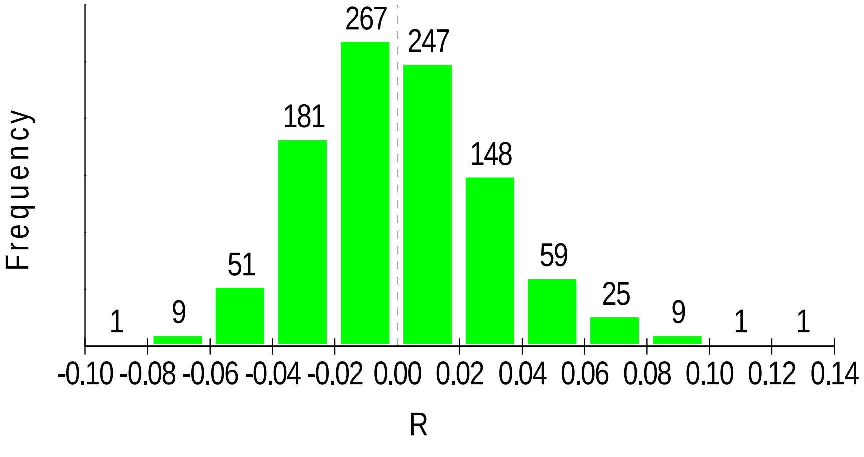


Figure 16: ANOSIM graph for the five vegetation types showing R−Values

2.3.5.2 Species Contribution to Similarity (SIMPER) among the vegetation communities

In order to compare the various vegetation communities and mountains in their species composition, it is important to identify which species primarily account for the above observed assemblage difference between the five vegetation types and six mountains. Species Contribution to Similarity (SIMPER) was used to quantify the contribution of each species in terms of percentage. The top five species from each vegetation type or mountain is listed in a table form as well as the first ten species contributing to dissimilarity between each pair of vegetation types or mountains. The results of the SIMPER analysis between vegetation communities revealing the contribution of each species is given in the form of percentage similarity/dissimilarity within and between vegetation communities in tabulation format (Table 8 and Table 9). The first five species (contributing most to the observed pattern) are listed for each vegetation community followed by the first ten species between each pair of vegetation communities.

Generally the vegetation communities from East Africa Mountains (Mt Kenya, Kilimanjaro and Mt Elgon) have closer affinities to each other as they cluster together (have more common species). This was also true for the plots of the various vegetation types within the Ethiopian Mountains. When species composition of single vegetation community was compared, such as the plots of rock outcrops or bogs or grasslands, the distribution of the plots generally takes a similar pattern where those plots from East Africa sub–region aggregates together due to higher degree of similarities between their species (Figure 17−19).

Table 8: Species Contribution to Similarities (SIMPER) in the five vegetation types of Afroalpine Zone

Species	**Average abundance**	**Average similarity**	**Similarity/SD**	**Contribution %**	**Cumulative %**
Helichrysum citrispinum	0.8	1.93	1.22	6.94	6.94
Arabis alpina	0.75	1.72	1.07	6.19	13.13
Cerastium octandrum	0.75	1.57	1.06	5.66	18.79
Sagina afroalpina	0.75	1.57	1.07	5.64	24.43
Asplenium aethiopicum	0.65	1.20	0.79	4.32	28.74
Ranunculus oreophytus	0.90	2.83	1.81	8.80	8.80
Crassula granvikii	0.85	2.49	1.44	7.74	16.54
Cardamine obliqua	0.75	1.95	1.03	6.05	22.59
Carex monostachya	0.75	1.88	1.06	5.84	28.43
Haplocarpha rueppellii	0.70	1.62	0.92	5.04	33.46
Koeleria capensis	0.81	2.65	1.25	11.34	11.34
Luzula abyssinica	0.69	1.77	0.87	7.65	18.98
Cerastium octandrum	0.69	1.70	0.86	7.35	26.34
Helichrysum forskahlii	0.56	0.99	0.63	4.26	30.59
Erica arborea	0.50	0.88	0.53	3.80	34.40
Cerastium octandrum	0.82	3.63	1.32	10.63	10.63
Alchemilla argyrophylla	0.82	3.34	1.35	9.8	20.43
Galium ruwenzoriense	0.73	2.95	0.98	8.67	29.10
Festuca abyssinica	0.73	2.84	0.98	8.34	37.43
Arabis alpina	0.64	2.36	0.77	6.92	44.36
Cardamine obliqua	0.63	1.73	0.72	7.57	7.57
Peucedanum kerstenii	0.50	1.11	0.51	4.86	12.43
Helichrysum stuhlmannii	0.50	1.11	0.51	4.86	17.29
Galium ruwenzoriense	0.50	1.11	0.51	4.86	22.15
Alchemilla argyrophylla ssp. argyrophylla	0.50	1.11	0.51	4.86	17.01

Table 9: Pairwise Comparison between the five vegetation community types from Six Eastern Africa countries

Group rock outcrop & bog; average dissimilarity 81.64%; total no. of species 158						
Species	Average abundance 1	Average abundance 2	Average dissimilarity	Dissimilarity/Standard deviation	Contribution %	Cumulative %
Ranunculus oreophytus	0.10	0.90	1.36	1.87	1.67	1.67
Carex monostachya	0.00	0.75	1`.24	1.58	1.51	3.18
Arabis alpina	0.75	0.05	1.22	1.49	1.50	4.68
Helichrysum citrispinum	0.80	0.15	1.19	1.42	1.50	6.13
Crassula granvikii	0.25	0.85	1.18	1.34	1.45	7.58
Limosella major	0.00	0.70	1.14	1.40	1.39	8.98
Cardamine obliqua	0.15	0.75	1.14	1.31	1.39	10.37
Asplenium aethiopicum	0.65	0.05	1.04	1.22	1.27	11.64
Subularia monticola	0.05	0.60	1.02	1.12	1.25	12.88
Crepis dianthoseris	0.60	0.25	0.93	1.03	1.14	14.02
Group: Rock outcrop & grassland; average dissimilarity 79.19%; total of 150 species						
Arabis alpina	0.75	0.06	1.26	1.47	1.59	1.59
Koeleria capensis	0.3	0.81	1.11	1.19	1.40	3.00
Helichrysum citrispinum	0.80	0.31	1.08	1.17	1.36	4.36

Asplenium aethiopicum	0.65	0.06	1.07	1.20	1.35	5.71
Sagina afroalpina	0.75	0.31	1.03	1.15	1.30	7.01
Crepis dianthoseris	0.60	0.44	0.91	0.96	1.15	8.16
Erica arborea	0.45	0.50	0.88	0.94	1.11	9.27
Helichrysum forskahlii	0.55	0.56	0.88	0.99	1.11	10.37
Alchemilla microbetula	0.55	0.44	0.87	0.97	1.09	11.47
Pentaschistis borussica	0.40	0.44	0.87	0.94	1.09	12.56
Group: Bog & grassland; average dissimilarity 82.41%; total of 145 species						
Crassula granvikii	0.85	0.06	1.51	1.76	1.83	1.83
Ranunculus oreophytus	0.90	0.25	1.35	1.40	1.64	3.470.75
Cardamine obliqua	0.75	0.06	1.33	1.42	1.62	5.09
Carex monostachya	0.75	0.13	1.28	1.37	1.55	6.64
Limosella major	0.70	0.00	1.26	1.38	1.53	8.17
Haplocarpha rueppellii	0.70	0.13	1.18	1.26	1.44	9.60
Subularia monticola	0.60	0.00	1.15	1.14	1.40	11.0
Koeleria capensis	0.40	0.81	1.11	1.05	1.34	12.35
Sagina afroalpina	0.60	0.31	1.00	1.02	1.22	13.56
Helichrysum forskahlii	0.45	0.56	0.94	0.96	1.14	14.70
Group: Rock outcrop & *Dendrosenecio*; average dissimilarity 79.64%; total of 127 species						
Helichrysum	0.80	0.00	1.58	1.78	1.99	1.99

citrispinum						
Festuca abyssinica	0.25	0.73	1.25	1.18	1.57	3.56
Cardamine oblique	0.15	0.64	1.24	1.14	1.55	5.11
Sagina afroalpina	0.75	0.27	1.19	1.20	1.50	6.61
Galium ruwenzoriense	0.30	0.73	1.18	1.14	1.48	8.09
Asplenium aethiopicum	0.65	0.18	1.17	1.13	1.47	9.56
Luzula abyssinica	0.60	0.18	1.14	1.10	1.43	10.99
Alchemilla argyrophylla	0.40	0.82	1.10	1.07	1.39	12.37
Crepis dianthoseris	0.60	0.27	1.10	1.03	1.38	13.75
Helichrysum forskahlii	0.55	0.36	1.07	0.98	1.34	15.09`
Group: Bog & Dendrosenecio; average dissimilarity 79.89%; total of 110 species						
Crassula granvikii	0.85	0.09	1.68	1.71	2.11	2.11
Ranunculus oreophytus	0.90	0.18	1.64	1.60	2.06	4.17
Carex monostachya	0.75	0.00	1.58	1.60	1.98	6.15
Galium ruwenzoriense	0.15	0.73	1.48	1.28	1.85	8.00
Limosella major	0.70	0.00	1.46	1.40	1.83	9.82
Arabis alpina	0.05	0.64	1.44	1.20	1.80	11.63
Haplocarpha rueppellii	0.70	0.09	1.41	1.33	1.76	13.39
Subularia monticola	0.60	0.00	1.35	1.15	1.68	15.07
Festuca abyssinica	0.35	0.73	1.27	1.07	1.59	16.66
Luzula abyssinica	0.65	0.18	1.26	1.16	1.58	18.24

Group: Grassland & Dendrosenecio; average dissimilarity 84.82%; total of 123 species						
Koeleria capensis	0.81	0.18	1.65	1.40	1.95	1.95
Alchemilla argyrophylla	0.13	0.82	1.64	1.53	1.94	3.89
Arabis alpina	0.06	0.64	1.51	1.19	1.78	5.66
Cardamine obliqua	0.06	0.64	1.46	1.19	1.72	7.39
Galium ruwenzoriense	0.25	0.73	1.44	1.17	1.70	9.09
Luzula abyssinica	0.69	0.18	1.43	1.19	1.69	10.77
Festuca abyssinica	0.31	0.73	1.36	1.11	1.61	12.38
Anthoxanthum nivale	0.13	0.55	1.17	1.02	1.38	13.77
Carduus keniensis	0.25	0.55	1.16	1.00	1.37	15.14
Helichrysum forskahlii	0.56	0.36	1.15	0.99	1.35	16.49
Group: Rock outcrop & Alchemilla; average dissimilarity 84.04%; total of 134 species						
Helichrysum citrispinum	0.80	0.25	1.28	1.28	1.52	1.52
Arabis alpina	0.75	0.25	1.21	1.23	1.44	2.96
Sagina afroalpina	0.75	0.25	1.19	1.24	1.41	4.37
Crepis dianthoseris	0.60	0.00	1.16	1.14	1.38	5.75
Cardamine obliqua	0.15	0.63	1.14	1.13	1.36	7.1
H. forskahlii	0.55	0.25	1.08	1.01	1.28	8.38
Asplenium aethiopicum	0.65	0.38	1.05	1.03	1.25	9.63
Luzula abyssinica	0.60	0.38	1.04	1.01	1.23	10.86
H. stuhlmannii	0.00	0.05	0.99	0.96	1.18	12.04
P. kerstenii	0.05	0.50	0.99	0.96	1.18	13.22

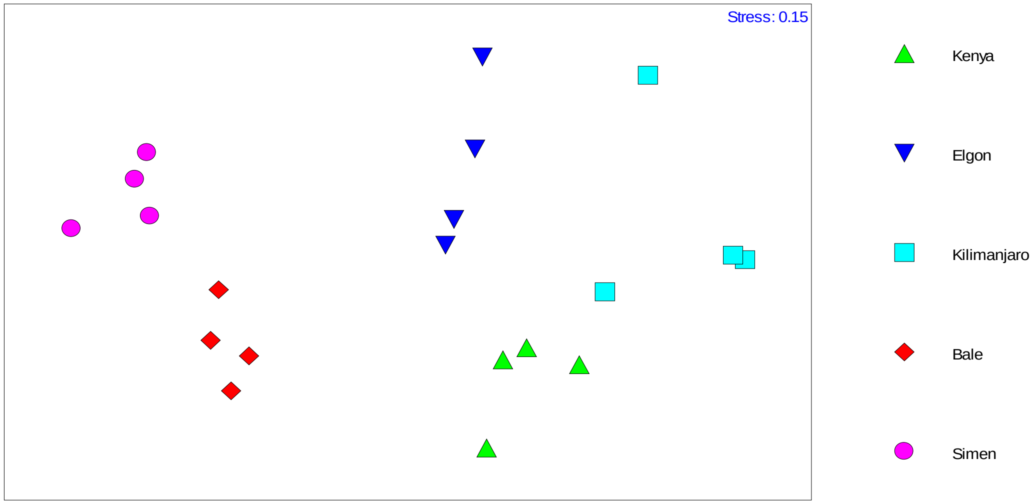


Figure 17: Comparison between species composition of the rock outcrop plots from Eastern Africa mountains using MDS graph

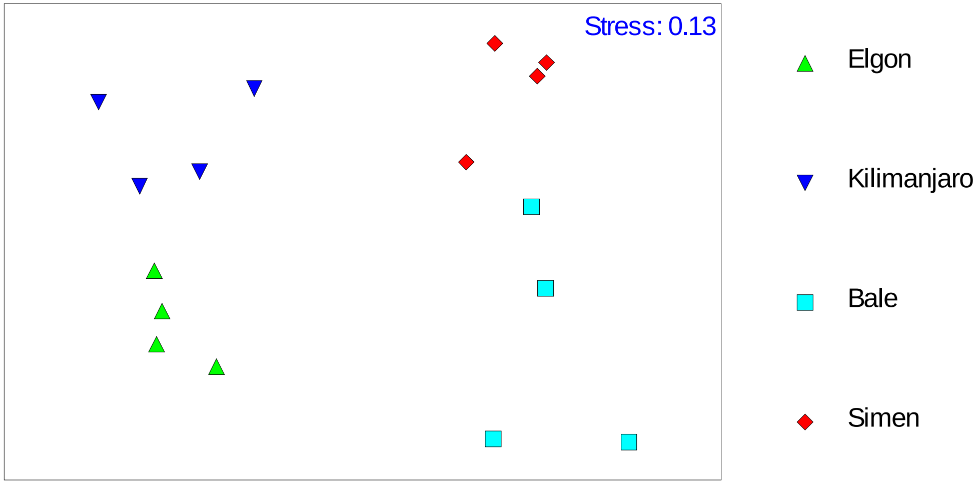


Figure 18: Comparison between species composition of the grassland plots from Eastern Africa mountains as revealed by MDS graph

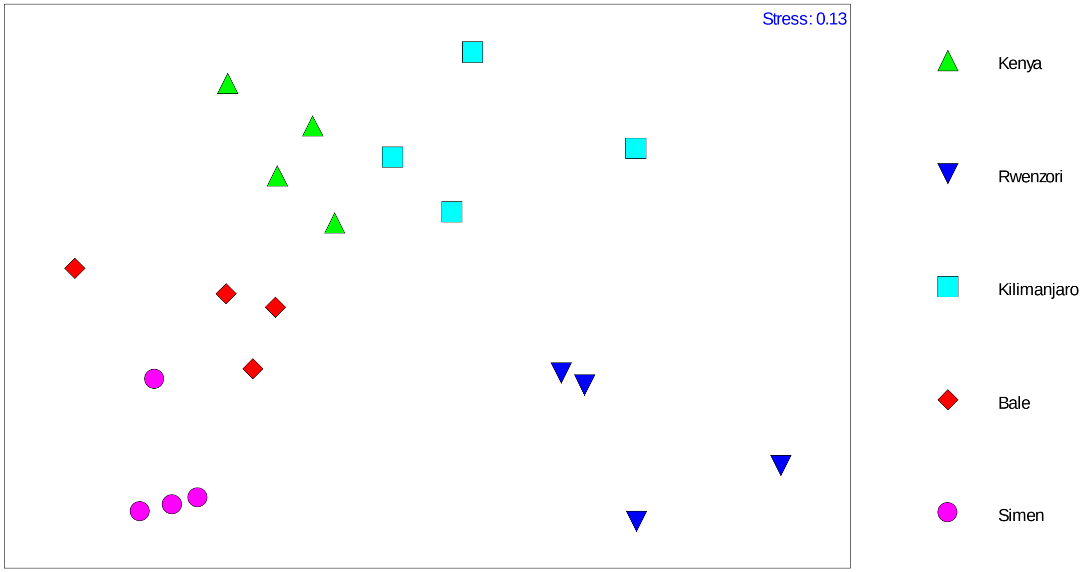


Figure 19: Comparison between species composition of the bog plots from Eastern Africa mountains as revealed by MDS graph

The genus *Dendrosenecio* was absent from Ethiopian Mountains since it is endemic to East Africa mountains. Comparisons of the plots of *Dendrosenecio* show clear distinction between Mt Ruwenzori, Elgon and Kenya. The differences between the mountains of Eastern Africa are listed in table 10.

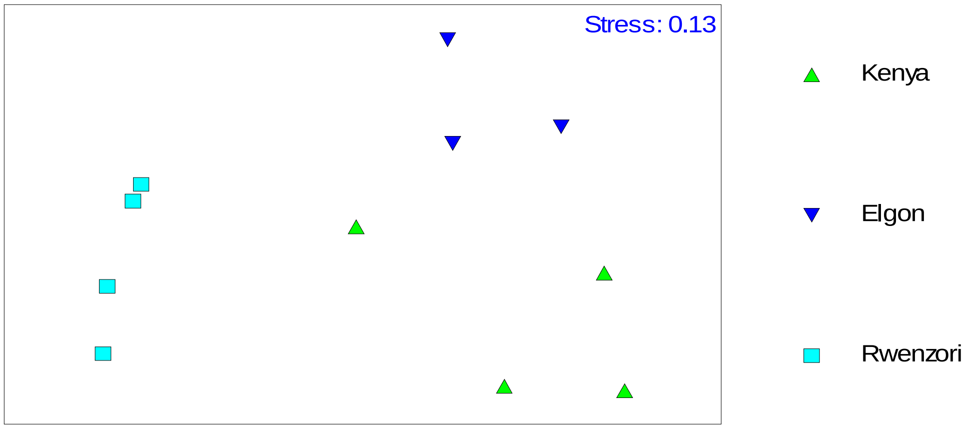


Figure 20: Comparison between species composition of the *Dendrosenecio* plots from East Africa Mountains as revealed by MDS graph

Table 10: Summary of the differences between the six mountains of East Africa and Ethiopia

Mountain	Nature of Formation	Age (MY BP)	Location	Rock type	Seasonality of rainfall	Mean Annual rainfall	Soil type
Kenya	Volcanic	2−3	Eastern arm	Chief rock present in addition to Kenyte and phonolite is basalt−are 2 varieties: − Massive olivine−basalt of the alpine zone (often columnar. Fissile olivine−basalt−occurs in the forest zone. Lavas of Kenya discharged in order: phonolite−Kenyte−Basalt (igneous rocks)	Bimodal−March to June (long rains) and October−December (Short rains	1500−2500 mm	−Lithosols characterised by shallow depth & stony occurring mainly in rock outcrops −Rankers & Gleysols: dark & very rich in organic matter, on top of brown, sandy, mottled loams occur on valley bottoms (*Dendrosenecio* vegetation type −Regosols−on ridges and Morraines (*Dendrosenecio*).
Elgon	Volcanic	22	Between eastern and Western(away from the rift)	Lava of Elgon is alkaline−Mainly nephilites and phonolites. The alpine region is covered by agglomerates and relatively young lava (1 % of entire elgon rock)	Bimodal−March to June (long rains) and October−December (Short rains	890−1525 mm	Common soils are: dystric (or Fibric) histosols with soil PH 4.5−5.7; Poorly developed rankers and Regosols (profile from 4190 was classified as rankers but was transition to Gleysols of lower slopes. True bogs/peat soils with high organic content common on valley bottoms (bog vegetation type Soils in Caldera are Regosols and humic Gleysols
Kilimanjaro	Volcanic	1−2	Eastern arm	Kilimanjaro rocks include Kenyte (foot of Kibo) & phonolitic trachytes,	Bimodal−March to May (long rains) and	250−500 mm in the Afroalpine	-Lithosols −Rankers & Gleysols (in valley bottoms)

				argitic−trachytes that often contain olivine, nepheline−phonolite and nephelinites. (range from sub−acidic rocks−trachytes & phonolitic obsidians to ultra−basic limburgite	October−December (Short rains		−Regosols−on ridges and slopes
Ruwenzori	Uplift	2	Western arm	Is a block of Eozoic rocks (gneisis and schists)−metamorphic rocks: Mica−schist, amphibolites, Calc−schists, quartzites, Muscovites and Cordierite−schists	Rains throughout the year (300 days)	5000 mm	Acidic soils-Histosol and occasionally Regosols and Rankers
Bale	Uplift/doming	Miocene and Oligocene (25−38)	Eastern arm	Basaltic and trachitic parent rock, agglomerates & tuffs. Vast quantities of basaltic lava covered large portion of underlying Mesozoic rock	Unimodal−Single wet season: March−October; November−February is dry season	800−1000 mm−alpine zone	Andosols, Lithosols −Rankers & Gleysols −Regosols
Simen	Uplift/doming	25	Western arm	Trappean Basaltic lava covered ancient Mesozoic rock	Unimodal: (April) May−October (November); December−March dry season. E−facing slopes receive more rain than W−facing slopes	500−1500 mm	Andosols

2.3.5.3 SIMPER among mountains

Species contributing to the similarity/dissimilarity within and between the six mountains are listed in table 11. The species listed in the table for each mountain and pair of mountains is the taxa that contribute most in the observed patterns. For example in Mt. Kenya *Dendrosenecio keniodendron*, *Carduus schimperi*, *Sagina afroalpina*, *Lobelia telekii* and *Anthoxanthum nivale* are the most abundant species that frequently occur in this mountain hence contributing greatly to the observed similarities among its vegetation communities. Similarly, the species contributing most to the observed similarities among the vegetation types of the Afroalpine zone of Mt. Elgon are: *Galium ruwenzoriense* (7.6%), *Helichrysum formosissimum* (7.5%), *Luzula abyssinica* (5.9%), *Koeleria capensis* (4.93) and *Geranium arabicum* (3.9%).

The average similarity between the vegetation types of Mt Kilimanjaro is approximately 40.0% and the similarity pattern is mainly contributed by the most abundant and frequently occurring species such as *Erica arborea* (8.8%), *Helichrysum newii* (6.8%), *H. forskahlii* (6.8), *Luzula abyssinica* (5.8%) and *Euryops dacrydioides* (5.6%). For Mt Rwenzori the top five species frequently occurring in the vegetation communities are *Dendrosenecio advinalis* (10.4%), *Helichrysum stuhlmannii* (8.4%), *Alchemilla argyrophylla* ssp. *argyrophylloides* (8.2%) and *Galium ruwenzoriense* (6.7%). The average similarity between the vegetation communities of Mt Ruwenzori is 51.6%.

In the case of Ethiopian Mountains, Bale and Simen, *Colpodium hedbergii* (5.2– 5.6%) and *Cerastium octandrum* (4.5–5.0%) are among the species contributing to the observed similarities between the vegetation communities of these mountains. *Dicrocephala chrysanthemifolia* (6.7%), *Haplocarpha rueppellii* (5.6%) and *Galium acrophyum* (5.1%) are the other frequently occurring species in the vegetation communities of Bale Mountain. Similarly *Sagina afroalpina* (4.5%), *Lobelia rhynchopetalum* (3.8%) and *Crassula granvikii* (3.5%) are the common species in Simen Mountains that contribute to the similarities of its vegetation communities.

For the pairwise comparison between the mountain pair, Mt. Kenya and Elgon show total dissimilarity of 74.0% that are attributed to endemic species of each mountain as well as the frequent species in each mountain. For example *D. keniodendron*, which is Mt Kenya endemic and *D. elgonensis* that is Mt Elgon endemic are the two most important species that distinguishes between the vegetation communities of the Afroalpine zones of the two mountains. Other species that account for the dissimilarity between Mt Kenya and Elgon are the ones that are very abundant/frequent in one mountain but rare in the other mountain. For example *Carduus schimperi* with average abundance of 1% and 0.2% in Mt Kenya and Elgon respectively, *Koeleria capensis* with average abundance of 1% in Mt Elgon and 0.1% in Mt Kenya , *H. formosissimum* with average abundance of 0.3% in Mt Kenya compared to Mt Elgon with 1% average abundance. Other species with differential average abundance among Mt Kenya and Elgon are: *Geranium arabicum* (0.1% in Mt Kenya; 0.6% in Elgon), *Galium acrophyum* (0.7% in Kenya; 0.2% in Elgon), *Alchemilla microbetula* (0.7% in Kenya; 0.1% in Elgon), *G. ruwenzoriense* (0.3% in Kenya; 0.1% in Elgon) and *Sagina afroalpina* (1% in Kenya; 0.4% in Elgon) (Table 11).

Table 11: Most important species contributing to Similarities in the individual six Mountains and pairwise comparison among Eastern Africa

Group: Mt Kenya; average similarity is 42.38%; a total of 30 species from 12 plots						
Species	**Average abundance**	**Average similarity**	**Similarity/ Std Dev.**	**Contribution %**	**Cumulative %**	

Dendrosenecio keniodendron	1.00	4.44	5.52	10.47	10.47	
Carduus schimperi	0.92	3.70	2.02	8.74	19.21	
Sagina afroalpina	0.83	2.86	1.39	6.74	25.96	
Lobelia telekii	0.75	2.35	1.05	5.55	31.50	
Anthoxanthum nivale	0.75	2.24	1.05	5.29	36.79	
Group: Mt Elgon; average similarity is 38.87%' total of 34 species						
Galium ruwenzoriense	0.91	2.94	2.01	7.56	7.56	
Helichrysum formosissimum	0.91	2.91	2.02	7.49	15.05	
Luzula abyssinica	0.82	2.29	1.33	5.89	20.94	
Koeleria capensis	0.73	1.92	0.99	4.93	25.87	
Geranium arabicum	0.64	1.51	0.77	3.88	29.75	
Group: Mt Kilimanjaro; average similarity 39.95%; total of 29 species						
Erica arborea	0.92	3.50	2.02	8.76	8.76	
Helichrysum newii	0.83	2.72	1.40	6.81	15.57	
Helichrysum forskahlii	0.83	2.72	1.40	6.81	22.38	
Luzula abyssinica	0.75	2.30	1.03	5.75	28.14	
Euryops dacrydioides	0.75	2.23	1.06	5.58	33.72	
Group: Bale; average similarity 31.44%; total of 38 species						
Dicrocephala chrysanthemifolia	0.75	2.09	1.05	6.65	6.65	
Haplocarpha rueppellii	0.69	1.76	0.88	5.59	12.24	
Colpodium hedbergii	0.69	1.65	0.89	5.23	17.47	
Galium acrophyum	0.63	1.61	0.76	5.12	22.60	
Cerastium octandrum	0.69	1.58	0.90	5.01	27.61	
Group: Simen; average similarity 35.62%; total of 61 species						
Colpodium hedbergii	1.00	2.35	9.00	6.61	6.61	
Cerastium octandrum	0.92	1.97	2.14	5.52	12.13	
Sagina afroalpina	0.83	1.59	1.42	4.47	16.60	
Lobelia rhynchopetalum	0.75	1.36	1.08	3.83	20.43	
Crassula granvikii	0.75	1.26	1.07	3.53	23.95	
Group: Ruwenzori; average similarity 51.60%; total of 18 species						
Cardamine obliqua	1.00	5.37	3.90	10.40	10.40	

Dendrosenecio advinalis	0.92	4.35	1.88	8.44	18.84	
Helichrysum stuhlmannii	0.92	4.32	1.89	8.38	27.22	
Alchemilla argyrophylla	0.92	4.23	1.94	8.2	35.42	
Galium ruwenzoriense	0.83	3.45	1.32	6.68	42.10	
Group: Kenya & Elgon; average dissimilarity 74.75%; total of 83 species						
Species	Average abundance 1	Average abundance 2	Average dissimilarity	Dissimilarity/ Std dev.	Contribution %	Cumulative %
Dendrosenecio keniodendron	1.00	0.00	2.01	6.22	2.69	2.69
Carduus schimperi	0.92	0.18	1.54	1.71	2.05	4.740.08
Koeleria capensis	0.08	0.73	1.43	1.43	1.91	6.65
Helichrysum formosissimum	0.25	0.91	1.40	1.47	1.88	8.53
Geranium arabicum	0.08	0.64	1.29	1.22	1.73	10.26
D. elgonensis ssp. barbatipes	0.00	0.64	1.25	1.27	1.67	11.93
Galium acrophyum	0.67	0.18	1.23	1.20	1.65	13.58
Alchemilla microbetula	0.67	0.09	1.23	1.28	1.64	15.22
Galium ruwenzoriense	0.33	0.91	1.22	1.27	1.63	16.86
Sagina afroalpina	0.83	0.36	1.21	1.17	1.61	18.47
Group: Mt Kenya & Kilimanjaro; average dissimilarity 75.97%; a total of 71 species						
Dendrosenecio keniodendron	1.00	0.00	2.21	4.95	2.91	2.91
Carduus schimperi	0.92	0.00	2.03	2.69	2.67	5.59
Lobelia telekii	0.75	0.00	1.64	1.60	2.16	7.74
Euryops dacrydioides	0.00	0.75	1.60	1.63	2.11	9.85
Erica arborea	0.25	0.92	1.58	1.46	2.08	11.93
Helichrysum newii	0.17	0.83	1.58	1.55	2.08	14.01
Koeleria capensis	0.08	0.67	1.40	1.25	1.84	15.85
Sagina afroalpina	0.83	0.33	1.40	1.21	1.84	17.69
Galium acrophyum	0.67	0.17	1.38	1.19	1.82	19.51
Arabis alpina	0.58	0.08	1.31	1.10	1.73	21.23
Group: Mt Elgon & Kilimanjaro; average dissimilarity 73.25 %; a total of 86 species						

Galium ruwenzoriense	0.91	0.08	1.66	2.09	2.27	2.27
Euryops dacrydioides	0.00	0.75	1.45	1.65	1.98	4.25
Helichrysum newii	0.18	0.83	1.38	1.50	1.88	6.13
Helichrysum formosissimum	0.91	0.25	1.36	1.48	1.86	8.00
Erica arborea	0.27	0.92	1.36	1.42	1.86	9.85
Dendrosenecio elgonensis ssp. barbatipes	0.64	0.00	1.24	1.26	1.70	11.55
Lobelia telekii	0.64	0.00	1.24	1.27	1.69	13.24
Lobelia deckenii	0.00	0.58	1.18	1.13	1.61	14.85
Artemisia afra	0.55	0.00	1.11	1.06	1.52	16.37
Agrostis gracilifolia	0.55	0.08	1.11	1.04	1.51	17.88
Group: Mt Kenya & Bale; average dissimilarity is 82.59%; a total of 101 species						
Dendrosenecio keniodendron	1.00	0.00	2.09	5.14	2.54	2.54
Lobelia telekii	0.75	0.00	1.55	1.60	1.88	4.41
Dicrocephala chrysanthemifolia	0.00	0.75	1.54	1.60	1.87	6.28
Carduus schimperi	0.92	0.19	1.54	1.66	1.86	8.14
Anthoxanthum nivale	0.75	0.00	1.51	1.61	1.83	9.97
Alchemilla argyrophylla	0.75	0.00	1.51	1.61	1.83	11.81
Carex simensis	0.00	0.63	1.33	1.22	1.62	13.42
Festuca simensis	0.00	0.63	1.25	1.23	1.52	14.94
Swertia abyssinica	0.00	0.56	1.23	1.09	1.49	16.42
Colpodium hedbergii	0.25	0.69	1.22	1.16	1.47	17.90
Group: Mt Elgon & Bale; average dissimilarity is 85.27%; total no of species 113 species						
Galium ruwenzoriense	0.91	0.00	1.71	2.75	2.01	2.01
Helichrysum formosissimum	0.91	0.13	1.53	1.91	1.80	3.80
Dicrocephala chrysanthemifolia	0.09	0.75	1.33	1.46	1.56	5.36
Anthoxanthum nivale	0.64	0.00	1.26	1.27	1.47	6.84
Colpodium hedbergii	0.00	0.69	1.25	1.42	1.46	8.30
Dendrosenecio elgonensis ssp. barbatipes	0.64	0.00	1.18	1.27	1.39	9.69
Lobelia telekii	0.64	0.00	1.18	1.27	1.38	11.07
Geranium arabicum	0.64	0.19	1.14	1.14	1.34	12.41
Festuca simensis	0.00	0.63	1.14	1.24	1.34	13.75
Galium acrophyum	0.18	0.63	1.13	1.14	1.13	15.08
Group: Mt Kilimanjaro & Bale; average dissimilarity 85.19%; total no of species: 104 species						
Helichrysum newii	0.83	0.00	1.66	2.04	1.95	1.95
Erica arborea	0.92	0.13	1.65	1.88	1.94	3.89
Euryops dacrydioides	0.75	0.00	1.51	1.62	1.77	5.66
Dicrocephala chrysanthemifolia	0.08	0.75	1.47	1.45	1.73	7.39
Pentaschistis	0.67	0.00	1.43	1.33	1.68	9.07

borussica						
Colpodium hedbergii	0.00	0.69	1.36	1.39	1.60	10.67
Carex simensis	0.00	0.63	1.33	1.22	1.56	12.23
Conyza subscaposa	0.67	0.06	1.30	1.27	1.52	13.75
Haplocarpha rueppellii	0.17	0.69	1.29	1.22	1.52	15.27
Carduus keniensis	0.67	0.00	1.29	1.35	1.51	16.79
Group: Mt Kenya & Simen; average dissimilarity: 83.10%; total species: 137 species						
Dendrosenecio keniodendron	1.00	0.00	1.54	6.96	1.85	1.85
Lobelia rhynchopetalum	0.00	0.75	1.20	1.67	1.44	3.29
Colpodium hedbergii	0.25	1.00	1.17	1.67	1.41	4.70
Lobelia telekii	0.75	0.00	1.14	1.66	1.37	6.08
Anthoxanthum nivale	0.75	0.00	1.12	1.66	1.35	7.43
Alchemilla argyrophylla	0.75	0.00	1.12	1.66	1.35	8.78
Festuca simensis	0.00	0.75	1.12	1.66	1.35	10.13
Trifolium multinerve	0.00	0.67	1.03	1.38	1.24	11.37
T. cryptopodium	0.00	0.67	1.02	1.37	1.23	12.59
Rytidosperma subulata	0.00	0.67	1.01	1.37	1.22	13.82
Group: Mt Elgon & Simen; average dissimilarity: 88.24%; total species: 147 species						
Colpodium hedbergii	0.00	1.00	1.43	7.92	1.63	1.63
Galium ruwenzoriense	0.91	0.00	1.29	1.91	1.47	3.09
Helichrysum formosissimum	0.91	0.00	1.29	1.92	1.46	4.55
Lobelia rhynchopetalum	0.00	0.75	1.11	1.68	1.26	5.82
Crassula granvikii	0.00	0.75	1.06	1.68	1.20	7.02
Festuca simensis	0.00	0.75	1.05	1.67	1.18	8.20
Alchemilla microbetula	0.09	0.75	1.00	1.50	1.13	9.33
Trifolium multinerve	0.00	0.67	0.96	1.39	1.09	10.42
Rytidosperma subulata	0.00	0.67	0.95	1.38	1.07	11.49
Anthoxanthum nivale	0.64	0.00	0.94	1.29	1.06	12.56
Mt. Kilimanjaro & Simen; average similarity: 87.98%; total no of 140 species						
Colpodium hedbergii	0.00	1.00	1.53	6.58	1.74	1.74
Helichrysum newii	0.83	0.00	1.24	2.12	1.40	3.15
Lobelia rhynchopetalum	0.00	0.75	1.19	1.66	1.36	4.50
Euryops dacrydioides	0.75	0.00	1.12	1.67	1.27	5.78
Festuca simensis	0.00	0.75	1.11	1.65	1.27	7.04
Erica arborea	0.92	0.25	1.10	1.50	1.25	8.30
Pestaschistis borussica	0.67	0.00	1.05	1.36	1.19	9.48
Trifolium multinerve	0.00	0.67	1.02	1.37	1.16	10.65
Trifolium	0.00	0.67	1.02	1.36	1.16	11.80

cryptopodium						
Alchemilla microbetula	0.17	0.75	1.01	1.37	1.15	12.96
Group: Mt Bale & Simen; average dissimilarity: 74.34%; total no. of species: 130 species						
Trifolium multinerve	0.00	0.67	0.99	1.38	1.33	1.33
Crassula granvikii	0.19	0.75	0.96	1.34	1.29	2.62
Rytidosperma subulata	0.13	0.67	0.92	1.26	1.24	3.86
Trifolium cryptopodium	0.13	0.67	0.92	1.25	1.23	5.09
Crepis dianthoseris	0.19	0.67	0.89	1.20	1.19	6.28
Dicrocephala chrysanthemifolia	0.75	0.33	0.88	1.15	1.18	7.47
Carex simensis	0.63	0.17	0.86	1.15	1.18	7.47
Ranunculus oreophytus	0.25	0.58	0.83	1.06	1.12	9.74
Carduus schimperi	0.19	0.58	0.81	1.08	1.09	10.83
Haplocarpha rueppellii	0.69	0.42	0.77	1.04	0.04	11.87
Group: Mt Kenya & Ruwenzori; average dissimilarity 81.67%; total no of species: 68						
Dendrosenecio keniodendron	1.00	0.00	2.44	4.49	2.98	2.98
Carduus schimperi	0.92	0.00	2.44	2.60	2.74	5.72
Dendrosenecio advinalis ssp. *advinalis*	0.00	0.92	2.21	2.61	2.70	8.42
Helichrysum stuhlmannii	0.00	0.92	2.20	2.60	2.69	11.12
Sagina afroalpina	0.83	0.00	1.97	1.97	2.41	13.52
Lobelia wollastonii	0.00	0.75	1.96	1.62	2.40	15.92
Alchemilla johnstonii	0.08	0.83	1.82	1.69	2.13	18.15
Lobelia telekii	0.75	0.00	1.80	1.57	2.20	20.36
Cardamine obliqua	0.33	1.00	1.66	1.34	2.04	22.39
Galium acrophyum	0.67	0.00	1.66	1.33	2.03	24.42
Group: Mt Elgon & Ruwenzori; average dissimilarity 81.12 %; total no. of species 87						
Dendrosenecio advinalis ssp. *advinalis*	0.00	0.92	1.97	2.74	2.43	2.43
Helichrysum stuhlmannii	0.00	0.92	1.97	2.75	2.42	4.86
Lobelia wollastonii	0.00	0.75	1.74	1.65	2.14	7.00
Koeleria capensis	0.73	0.00	1.61	1.53	1.98	8.98
Cardamine obliqua	0.27	1.00	1.60	1.53	1.98	10.96
Helichrysum formosissimum	0.91	0.33	1.43	1.27	1.76	12.72
Geranium arabicum	0.64	0.08	1.41	1.20	1.74	14.46
Luzula abyssinica	0.82	0.33	1.36	1.20	1.68	16.14
Anthoxanthum nivale	0.64	0.17	1.36	1.15	1.68	17.82
Helichrysum forskahlii	0.64	0.08	1.35	1.20	1.67	19.49

Group: Mt. Kilimanjaro & Ruwenzori; average dissimilarity 83.65 %; total no. of species 73						
Dendrosenecio advinalis ssp. *Advinalis*	0.00	0.92	2.20	2.53	2.63	2.63
Helichrysum stuhlmannii	0.00	0.92	2.19	2.54	2.62	5.24
Lobelia wollastonii	0.00	0.75	1.95	1.60	2.33	7.57
Erica arborea	0.92	0.17	1.93	1.73	2.31	9.88
Helichrysum newii	0.83	0.00	1.91	1.99	2.28	12.17
Galium ruwenzoriense	0.08	0.83	1.84	1.65	2.20	14.36
Helichrysum forskahlii	0.83	0.08	1.83	1.74	2.19	16.56
Cardamine obliqua	0.25	1.00	1.83	1.54	2.19	18.74
Euryops dacrydioides	0.75	0.00	1.74	1.60	2.08	20.83
Pentaschistis borussica	0.67	0.00	1.68	1.30	2.00	22.83
Group: Mt Bale & Ruwenzori; average dissimilarity 90.06%; total no. of species 100						
Dendrosenecio advinalis ssp. *advinalis*	0.00	0.92	2.07	2.58	2.29	2.29
Helichrysum stuhlmannii	0.00	0.92	2.06	2.59	2.29	4.58
Alchemilla argyrophylla ssp. *argyrophylloides*	0.00	0.92	2.04	2.64	2.27	6.85
Galium ruwenzoriense	0.00	0.83	1.85	1.94	2.06	8.91
Alchemilla johnstonii	0.00	0.83	1.85	1.96	2.05	10.96
Lobelia wollastonii	0.00	0.75	1.83	1.61	2.03	12.99
Dichrocephala chrysanthemifolia	0.75	0.00	1.68	1.56	1.86	14.85
Cardamine obliqua	0.31	1.00	1.57	1.36	1.75	16.59
Haplocarpha rueppellii	0.69	0.00	1.54	1.37	1.71	18.31
Galium acrophyum	0.63	0.00	1.49	1.22	1.66	19.97
Group: Mt Simen & Ruwenzori; average dissimilarity 89.86%; total no. of species 132						
Dendrosenecio advinalis ssp. *advinalis*	0.00	0.92	1.48	2.86	1.65	1.65
Helichrysum stuhlmannii	0.00	0.92	1.48	2.87	1.65	3.30
Alchemilla argyrophylla ssp. *argyrophylloides*	0.00	0.92	1.47	2.89	1.64	4.94
Sagina afroalpina	0.83	0.00	1.35	2.06	1.51	6.44
Galium ruwenzoriense	0.00	0.83	1.34	2.06	1.49	7.93
Alchemilla johnstonii	0.00	0.83	1.33	2.07	1.48	9.42
Lobelia wollastonii	0.00	0.75	1.29	1.67	1.43	10.85

2.3.6 Community Description

The cover data of the sub-plots (5 sub–plots × 75 plots) were assessed in terms of percentage and was used to describe the various Afroalpine vegetation communities prevalent in the sampled plots from the five vegetation types across all the mountains sampled. The description of the vegetation communities outlined in table 12 (next page) was based on one or few dominant species in terms of cover to characterize the vegetation communities. For each of the vegetation types investigated one or few genera and species dominate the vegetation community and thus the names of the dominant genera and/or species are used to describe the vegetation communities. For example in bog vegetation type species of *Carex* such as *C. monostachya* and *C. runssoroensis* dominate the cover of the bog communities and thus the vegetation community is described as Carex bog community. However other bog species such as *Haplocarpha rueppellii*, *Subularia monticola*, and *Hydrocotyle sibthorpioides* among others are well represented in the bog community. In grassland community, usually the species of three genera viz: *Festuca*, *Agrostis*, and *Andropogon* are the dominant taxa. Other grass species are also well represented in grassland communities. These includes: *Koeleria capensis*, *Pentaschistis borussica*, *P. pictigluma*, *Pennisetum humile*. Non-grass species frequently occurring in grassland communities include *Alchemilla pedata*, *Helichrysum citrispinum* and *Euryops prostrata* among others.

In *Dendrosenecio* and *Alchemilla* vegetation communities the dominant species are those belonging to the two genera *Dendrosenecio* and *Alchemilla* respectively. There are no specific genera or species completely dominating in rock outcrop vegetation type. However members of the genera such as *Helichrysum*, *Festuca*, *Pentaschistis*, *Rytidosperma* and *Deschampsia* among others co–dominate in one or more mountains (Table 12).

Table 12: Summary of Community description from the five Afroalpine vegetation types

Mountain	**Habitat/plot No.**	**Community Description**
Elgon	Rock outcrop 1	*Festuca abyssinica−Helichrysum* dominated rock outcrop community
Elgon	Rock outcrop 2	*Helichrysum citrispinum−Agrostis sclerophylla* dominated rock outcrop community
Elgon	Rock outcrop 3	*Carex simensis−Crassula* cf *schimperi* dominated rock outcrop
Elgon	Rock outcrop 4	*Helichrysum citrispinum−Deschampsia flexuosa* dominated rock outcrop community
Elgon	Grassland 1	*Festuca abyssinica−Agrostis −Koeleria capensis−Pennisetum* dominated Grassland
Elgon	Grassland 2	*Festuca abyssinica−Geranium arabicum−Koeleria capensis−Agrostis* dominated Grassland
Elgon	Grassland 3	*Festuca abyssinica−Agrostis−Pennisetum humile* dominated Grassland community
Elgon	Grassland 4	*F. abyssinica−Pennisetum humile−Colpodium hedbergii−Koeleria capensis* dominated G/land
Elgon	*Dendrosenecio* 1	*Dendrosenecio elgonensis* ssp. *elgonensis−Alchemilla argyrophylla* dominated woodland
Elgon	*Dendrosenecio* 2	*D. elgonensis* ssp. *barbatipes−Alchemilla johnstonii−A. argyrophylla* dominated woodland
Elgon	*Dendrosenecio* 3	*D. elgonensis* ssp. *barbatipes−Alchemilla argyrophylla−A. johnstonii* dominated woodland
Ruwenzori	*Dendrosenecio* 1	*Dendrosenecio advinalis* ssp. *advinalis−Arabis alpina* dominated forest community
Ruwenzori	*Dendrosenecio* 2	*D. advinalis* var. *petiolatus−Luzula johnstonii−Lobelia wollastonii* dominated forest community
Ruwenzori	*Dendrosenecio* 3	*Dendrosenecio advinalis* dominated forest community
Ruwenzori	*Dendrosenecio* 4	*Dendrosenecio advinalis* var. *petiolatus−Arabis alpina* dominated alpine forest community
Ruwenzori	Bog 1	*Carex runssoroensis−Hydrocotyle sibthorpioides−Helichrysum formosissimum* bog community
Ruwenzori	Bog 2	*Carex runsoriensis−Helichrysum stuhlmannii−Isolepis fluitans* dominated bog community
Ruwenzori	Bog 4	*Carex runssoroensis−Alchemilla johnstonii* dominated bog community
Ruwenzori	*Alchemilla* 1	*Alchemilla argyrophylla* ssp. *argyrophylloides−A. johnstonii* dominated shrubland community

Ruwenzori	Alchemilla 2	*Alchemilla johnstonii−A. argyrophylla* dominated sclerophyllous shrubland community
Ruwenzori	Alchemilla 3	*Alchemilla argyrophylla* ssp. *argyrophylloides−A. johnstonii−A. triphylla* dominated shrubland community
Ruwenzori	Alchemilla 4	*Alchemilla argyrophylla* ssp. *argyrophylloides* dominated *Alchemilla* shrubland community
Kilimanjaro	Grassland 1	*Poa leptoclados−A. microbetula−Festuca abyysinica* dominated Grassland community
Kilimanjaro	Grassland 2	*Festuca abyssinica−Helichrysum citrispinum* dominated Grassland community
Kilimanjaro	Grassland 3	*Festuca abyssinica −Deschampsia flexuosa* dominated Grassland community
Kilimanjaro	Grassland 4	*Pentaschistis*/*Andropogon* TZ 0837 dominated Grassland community
Kilimanjaro	Bog 1	*Carex monostachya* dominated bog community
Kilimanjaro	bog 2	*Carex monostachya* dominated bog community
Kilimanjaro	bog 3	*Carex monostachya−Alchemilla johnstonii* dominated community
Kilimanjaro	bog 4	*Carex monostachya−Alchemilla johnstonii* dominated bog community
Kilimanjaro	Rock outcrop 1	*Deschampsia flexuosa−Helichrysum citrispinum−H. newii* dominated rock outcrop community
Kilimanjaro	Rock outcrop 2	*Pentaschistis borussica−Helichrysum forskahlii* dominated rock outcrop community
Kilimanjaro	Rock outcrop 3	*Helichrysum newii−Alchemilla johnstonii* dominated rock outcrop community
Kilimanjaro	Rock outcrop 4	*Helichrysum forskahlii−Pentaschistis borussica−Isolepis* dominated rock outcrop community
Bale	Rock outcrop 1	*Festuca* cf *macrophylla−Helichrysum citrispinum−Pentaschistis pictigluma* dominated rock outcrop
Bale	Rock outcrop 2	*Helichrysum citrispinum var citrispinum−Cineraria deltoidea−Crassula* dominated rock outcrop
Bale	Rock outcrop 3	*Festuca simensis−Pentaschistis pictigluma−Cineraria deltoidea−Crassula* dominated rock outcrop
Bale	Rock outcrop 4	*Carex simensis−Helichrysum citrispinum−Lobelia rhynchopetalum* dominated rock outcrop
Bale	bog 1	*Carex monostachya−Galium acrophyum* (ET−0014)−*Deschampsia caespitosa* dominated bog community
Bale	bog 2	*Carex monostachya−Deschampsia caespitosa−Galium acrophyum* dominated bog
Bale	bog 3	*Carex monostachya−Haplocarpha rueppellii−Eriocaulon* ET−0517 dominated bog
Bale	bog 4	*Carex monostachya−Subularia monticola−Alchemilla pedata* dominated bog
Bale	Grassland 1	*Festuca simensis−Alchemilla pedata* dominated grassland community
Bale	Grassland 2	*Festuca simensis−Euryops prostratus−Alchemilla pedata* dominated grassland
Bale	Grassland 3	*Andropogon* cf *lima−Festuca abyssinica−Alchemilla pedata* dominated grassland
Bale	Grassland 4	*Andropogon* cf *lima−Festuca simensis−Alchemilla pedata−Trifolium elgonensis* dominated grassland
Bale	*Alchemilla 1*	*Alchemilla haumannii* (84%)−*Alchemilla* cf *microbetula* dominated *Alchemilla* community
Bale	*Alchemilla 2*	*Alchemilla haumannii* (91%) dominated *Alchemilla* community
Bale	*Alchemilla 3*	*Alchemilla pedata* (94%) dominated *Alchemilla* community
Bale	*Alchemilla 4*	*Alchemilla microbetula−Alchemilla pedata−Isolepis fluitans* dominated *Alchemilla* community

Simen	Grassland 1	*Festuca simensis−Pentaschistis pictigluma−Andropogon* dominated Grassland community
Simen	Grassland 2	*Festuca simensis* (64%)−*Alchemilla abyssinica−Pentaschistis pictigluma* dominated community
Simen	Grassland 3	*Helictotrichon elegantum−Festuca simensis* dominated grassland
Simen	Grassland 4	*Festuca simensis−Carex monostachya−H. citrispinum−Pentaschistis pictigluma* dominated grassland
Simen	Rock outcrop 1	*Colpodium hedbergii−Plantago afra−Pentaschistis pictigluma* dominated rock outcrop community
Simen	Rock outcrop 2	*Plantago afra−Cotula abyssinica−Alchemilla microbetula−Gnaphalium unionis−Vulpia bromoides* dominated rock outcrop
Simen	Rock outcrop 3	*Colpodium hedbergii* (7%)−*Rytidosperma subulata* dominated rock outcrop
Simen	Rock outcrop 4	*Rytidosperma subulata−Vulpia bromoides−Crepis rueppellii−Lychnis abyssinica−Pentaschistis pictigluma* dominated rock outcrop
Simen	bog 1	*Carex monostachya* (60%)−*Alchemilla abyssinica−Pentaschistis pictigluma* dominated bog community
Simen	bog 2	*Cotula cryptocephala−Isolepis fluitans−Ranunculus oligocarpus* dominated bog
Simen	bog 3	*Carex monostachya−Haplocarpha rueppellii−Ranunculus oligocarpus−Cotula abyssinica* dominated bog
Simen	bog 4	*Cotula cryptocephala−Callitriche oreophila−Veronica anagalis−aquatica* dominated bog community
Kenya	Rock outcrop 1	*Dendrosenecio keniodendron−Festuca abyssinica−Pentaschistis borussica* dominated rock outcrop community
	Rock outcrop 2	*Festuca abyssinica−Dendrosenecio keniodendron−Alchemilla microbetula−Crepis dianthoseris* dominated rock outcrop
Mt. Kenya	Rock outcrop 3	*Lobelia telekii−Agrostis−Dendrosenecio keniodendron* dominated rock outcrop
Mt. Kenya	Rock outcrop 4	No data
Mt. Kenya	*Dendrosenecio 1*	*Dendrosenecio keniodendron−Festuca* pilgeri−*Senecio* cf *polyadenus* dominated *Dendrosenecio* woodland community
Mt. Kenya	*Dendrosenecio 2*	*Dendrosenecio keniodendron−Festuca pilgeri−Lobelia telekii* dominated *Dendrosenecio* woodland
Mt. Kenya	*Dendrosenecio* 3	No data
Mt. Kenya	*Dendrosenecio 4*	*Dendrosenecio keniodendron−Alchemilla johnstonii−Festuca pilgeri* dominated *Dendrosenecio* community
Mt. Kenya	Bog 1	*Carex monostachya* (32%)−*Festuca pilgeri−Haplocarpha rueppellii−Ranunculus oligocarpus* dominated bog community
Mt. Kenya	Bog 2	*Alchemilla microbetula−Lobelia gregoriana* subsp−*gregoriana−Festuca pilgeri−Haplocarpha rueppellii* dominated bog
Mt. Kenya	Bog 3	*Carex monostachya* (61%)−*Ranunculus oreophyton* dominated bog
Mt. Kenya	Bog 4	*Festuca pilgeri−Alchemilla microbetula−Ranunculus stagnalis−Carex monostachya* dominated bog

2.4 DISCUSSION AND CONCLUSION

2.4.1 Species dominance in the Afroalpine vegetation of Eastern Africa

Compared to other ecosystems such as tropical rainforests and the adjacent Afromontane moist forest of African Mountains, the Afroalpine zone are considered to be species ‘poor’ (Hedberg, 1970; White, 1978a). Afroalpine vegetation communities of Eastern Africa are dominated by six families, namely Asteraceae (69 species), Poaceae (37 species), Caryophyllaceae (16 species), Lamiaceae (12 species), Cyperaceae (11 species) and Rosaceae (10 species) that constitute 56% of all the species sampled. This indicates the dominance of few families in the colonization and occurrence of their species in the sampled vegetation communities and mountains. Asteraceae and Poaceae alone account for more than a third (38%) of all the species of Afroalpine revealing the importance and dominance of the species of these two families.

A number of factors probably contributed to the success of these two families. Members of the grass family for example have tiny light seeds (morphological adaptation) capable of being blown for a long distance from the source region and presumably deposited in the virgin non−inhabited bare rocks of the mountains during and after the initial processes of orogeny (mountain formation). Wind dispersal is one of the main mechanisms effecting long distance dispersal for Afroalpine plants (Troll, 1952; Coe, 1967; Hedberg, 1964b & 1970). This is especially true for the light seeded plants like grass species, members of *Orchidaceae* and Pteridophytes among others. Moreover, *anemochory* is thought be the hallmark of pioneer vegetation (Van der Pijl, 1969) and its significance is directly proportional to the altitudinal height of the mountains (Hedberg, 1970). A classical circumstantial evidence of the success of Poaceae and/or members of Asteraceae was revealed by the recent discovery of species identified to be *Senecio purtschelleri* Engl., and *Crepis Dianthoseris* both members of Asteraceae at the summit of Mt Kilimanjaro which might be partly explained by recent case of wind dispersal (Hedberg, 1970).

In addition to having relatively light seeded plants many species of the genus *Helichrysum*, *Senecio* and other genera of Asteraceae that are evidently abundant in Afroalpine plant communities are morphologically endowed with parachute like structures. These are adapted for air floatation/dispersal and are capable of being blown high up especially during strong winds prevalent in Afroalpine zone and storms like cyclones which is not infrequent in high mountains (Hedberg, 1970). Increased chances of successful establishment of the diaspores after arrival in the various mountain enclaves (refugia) could have allowed the species and genera of these dominant families to establish successful populations. This is often possible through physiological and/or genetic adaptation such as increased power of germination as well as ability to withstand the vagaries of extreme climatic conditions and biotic competition for dearth resources especially during the initial colonization of virgin habitats.

The occurrence of fire which may be naturally induced e.g. by volcanicity, lightening, etc. or mostly caused by anthropogenic factors is rampant in African high Mountains and else where. Fire is thought to significantly affect the sub−alpine (ericaceous) and alpine plant communities mostly aiding the spread and dominance of grassland communities (Wesche *et al.,* 2000). Wesche noted the remarkable ability of grassland communities for their adaptation to these fires through quick recovery as well as the non−effect of the fire on species composition and the relative cover of the grass and other associated species while recovering. This enables grass species and associated herbaceous species to expand their ranges through rapid regeneration after incidents of fire. This explains the frequent occurrence and relatively high cover of grass and associated species not only in the grassland vegetation but also in other Afroalpine vegetation types especially in rock outcrop. Hence grassland is the most conspicuous vegetation type in terms of percentage land cover in the entire mountain studied. Mount Rwenzori is an exception to this pattern since it is dominated by extensive bogs (in the valleys e.g. Bujuku) and *Dendrosenecio* forest (slopes and ridges) due to the exceptionally high precipitation.

2.4.2 Description of the communities of the five vegetation types of Afroalpine zone

The communities frequently occurring in the five vegetation types sampled, viz., rock outcrops, bogs, grasslands, *Dendrosenecio* forest/woodland and *Alchemilla* shrubland correspond well with those described by Hedberg (1964b). The main communities prevalent in these vegetation types include *Carex runssoroensis*−*C. monostachya*−*Deschampsia caespitosa* dominated bogs. The genera *Carex* and *Deschampsia* are the typical bog species that usually requires standing water or soil saturated with water common in this vegetation type. In most mountains studied, *C. monostachya* is the common dominant species in bogs except in Mt Rwenzori which, is dominated by *C. runssoroensis*. Other bog species common in this vegetation type are *Haplocarpha rueppellii*, *Hydrocotylee sibthorpioides* and *Subularia monticola* among others.

In grassland communities, *Festuca* species often form the dominant cover in most of the grasslands studied. *Festuca abyssinica* and *F. simensis* are the two main species with the former being the more widespread species. Other genera that are very common in grassland vegetation type include *Pentaschistis* (represented mainly by *P. borussica* and *P. pictigluma*), *Andropogon* (*A. lima*), *Agrostis* (*A. gracilifolia* and *A. schimperiana*), *Pennisetum* (*P. humile*) and *Poa* (*P. leptoclados*). In *Dendrosenecio* forest/woodland vegetation community the dominant species are the woody *Dendrosenecio* species in the upper story and *Alchemilla* species in ground cover. Usually in each mountain an endemic or near endemic species of *Dendrosenecio* occur. For example in Mt Elgon it is represented by *D. elgonensis* while in Mt Rwenzori and Mt Kenya it is represented by *D. advinalis* and *D. keniodendron* species respectively. In *Alchemilla* vegetation type it is usually dominated by the genus *Alchemilla* represented mostly by *Alchemilla argyrophylla, A. johnstonii*, *A. pedata* and *A. haumannii* species. Although species of *Alchemilla* are frequent across the entire mountains, *Alchemilla* vegetation community type is not well developed as only two plots in Bale and Rwenzori could be found for analysis. In rock outcrop vegetation type several genera including *Helichrysum, Festuca, Koeleria, Colpodium, Plantago* and *Pentaschistis* co–dominate the rock outcrop communities. The species that forms the dominant cover of the above genera include: *Helichrysum citrispinum*, *H. forskahlii*, *H. newii*, *Festuca simensis*, *F. abyssinica*, *Koeleria capensis*, *Plantago afra*, *Pentaschistis pictigluma* and *P. borussica*. Other species that are frequent in rock outcrop community are *Cineraria deltoidea*, *Deschampsia flexuosa* and *Crassula* species.

2.4.3 Comparative assessment of species composition between and within five vegetation types of Afroalpine zone of Eastern Africa

Among the 20 plots of rock outcrop sampled across the six mountains reveal marked similarities between all the mountains except Simen in terms of the structure of communities and species assemblage/composition. The dominant genera and species in this vegetation type that are at least prevalent in two or more mountains are *Helichrysum* represented by *H. citrispinum* in Mt Elgon, Kilimanjaro, and Bale. In addition *H. newii* and *H. forskahlii* occur in Mt Kilimanjaro. The above mountains occur along the eastern side of the rift valley. *Festuca* is represented by *F. abyssinica* in Mt Kenya and Elgon, which are geographically in close proximity thus explaining the observed pattern of similarity while *F. simensis* and *F. macrophylla* occur in Bale. Three species of the genus *Deschampsia* occur in Afroalpine zone of Eastern Africa. The first one *D. caespitosa* is a bog species while *D. flexuosa* var. *afromontana* and D. angusta are common in rock outcrop community in most of the mountains but forms dominant cover in Mt Elgon and Kilimanjaro rock outcrop community. The genus *Pentaschistis* is well represented in rock outcrop community by two species viz. *P. borussica* in that it forms dominant cover in Mt Kilimanjaro, and *P. pictigluma* var. *pictigluma* with golden colour inflorescence common in Bale and Simen. This variety is endemic to Ethiopian Mountains. The *Alchemilla* species prevalent in rock outcrop community include *A. microbetula* in Mt. Kenya and Simen, *A. johnstonii* in Kilimanjaro and A. *argyrophylla* in Mt. Kenya and Ruwenzori. However in Mt Kenya and Rwenzori are represented by two different subspecies of *A. argyrophylla* (*A. argyrophylla* ssp. *argyrophylla* in Mt Kenya and *A. argyrophylla* ssp. *argyrophylloides* in Rwenzori).

Carex species are predominantly bog species but occasionally is found in other vegetation types such as rock outcrop community especially in wet zones. For example *C. simensis* occur in Elgon and Bale both of them being relatively old mountains along the eastern rift valley. *Agrostis* species are among the dominant genera in grassland community but it frequently occurs in rock outcrop community e.g. *Agrostis sclerophylla* occur in the mountain summit of Mt. Elgon & Kenya. *Crassula* species are often found in crevices of rock outcrop community e.g. *C. schimperi* occur both in Elgon and Bale Mountain. *Lobelia* is among the few woody species prevalent in Afroalpine zones of Eastern Africa. In rock outcrop community, *L. telekii* frequently occur in Mt Kenya while L. *rhynchopetalum* is common in Bale. *Crepis* is represented by *C. dianthoseris* in Mt Kenya and *C. rueppellii* in Simen. *Cineraria deltoidea* is another common rock outcrop species that occur in several mountains especially common in Simen and Kilimanjaro. Other dominant genera in the rock outcrop community which, are mountain specific include *Rytidosperma* (*R. subulata*), *Colpodium* (*C. hedbergii*), *Plantago* (*P. afra*), *Cotula* (C. *abyssinica*), *Gnaphalium unionis*, *Vulpia bromoides*, *Crepis rueppellii* and *Lychnis abyssinica* all in Simen; *Dendrosenecio keniodendron* in Mt Kenya and *Isolepis* sp. in Kilimanjaro.

In boggy vegetation type there was generally uniformity across all the mountains in the generic composition. However there were differences in the species composition, which, were dominated by *hydrophilic* species mainly from the tussock forming genus *Carex* and acaulecent plants like *Haplocarpha* species. Mount Ruwenzori, the wettest mountain (Hedberg; 1964b; Wesche *et al.,* 2000) significantly differs from the rest of the mountains in terms of species composition of the most dominant taxa. For example the tussock forming *Carex runsoroensis* is the dominant species in all the four vegetation types sampled from Rwenzori with almost pure stands of this species in some cases in terms of cover. The rest of the mountains are dominated by *Carex monostachya* in association with various members of other genera. In Ruwenzori, beside *Carex*, other taxa with significant representation include *Hydrocotyle sibthorpioides*, *Isolepis fluitans*, *Helichrysum stuhlmannii*, *H. formosissimum* and *Alchemilla argyrophylla* ssp. *argyrophylloides* (Rwenzori endemic). In Mt Kilimanjaro, *C. monostachya* and *Alchemilla johnstonii* co−dominates in the bog community.

In the remaining three mountains viz. Bale, Mt Kenya and Simen other dominant genera include *Ranunculus* variously represented by *R. oligocarpus* in Mt Kenya and Simen, *R. oreophytus* and *R. stagnalis* in Mt Kenya. *Haplocarpha* is represented by *H. rueppellii* in Mt Kenya, Bale and Simen while *Alchemilla* is represented by *A. microbetula* in Mt Kenya, *A. pedata* in Bale and *A. abyssinica* in Simen. However, *Cotula cryptocephala*, *Isolepis fluitans*, *Callitriche oreophila*, *Veronica anagalis−aquatica* are other dominant species in Mt Simen only although some of them may have been recorded from the other mountains. This makes Mt Simen rather unique compared to other mountains. From the generic composition, it is clear that the water loving plants (hydrophyllics taxa) or bog species dominate since water is critical in determining distribution and dominance of species in this vegetation type as the Afroalpine species exhibit different levels of water tolerance. Consequently the wettest mountain Rwenzori, which receives rain almost every day, has the best developed bogs with almost pure stands of tall lash green *Carex runssoroensis* tussocks making it significantly different from the rest of the mountains. Often the bogs here are characterized by the permanent presence of surface water in most parts of the expansive bogs.

The genera and species of the family Poaceae dominate the floristic composition of grassland community. In almost all the mountains, species of *Festuca* (*F. abyssinica* in EA Mountains and *F. simensis* in Ethiopian Mountains) dominates the species composition of the sampled plots. In Mt. Elgon, *F. abyssinica*, *Koeleria capensis*, *Pennisetum humile* and *Colpodium* species forms the dominant taxa in grassland communities. In Mt. Kilimanjaro, *Poa leptoclados*, *F. abyssinica*, *P. borrusica* and *Andropogon lima* forms the dominant species with *Alchemilla microbetula* having significant occurrence. *Festuca simensis*, *P. pictigluma*, *Andropogon lima* and *Helictotrichon elegantum* dominate grassland species in Simen with significant presence of *A. abyssinica* and *H. citrispinum* species. In Bale, *F. simensis*, *A. pedata* and *A. lima* forms the dominant species of grassland community.

Species of the genus *Pentaschistis* are among the most conspicuous grass species in the Afroalpine zone along with *Festuca* species. The species of *Pentaschistis* that are known to occur in the study area and, which have been sampled both within and outside the plots include *P. borussica*, *P. trisetoides*, *P. dolichochaeta*, *P. chrysurus*, *P. pictigluma* var. *pictigluma*, *P. pictigluma* var. *minor*, *P. pictigluma* var. *gracilis*, and *P. pictigluma* var. *mannii*. *Pentaschistis borussica* is the most widely distributed species occurring in all the mountains except Simen. Its preferred vegetation communities are rock outcrop and grassland, rarely occurring in bogs and *Dendrosenecio* forest/woodland. The other widely distributed species is *P. pictigluma*. However this species was represented in most of the mountains by one or two varieties. *Pentaschistis pictigluma* var. *pictigluma* and *P. trisetoides* are endemic to Ethiopian Mountains. Most of the known collections including collections from this study of *P. pictigluma* var. *gracilis* are from Ethiopia. In addition *P. dolichochaeta*, a robust species is endemic to Shewa region of Ethiopia especially in Wafwasha forest and the nearby Ancober highland occurring below Afroalpine zone [sub– alpine] (2900 to 3000 m). Similarly *P. chrysurus* is endemic to Tanzania (Mt. Kilimanjaro, Mt. Meru and nearby highlands including Mt. Hanang). This species also occurs below the alpine zone (2500−3400 m) mostly in thickets around the forest zone.

In *Dendrosenecio* vegetation type, only three East Africa countries viz., Mt Kenya, Elgon (Kenya/Uganda) and Rwenzori were sampled as this conspicuous Afroalpine genus was absent from Ethiopian Mountains. Mount Kilimanjaro, the driest of all the mountains studied had only scattered *Dendrosenecio* trees in the Afroalpine zone, which could not form continuous plot of *Dendrosenecio* community comparable to other mountains for sampling and analysis. Hence no continuous woodland/forest plots of the required size of *Dendrosenecio* could be found in Mt. Kilimanjaro.

Each of the three mountains sampled had an endemic vicariant species of *Dendrosenecio* as the dominant species. This was associated frequently and/or co−dominated occasionally with other woody (*Lobelia*) or shrubby *Alchemilla* or *Helichrysum* species. For example, in Mt Elgon *D. elgonensis* (*D. elgonensis* ssp. *elgonensis* and *D. elgonensis* ssp. *barbatipes*) was the dominant species frequently co−dominated at the ground level by *A. argyrophylla* ssp. *argyrophylla* and *A. johnstonii*. *Dendrosenecio keniodendron* dominates Mt Kenya *Dendrosenecio* woodland with frequent association at the ground level with *Festuca pilgeri* and occasionally *A. johnstonii*. In Rwenzori, *Dendrosenecio* vegetation type was well developed often forming dense moist forest dominated by *D. advinalis* ssp. *advinalis* and *D. advinalis* var. *petiolatus* with branches and dead *Dendrosenecio* wood on the ground covered with thick moss and other epiphytic species like *Galium ruwenzoriense*. At the ground level this species is frequently associated with *Arabis alpina*, *Lobelia wollastonii* (Rwenzori and Virunga endemic) and *Luzula johnstonii*.

Alchemilla community was the least extensively developed vegetation type in the whole of the study area although well represented by many species across the entire mountains. As such only eight plots were sampled from two mountains (Bale in Ethiopia and Rwenzori in East Africa) and the other mountains lacked sizable plots for sampling and analysis. In Ruwenzori the *Alchemilla* communities were dominated in terms of species cover and presence by *A. argyrophylla* ssp. *argyrophylloides* and *A. johnstonii* with frequent association of *A. triphylla*. On the other hand, *A. haumanii* was basically the sole dominant species in Bale often with cover of over 84%. In one plot however, *A. micrbetula*, *A. pedata* and *Isolepis fluitans* (all frequently found in bogs) dominated the *Alchemilla* community (was perhaps wet zone resembling boggy conditions thus attracting nearby bog species).

Jaccard’s pair wise similarity index revealed that rock outcrop and grassland vegetation types were the most similar with J’ value of 52. A total of 118 species were common from these two vegetation types while they have combined differences of 109, that is, either occurs in rock outcrop or grassland. The other pairs that share relatively higher degree of similarity are bogs and grassland (J'=44.0; common−96; different 122) and rock outcrop and bog (J=41.0; common−101; different−143). The higher degree of similarity can be attributed to a number of factors. First the most important abiotic factors affecting the Afroalpine species include (but not limited to) light, water and edaphic factors respectively in addition to intra and interspecific competition. One common thing with these three vegetation types was the openness and the availability of maximum light due to the near absence of large woody species of *Dendrosenecio*, *Lobelia* and shrubby and dense *Alchemilla/Helichrysum* species that have the potential of obstructing/and limiting light penetration to the ground layer. Hence the genera and species common to these vegetation communities are non−shade loving herbaceous taxa often with creeping, climbing, tussock forming and acaulecent habits. As a result there are marked dissimilarity between grassland and *Dendrosenecio* communities (J=22.0; common−40; different−145) and/or rock outcrop and *Alchemilla* (J=26.0; common−55; different−145).

Both *Dendrosenecio* and *Alchemilla* communities, which are dominated by the species of these two genera, have the tendency to fairly give dense cover to the ground below significantly limiting light penetration on to the ground layer. This limit the establishment or occurrence of many Afroalpine species–mostly herbaceous annuals with creeping habit, reduced stems and non−tussock forming grass species. In most cases these constitute significant number of Afroalpine species (Hedberg, 1964b). Therefore *Dendrosenecio* and *Alchemilla* vegetation types are thought to be the most species poor among all the five vegetation communities sampled during the study.

In addition to its primary role of photosynthetic regulation, light from the solar radiation has cascading effect on other equally important abiotic factors such as its direct role of temperature regulation as well as its influence on evapotranspiration, frequent thawing (daytime) and freezing (night) peculiar in Afroalpine zone which creates “artificial” water shortage (Hedberg, 1964b; Wesche, 2000). This is essentially why there are large fluctuations of temperature in the Afroalpine zones of the high mountains in tropical Africa during the day and night, that is, “summer everyday and winter every night” (Hedberg, 1957). Sun light too influences directly water uptake by plant since during the night and the early hours of the day, the soil temperatures is below zero, impairing water and nutrient uptake or at least slowing the process of water uptake significantly. Consequently most species found in these three vegetation types, which are species rich have developed both physiological and morphological adaptation to tide over the extreme conditions of temperature fluctuations and artificial water shortages. These include developing xeromorphic characteristics like stem reduction e.g. *Haplocarpha* species and *Haplosciadium* species, tussock forming habit for insulation and protection of vascular tissue e.g. *Carex* and *Festuca* species, and sclerophyllous shrubby characters with convolute or revolute leaves e.g. *Alchemilla* and *Helichrysum* species to reduce evapotranspiration (Hedberg, 1964b).

2.4.4 Comparative assessment of species richness and abundance between the five vegetation types

In terms of species richness, the rock outcrop vegetation type was the most species rich and significantly different with regard to this parameter compared to both *Dendrosenecio* and *Alchemilla* vegetation communities. Similarly bogs are more species rich compared to *Dendrosenecio* vegetation community. Hence the null hypothesis of no significant differences in the plant species richness between the vegetation types is rejected ($P< 0.05$). A total of 188, 157, 68 and 77 species were either recorded or collected from rock outcrops, bogs and grasslands, *Dendrosenecio* and *Alchemilla* vegetation types respectively. A number of possible reasons can be given to explain the richness of the rock outcrop compared to other vegetation types. First, rock outcrop provides many microhabitats or niches where diverse number of species with different requirements of optimal conditions of abiotic and biotic factors can thrive compared to other vegetation types. For example in rock outcrops we have caves for shade lovers and epiphytic plants, crevices and shallow depressions where water can collect to mimic boggy condition where bog species can colonize and shallow or thin soil cover that favours grasses and herbaceous species. However species diversity and evenness between the five vegetation types appear to be uniform with no significant variations.

2.4.5 Comparative assessment of species composition between the alpine zone of the six mountains of Eastern Africa

Comparative analysis of the species composition and community ecological analysis revealed a general pattern of similarity and/or differences between the six mountains based on several factors: −

- Geographical location of the mountains
- Age of the formation of the mountains
- Geological history of the mountains
- Climatic factors
- Edaphic or Soil factors

From this study, the degree of the similarity between the mountains was more or less inversely related to geographical distance between the mountains and interestingly their location along the rift valley systems (eastern verse western arm). The “sky−islands” of each of the mountains tops serves as refugia with effective isolation similar to oceanic islands off the coast of the nearest mainland. The only biotic interchange between these enclaves is thought to be almost always through long distance dispersal followed by successful establishment of the migrating/colonizing species (Hedberg, 1970). Hence it follows that “the sky islands” isolations increases with both distances from each other and the height of individual mountain. Therefore, the distances (geographical location) as well as the location along the arm of rift valley systems (Rwenzori and Simen on the western arm and East Africa Mountains and Bale on the eastern arm) influence species composition of the Afroalpine flora across the mountains.

Consequently Mt Kenya, Kilimanjaro, and Elgon share many common species and are floristically similar compared to the two Ethiopian Mountains and to a lesser extent Ruwenzori since the latter has unique attributes including its location on the western arm of the rift valley system and non–volcanic origin. Mount Kenya and Kilimanjaro, the two closest mountains in East Africa show the highest degree of similarity (Jaccard’s similarity index: 44.4). In addition the similarities between the East Africa mountains viz: Mt Kenya, Kilimanjaro, Elgon and to a lesser extent Mt Ruwenzori is due to having similar species composition especially such species like *Anthoxanthum nivale* K. Schum*., Alchemilla argyrophylla* Oliv*., Carduus keniensis* R.E.Fr*., Helichrysum newii* Oliv. & Hiern among others that frequently occurred in many plots across these mountains. However each of the mountains has its endemic species which are localized to that mountain. For example, *Dendrosenecio elgonensis* (T.C.E.Fr.) E.B. Knox is endemic to Mt Elgon, *Euryops dacrydioides* Oliv. (Mt Kilimanjaro), *Dendrosenecio keniodendron* (R.E.Fr. & T.C.E.Fr.) B.Nord. (Mt Kenya), *D. keniensis* (Baker f.) Mabb. (Kenya), *Helichrysum stuhlmannii* O. Hoffm., *D. advinalis* (Stapf) E.B. Knox and *Lobelia wollastonii* Baker f. that are localized to Mt Ruwenzori.

Similarly Bale and Simen have higher Jaccard's similarity index than between any other pair for the same reason (J' 47.05). Again Bale and Simen (Ethiopian) share many species that are endemic to these two mountains. These species include *Rytidosperma subulata* (A.Rich.) Cope*, Lobelia rhynchopetalum* Hemsl, *Festuca simensis* A. Rich.*, Pentaschistis pictigluma* (Steud.) Pilg. (including var. *pictigluma* and var. *gracilis*) and *Valerianella microcarpa* Loisel among others. Mount Bale and Simen like the East Africa Mountains have their own endemic species such as *Rytidosperma grandiflora* (Hochst. Ex A. Rich.) S.M. Phillips, *Aphanes bachitii* (Haum. & Balle) Rothm., *Pimpinella pimpinelloides* (Hochst.) Wolff and *Argyrolobium schimperianum* Hochst. Ex A.Rich. for Simen. *Swertia crassiuscula* ssp. *robusta* Sileshi, *S. macrosepala* ssp. *microseperma* Sileshi, *Geranium* sp. = Miehe 3002 (Bale) and *Euryops prostrata* B. Nord. are endemic to Bale. Hence there are various levels of separation between the mountains in terms of the species composition from the 75 plots sampled.

Mount Ruwenzori exhibit marked difference from other East Africa and Ethiopian Mountains in that it has a number of species endemic to this mountain and was different from the rest of the mountains. This was the only mountain in East Africa sampled that is non−volcanic, i.e. it was formed by the up thrust (rise) of part of the African plate and consequently the soil and the parent rocks are quite different from those of East Africa. Secondly Rwenzori was the wettest and presumably the coldest mountain sampled. Although it has dense and moist *Dendrosenecio* forest, thick *Alchemilla* community and extensive swampy bogs it's the most species poor compared to the rest of the mountains. The same reasons or factors such as sunlight availability (due to dense growth and cloudiness), water stress etc discussed earlier under the vegetation communities can be stated to explain this observed pattern.

Ruwenzori was also the only mountain after Simen that is located in the western arm of rift valley, which therefore provides another third level of isolation (barrier to dispersal) since the rift systems provides partial isolation between the mountains (Hedberg, 1970). The parent rock and soil types of Rwenzori was significantly different from all other mountains studied since it constitute ancient Eozoic rocks (gneises and schists) that is, metamorphic rocks including such rocks like mica−schist, amphibolites, calc−schists, quartzites, muscovites and cordierite−schists (Gregory, 1921) while the rest of the mountains were formed from basaltic lava.

The species richness among five out of the six mountains (Kenya, Elgon, Rwenzori, Kilimanjaro and Bale) is not significantly different from each other. Consequently the null hypothesis (hypothesis two) is accepted, that is, $p > 0.05$. However the species richness of Simen mountain is significantly different from the rest ($p < 0.05$) thus in this case rejecting the null hypothesis.

The age of the six mountains studied ranges from 2 to 3.5 MY BP to over 20 MY BP in the case of Mt Elgon and Ethiopian Mountains. The Ethiopian massifs started rising about 70 MY BP and are therefore much older than those of East Africa. Consequently they have had a considerable geological time scale for accumulation of divergent characters and evolution of diverse Afroalpine flora compared to say Mt Kenya and Kilimanjaro (“baby Mountains”). One other major difference between Ethiopian Mountains and those of East Africa was the absence of keystone genus of the Afroalpine flora, the giant rosette plant viz: the genus *Dendrosenecio* (*Asteraceae*) and the vicariant nature of the species of the genus *Lobelia* (*Lobeliaceae*). Moreover, Simen and Bale exhibit different rainfall pattern in that they have unimodal pattern of rainfall distribution where there is single long rainy season and single short dry spell compared to East African mountains which have bimodal pattern of rainfall (two rainy seasons and two dry seasons). These factors perhaps explain the species richness of these mountains and the high degree of dissimilarity with those of East Africa (Gashaw & Fetene, 1996).

Despite the above stated differences between the mountains regarding the geological history, climatic condition variations and existence of differential characteristics of the edaphic factors the overall similarities in the species composition between the mountains is quite remarkable. Hence there are no significant differences in the species composition among the mountain studied thus affirming the statement of the hypothesis.

2.4.6 Heterogeneity Assessment

The mean values of R for the ANOSIM results indicate that the five vegetation types were significantly different from each other and can be easily recognized thus rejecting the null hypothesis four (all the vegetation types of Afroalpine zone are homogenous). However the heterogeneity of the vegetation types was blurred by overlap in terms of species composition. For example vegetation types such as rock outcrop vs. grassland are barely separable at all ($R< 0.25$) while rock outcrop vs *Dendrosenecio*, rock outcrop vs *Alchemilla*, bog vs *Alchemilla*, bog vs grassland, grassland vs *Alchemilla*, and *Dendrosenecio* vs *Alchemilla* are overlapping but fairly separable. However, rock outcrop vs bog and bog vs *Dendrosenecio* are overlapping but clearly separable ($R > 0.5$).

In the SIMPER analysis among the five vegetation types− rock outcrops, bogs, grasslands, *Dendrosenecio* and *Alchemilla* −from the entire six mountains communities several keystone species that are ubiquitously distributed emerge that greatly contribute to the overlapping of the vegetation communities. Key among these species are: *Erica arborea* (Ericaceae), *Colpodium hedbergii* (Poaceae), *Helichrysum formosissimum* (Asteraceae), *Cerastium octandrum* (Caryophyllaceae), *Gallium acrophyum* (Rubiaceae), *Anthoxanthum nivale* (poaceae), *Alchemilla argyrophylla* (Rosaceae) and *Arabis alpina* (Brassicaceae) which frequently occur in the various vegetation types studied.

The species richness, abundance and diversity varies across the vegetation communities and mountains. Species composition among the five vegetation communities investigated show higher similarities between grassland, rock outcrop and bog communities compared to *Dendrosenecio* and *Alchemilla* communities. The former also show higher species diversity and richness compared to the latter. Mountains from East Africa (Kenya, Tanzania and Uganda) countries show less species richness and less diversity compared to the Ethiopian mountains. Species composition among the mountains of East Africa show higher degree of similarity compared to the Ethiopian mountains. Factors such as the age, geological history of the mountains, distance between the mountains, edaphic factors and climatic conditions are responsible for the observed patterns of species composition among the various mountains investigated.

CHAPTER THREE: PHENETIC AND PHYLOGENETIC ANALYSIS OF THE GENUS *PENTASCHISTIS* (NEES) SPACH (POACEAE) OCCURRING IN EASTERN AFRICAN MOUNTAINS

3.1 LITERATURE REVIEW

3.1.1 Distribution and Description of the genus *Pentaschistis*

The African endemic genus *Pentaschistis* is among the largest genera in the tribe *Danthonieae* (*Danthonioideae*, Poaceae). There are about 70 species of the genus *Pentaschistis*, mainly occurring in Southern Africa but also extending northwards on the high mountains of East Africa, Ethiopia, Cameroon and Madagascar [figure 21] (Linder & Ellis, 1990).

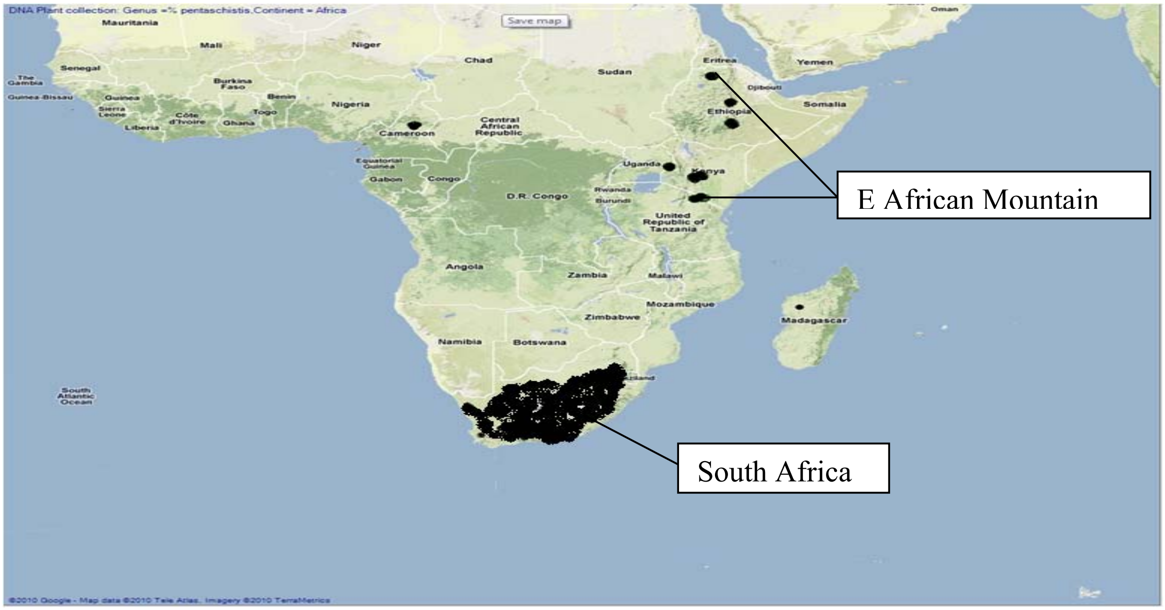


Figure 21: Worldwide Distribution of the species of *Pentaschistis* (Source: Google earth Modified: www.google.com/earth/download/ 17th November 2010)

Pentaschistis (Nees) Spach, Hist. Nat. Veg. Phan. 13: 164 (1864); Stapf in F.C. 7: 480 (1899); McClean in *S. Afr. J. Sci*. 23: 273–282 (1926); Chippindal in Grasses & pastures, 254

(1955); Clayton in F.T.E.A. (Gramineae. Pt. 1): 124 (1970); Dyer, Gen. S. Afr. Pl. 2: 839 (1976); Clayton & renvoize, *Gen. Gram*. 174 (1986). *Danthonia* DC subgen. *Pentaschistis* Nees in *Linnaea* 11: 125 (litt. ber.) (1837), Nees, Fl. Afr. Austr. 280 (1841). Type species: *Danthonia curvifolia* Schrad.

Members of the genus *Pentaschistis* (Poaceae) are annuals or perennials with linear to folded leaf blades. The inflorescences are panicles that are either open or contracted, occasionally with glandular branches. The spikelets are 2−flowered, enclosed by the, lanceolate to oblong glumes. These glumes are subequal, narrowly lanceolate to lanceolate, keeled, and 1−3 nerved. The lemmas are lanceolate to oblong, 5−9 nerved, 2−lobed, and awned from the sinus of the lobes. The awns are geniculate, mostly with twisted column. The palea is narrow, usually as long as the lemma. The callus is short and bearded (Linder & Ellis, 1990; Clayton, 1970; Phillips, 1995).

3.1.2 Nomenclatural background of the genus *Pentaschistis*

The first description of grasses that are currently included in *Pentaschistis* was by Thunberg in his *Prodromus Plantarum Capensium* written and published on 1794 where he described five species (two in *Holcus* L. and three in *Avena* L.). The next group of species were described by Schrader, H.A. (1821) from specimens collected at Cape by Hesse where all of them were placed in *Danthonia* DC. Nees ab Esenbeck (1832, 1841) recognized several genera for the species now in *Pentaschistis* in *Flora Capensis*.

McClean (1926) transferred all the awnless two flowered species from *Achneria* to *Pentaschistis*. He placed awnless species of *Pentaschistis* in *Eriachne*, while those with awns in *Danthonia* section *Pentaschistis*. However, he placed *P. capensis* in the genus *Triraphis*. Otto Stapf (1899, 1910, and 1915) raised the awned species of *Danthonia* section

Pentaschistis to full genus *Pentaschistis* while retaining the awnless two flowered species in the genus *Achneria*. He also placed *Triraphis* of Nees in *Pentaschistis* and the large spikelet forms in *Pentameris*. Hubbard (1937) in Flora of Tropical Africa recognized 11 species of *Pentaschistis* from Tropical African Mountains. He adopted a very narrow species concept where he recognized a distinct species for each mountain block (Linder & Ellis, 1990). For example, he recognized *P. ruwenzoriensis* C.E. Hubb. (from Mt. Ruwenzori), *P. meruensis* C.E. Hubb. (from Mt. Meru), *P. expansa* (Pilg.) C.E. Hubb. (from Mt. Kenya) and *P. borussica* from several mountains as distinct species. However all these four species, which have open panicles, were merged under *P. borussica* (K. Schum.) Pilg. by Clayton (1970). Clayton (1969) also transferred *Eriachne malouinensis* to *Pentaschistis*. Phillips, (1994) reduced species with contracted panicles from various mountains previously treated as distinct species (Clayton, 1970) in FTEA, namely *P. minor* and *P. mannii* as varieties under *P. pictigluma* (Steud.) Pilg.

The researchers based their intuitive interpretations almost wholly on gross morphology and were guided by inevitable differing intuitive taxonomic interpretations inherent in each individual researcher, which consequently led to differing species concepts from the narrowest (Linder &Ellis, 1990 and Clayton, 1970) to the broadest (Phillips, 1994 and 1995). Hence Clayton, (1970) and Linder & Ellis (1990) recognized *Pentaschistis pictigluma* (Steud.) Pilg. *minor* (Ballard & Hubbard) Ballard & Hubbard, *P. gracilis* S. M. Phillips, *P. mannii* C.E. Hubbard, *P. minor* (Ballard & Hubbard) Ballard & Hubbard and *P. imatogensis* C.E. Hubbard at specific rank while Phillips (1994,1995) place these taxa at infraspecific ranks under the species *P. pictigluma* (Table 13) after failing to get clearly distinguishing characters following her numerical analysis of several characters. This varying species circumscription brings the total species recognized by various botanists to between six and ten that occur in the tropical African Mountains.

Table 13: A summary of the species of *Pentaschistis* recognized by W. D. Clayton, S. Phillips and P. Linder in East Africa and Ethiopian mountains

W. D. Clayton (1970)	**S. M. Phillips (1994 & 1995)**	**H.P. Linder & R.P. Ellis(1990)**
P. chrysurus	–	*P. chrysurus*.
P. natalensis	–	*P. natalensis*
P. borussica	*P. borussica*	*P. borussica*
P. minor	*P. pictigluma* var. *minor*	*P. minor*
P. mannii	*P. Pictigluma* var. *mannii*	*P. mannii*
–	–	*P. imatogensis*
–	*P. pictigluma* var. *pictigluma*	*P. pictigluma*
–	*P. pictigluma* var. *gracilis*	*P. gracilis*
–	*P. trisetoides*	*P. trisetoides*
–	*P. dolichochaete*	–

3.1.3 Previous phylogenetic analysis

Various molecular techniques are currently available for genetic diversity as well as phylogenetic inferences including but not limited to restriction site analysis, comparative sequencing, analysis of structural rearrangements and polymerase chain reaction (PCR) based techniques (Baker *et al*., 1999). DNA sequencing techniques such as the one using nuclear ribosomal DNA region and chloroplast DNA sequences are popular for phylogenetic studies over a wide range of taxonomic levels. Recently, phylogenetic studies have focussed on the use of chloroplast DNA (cpDNA) sequences because it is quite informative across many taxonomic levels (Taberlet *et al.,* 1991). The non-coding cpDNA region are more often used for drawing phylogenetic relationships especially at lower taxonomic levels (Baker *et al*.,

1999) since they evolve more rapidly compared to the coding cpDNA regions thereby accumulating insertion/deletion (Indels) at faster rate.

Phytogeographically, species of Afroalpine plants have complex derivation and are therefore categorized into nine *flora elements* based on the supposed areas of origin of each species, that is, the areas in which they have the majority of their closest relatives (Hedberg, 1961). Despite the close proximity, the flora of the afro−alpine is floristically distinct and ecologically isolated from the surrounding montane forest and savanna vegetation (Hedberg, 1970; Brühl, 1997; Menocal, 2004) and thus has been described by Hedberg (1970) as isolated temperate "islands" since the low lying montane and savanna vegetation separate the mountain enclaves from each other and from the rest of the floral elements. Hence the nearest relatives of this Afroalpine enclaves are found not in the neighbouring tropical forest and savannah but in alpine zones of Northern and Southern Hemispheres such as Eurasia (Boreal element), the Mediterranian zone, Himalaya, Cape region and South Africa among others (Hedberg, 1970). Therefore, like oceanic islands such as Galapagos and Hawaii, colonization of this Afroalpine zone is thought for a long time to occur through infrequent long distance dispersal from the nearest mainland or alpine zones (Hedberg, 1970; Lomolino *et al.*, 2006).

Several recent phylogenetic studies using chloroplast DNA regions of common Afroalpine genera such as *Alchemilla*, *Arabis*, *Carex*, *Lychnis*, *Swertia* and *Ranunculus* indicate that species from these genera have colonized Afroalpine zones of tropical African mountains. This happened through migration from distant areas such as Eurasia, Himalaya, South Africa and Mediterranean areas among others (Koch *et al.*, 2006; Assefa *et al.*, 2007; Galley *et al.*, 2007; Popp *et al.*, 2008; gehrke & Linder, 2009). Some recent phylogenetic and phylogeographic studies combined the use of cpDNA and Internal Transcribed Spacer (ITS) regions of nrDNA for phylogenetic reconstruction in the sub-family *Danthonioideae* (Baker *et al*., 1995, 2000, 2003, 2007; Verboom *et al*., 2006; Galley & Linder, 2007; Pirie *et al*., 2008) as well as improving the generic classification of this sub-family which is a taxonomically difficult group (Linder & Ellis, 1990).

A species level phylogeny of the *Pentaschistis* clade (*Pentaschistis*, *Prionanthium* and *Pentameris*) based on plastid DNA sequence data was constructed by Galley and Linder (2007) to resolve phylogenetic relationships within the clade. In this study I attempted to improve the phylogeny of *Pentaschistis* clade first by including all the species occurring in the East Africa and Ethiopian Mountains absent from previous phylogenetic analysis as well as using the ITS markers in addition to chloroplast sequence markers in resolving the phylogenetic relationship of the Afroalpine sub–clade of the *Pentaschistis* clade.

Hence this study is giving the analysis, mainly morphological and genetic analysis that hopefully will clarify the taxonomic treatment of *Pentaschistis* previously addressed by researchers.

3.2 Materials and Methods

3.2.1 Sampling design and daw data collection

Herbarium voucher specimens were obtained from 75 plots in six mountains where plots of 100 × 100 m were sampled for morphological studies. For each population of *Pentaschistis* occurring in the plots, 5 plants were sampled, one from each of the four corners and one from the middle. Leaves from these plants were put in tubes containing silica gel for molecular analysis and the first three plants were taken as vouchers for morphological reference and verification. Identification was done both in the field and in the herbarium using literature materials such as Floras e.g. FTEA, botanical books such as Agnew & Agnew, 1994, Ellis & Linder, (1990). In addition to studying the species of *Pentaschistis* in the field, extensive study of herbarium specimens were conducted at the East African herbarium at Nairobi, Addis Ababa, Uganda, Tanzania and loaned materials from Kew herbarium including all type specimens for detailed morphological study of species of *Pentaschistis*.

Tiny parts of the inflorescence such as the awns, glands, apical bristles and indumentums were observed under dissecting microscope (De Wild.) and photos taken. Variations on morphological characters such as culms length, lamina surface orientation, lamina width, presence of glands on leaves, panicle shape, length, width and glands presence on panicles, number of spikelets, spikelet length, glumes' colour, apex shape, presence of glands, awn length, apical bristle length and anther colour were recorded from at least five specimens in each species from collected voucher specimens including previous herbarium collections and data recorded in an excel spreadsheet for multivariate analyses (Cluster and Principal Component Analysis).

3.2.2 Sampling for phylogenetic analysis

Complete species sampling was attempted based on the taxonomy of Davidse (1988), Linder & Ellis (1990), Galley & Linder (2006) and Phillips (1994; 1995). A total of 83 aligned sequences (67 from gene bank, previous study and 16 from this study) representing 72 species (over 95% of species) were used in the phylogeny analysis. With the exception of five Afroalpine species including the four varieties of *P. pictigluma*, the rest of the samples were obtained from sequences of previous studies (Galley & Linder, 2007; Pirie *et al*., 2008) deposited in the gene bank. Two *Merxmuellera* species were selected as outgroups. Most of the samples used were silica dried although few herbarium specimens were used as well.

3.2.3 Phenetic analysis

Qualitative characters were coded and data matrix generated (Appendix 2a and 2b) for phenetic analysis using STATISTICA version 9.0. Both cluster analysis and Principal Component Analysis were conducted.

The distribution and habitat preference of the species of *Pentaschistis* were assessed from all the sampled plots and from outside the plots. The cumulative frequency of occurrence of *Pentaschistis* species were recorded on a table form and results presented in a simple line graph.

3.2.4 DNA analysis

Total genomic DNA was extracted from silica dried specimens or herbarium sheet using the standard CTAB protocol (Doyle & Doyle, 1987). Two non–coding regions of the chloroplast DNA viz: TrnL-F and rpL-16 and internal transcribed spacer (ITS) from nuclear ribosomal DNA were used for amplification and sequencing reactions. For both the plastid and the ITS regions, PCR amplifications were performed in Thermocycler machine Gene Amp PCR

System 9700 (Applied Biosyst., USA) using a total reaction volume of 20 µl with 25mM mgcl2, 10 × PCR buffer (Biolab, USA), 10 mM dNTPs, 10 µM primer and 1 unit of Taq polymerase (Biolab, USA) and 2µl DNA template of unknown concentration. Table 14 shows the regions amplified and sequenced and the primers used.

Table 14: Gene region amplified and sequenced and the primers used for amplification

Gene Region	Primers (PCR)	Primers (sequencing)	Source
trnL-F	c, f	c, d, e, f	Taberlet *et al*. 1991
rpL16	F71	F71	Baum *et al*. 1998
	R1000	R1000	Galley & Linder 2007
ITS	L/4	L/4	Baum *et al*. 1998

The trnL-F intron and intergenic spacer was amplified using a PCR protocol with an initial denaturation step of 80°C for 5 minutes followed by actual denaturation at 94°C for 1 min, followed by annealing temperature of 50°C for 1 min running for 35 cycles followed by an extension of temperature at 72°C for 2 min and terminated with final extension of 5 min at 5 min. The rpL16 intron was amplified using an initial denaturation step of 94°C for 4 min followed by 34 cycles of 1 min 94°C actual denaturation, 1 min at 55°C annealing step, followed by 1 min at 72°C extension and a final extension of 7 min at 72°C. The amplification of the nuclear marker region of ITS followed PCR protocol with an initial denaturation step of 4 min at 94°C followed by 35 cycles of actual denaturation of 30 s at 94°C, followed by annealing process for 1 min at 53°C, followed by initial extension for 3 min at 72°C and a final extension for 7 min at 72°C. PCR products were visualized on 2% agarose gel for confirmation of successful amplification through band observation and purified using the Agencourt AMPure XP system (Beckman Coulter, Brea, CA, USA) on a Beckman Coulter Biomek (Beckman Coulter) robot using the manufacturer's protocol. Cycle sequencing was performed on an Applied Biosystems 3730XL DNA Analyzer (Applied

Biosystems, Foster City, CA, USA) using the BigDye terminator version 3.1 with 5x sequencing buffer (Applied Biosystems) following the manufacturer's protocol.

3.2.5 Phylogenetic analysis

Bayesian analysis was performed on each of the markers separately and in combination using Bayesian inference, as implemented in MrBayes 3.2 (Huelsenbeck & Ronquist, 2003). Multiple sequence alignment was done using the ClustalW option in Bioedit version 7.0 and adjusted manually. MEGA v5.05 (Tamura *et al.,* 2011) was used to analyze the sequences' characteristics, such as length of sequence, number of variable characters and parsimony–informatives sites. The best fit substitution models for each of the three partions were chosen using MrModeltest v2.3 (Posada & Crandall, 1998) as implemented in PAUP* v. 4.0b10 (Swofford, 2003) using the Akaike information Criterion (Akaike, 1973).

Bayesian analyses were run as two parallel MCMC (Marcov Chain Monte Carlo) analyses using information from the model such as Nst, gamma/invigamma. For the separate analysis, each run covered five and ten million generations for plastid and ITS respectively, with one cold and three heated chains. Frequency sampling during the analysis for the plastid and ITS regions occurred after every 5000 generation. The combined analysis covered 15 million generation with sampling occurring after every 10, 000 generations. Convergence was diagnosed using the standard deviation of split frequencies (SDSF) and the likelihood of each parameter was checked for stability confirming sufficient convergence. In this case SDSF value of between 0.007 and 0.009 was obtained for both the single gene and combined analysis signaling enough convergences between the runs. Twenty five percent of the generations were discarded as burn–in and remaining summarized in a 50%–majority rule consensus tree with posterior probabilities (PP) as a measure of clade support.

3.3 RESULTS

3.3.1 Cluster analysis (CA)

A morphological data matrix involving 38 characters was analysed from 37 specimens (OTUs=specimens) of *Pentaschistis* representing nine taxa. The results indicate three major clusters. At linkage distance 100, two major clusters are visible that divides the tropical *Pentaschistis* into two clusters. Cluster A comprises of specimens representing the two narrow endemics*, P. dolichochaeta* and *P. chrysurus* in addition to the broadly distributed *P. natalensis*. These are showing continuous variation. Cluster B constitutes the broadly distributed species of *P. pictigluma* variations (*P. minor*, *P. mannii*, *P. pictigluma* and *P. gracilis*) and *P. borussica*. The only annual, *P. trisetoides* is nested within this cluster. At linkage distance 60, three major clusters are evident and are: *P. dolichochaeta*, *P. chrysurus* (Cluster A), *P. natalensis* (Cluster B) and *P. mannii*, *P. minor*, *P. borussica*, *P. gracilis* and *P. pictigluma* (Cluster C).

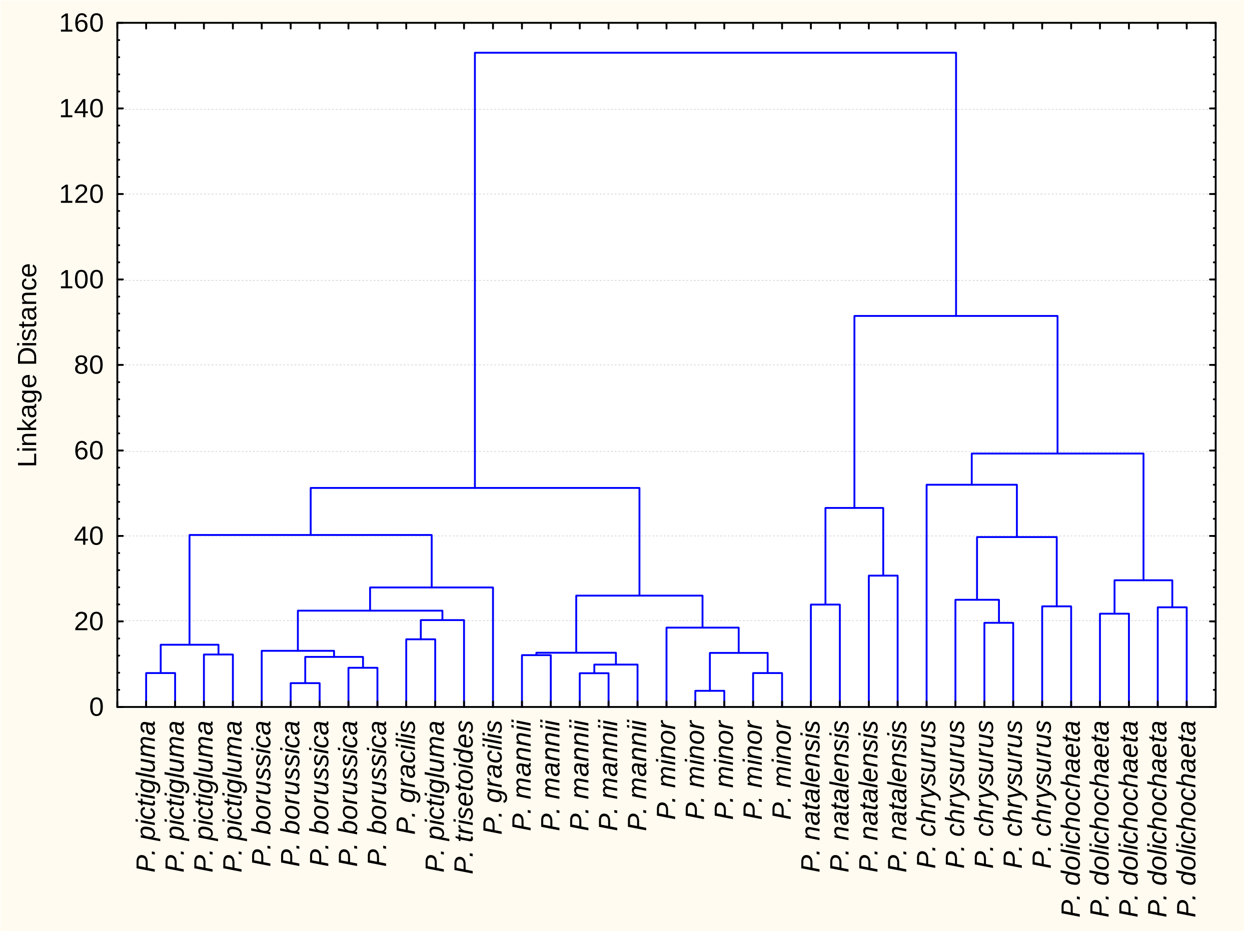


Figure 22: Phenogram of Custer Analysis for *Pentaschistis* species

3.3.2 Principal component analysis (PCA)

PCA is suitable for revealing patterns of continuous variation in a data set and allow us to recognise the same groups defined by cluster analyses. Hence the same data matrix was analysed using PCA except for one variable, leaf position that was not varying among the taxa and was therefore eliminated from the analysis. The result of PCA of 37 morphological characters showed similar pattern with that of Cluster Analyses (figure 23). Five groups are visible: *P. pictigluma* variations, *P. borussica*, *P. natalensis, P. chrysurus*−*P. dolichochaeta* and *P. trisetoides*. The first group on the top left are the two narrow endemic species *P. dolichochaeta* and *P. chrysurus*. Below this group is *P. natalensis* which, in the study area occur only in Tanzania. In the top right section of the PCA graph is the *P. pictigluma* species complex comprising of the four varieties (*P. pictigluma* var. *pictigluma*, *P. pictigluma* var. *minor*, *P. pictigluma* var. *mannii* and *P. pictigluma* var. *gracilis*). In the bottom right is the other broadly distributed species *P. borussica*. In between *P. pictigluma* and *P. borussica* occur the only annual *P. trisetoides* (Figure 23).

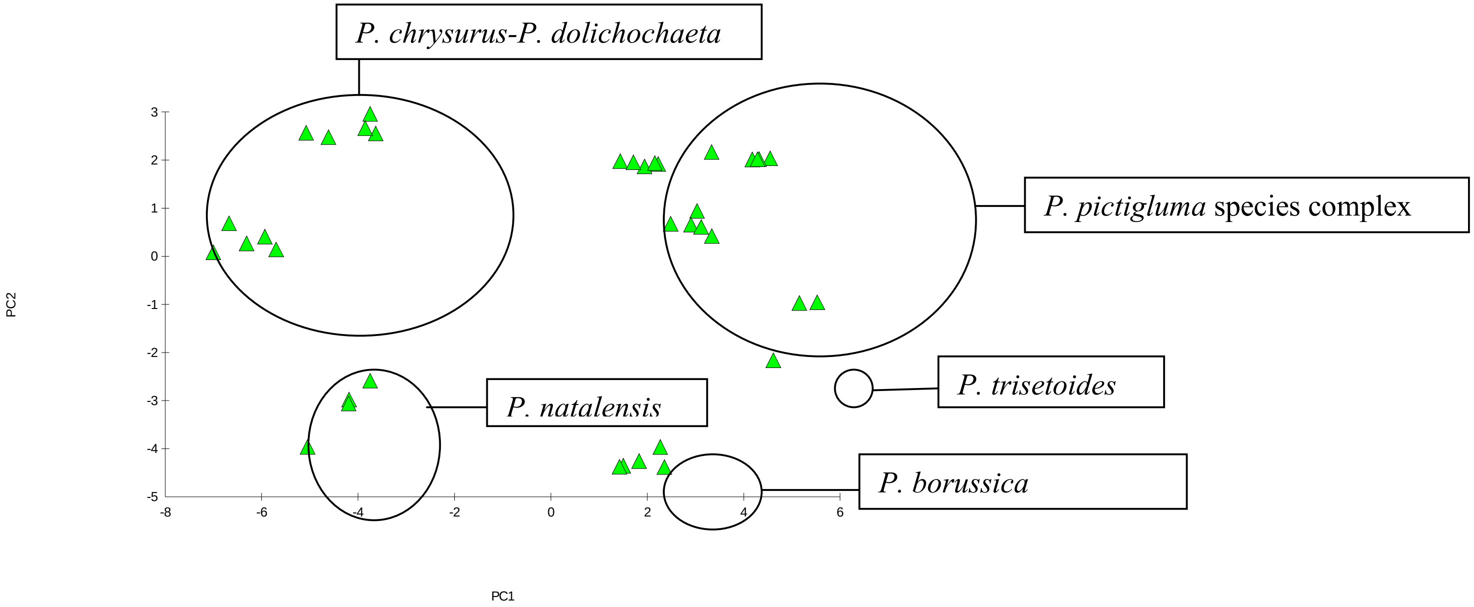


Figure 23: Scatter plot of the PCA results of morphological variations for *Pentaschistis* species

Table 15: Distribution of *Pentaschistis* species in Eastern African mountains

Species	Mountain	Vegetation Community	Altitude (m)
Pentaschistis borussica	Bale, Elgon, Kenya, Kilimanjaro, Rwenzori, Abedares and Meru	All the four vegetation types but frequent in rock outcrop and Alpine grasslands	3159 to 4337
Pentaschistis chrysurus	Kilimanjaro and Meru (Tanzania endemic)	Thicket/forest	2598 to 3594
Pentaschistis dolichochaeta	Ancober and Wafwasha forest	Forest	2800 to 3000
Pentaschistis pictigluma var. *pictigluma*	Bale and Simen (Ethiopian Endemic)	All vegetation types but frequent in rock outcrop and Alpine grasslands	3875-4122
Pentaschistis pictigluma var. *mannii*	Meru, Kilimanjaro and Kenya	Grassland and rock outcrop	3900-3936
Pentaschistis pictigluma var. *minor*	Bale, Kilimanjaro, Kenya and Elgon	All vegetation types, frequently in rock outcrops	3636 to 4461
Pentaschistis pictigluma var. *gracilis*	Bale and Ethiopian highlands	Grassland and *Alchemilla*	3705 to 4143
Pentaschistis trisetoides	Bale and Simen	Rock outcrop	3705 to 3760

3.3.3 Distribution and Ecological Analysis of *Pentaschistis* Species across the vegetation communities

Five species of the genus *Pentaschistis* (Poaceae) were sampled and recorded from the plots and outside the plots (Table 15 and 16). Those sampled from the plots are three species (figure 24) and include: *P. borussica*, *P. pictigluma* var. *gracilis*, *P. pictigluma* var. *minor*, *P. pictigluma* var. *pictigluma* and *P. trisetoides*. *Pentaschistis chrysurus* and *P. dolichochaeta* were sampled from outside the plots since they occurred below Afroalpine zone. Both species usually occur in more or less forest zone or bush thickets near trails

Table 16: Frequency of *Pentaschistis* species in the five vegetation communities of Afroalpine zone of Eastern Africa

Species	Rock outcrop	Bog	Grassland	*Dendrosenecio*	*Alchemilla*
Pentaschistis borussica	8	2	7	1	0
Pentaschistis pictigluma var.*gracilis*	0	1	0	0	1
Pentaschistis pictigluma var. *minor*	5	1	2	1	0
Pentaschistis pictigluma var. *pictigluma*	5	4	2	0	0
Pentaschistis trisetoides	2	0	0	0	0

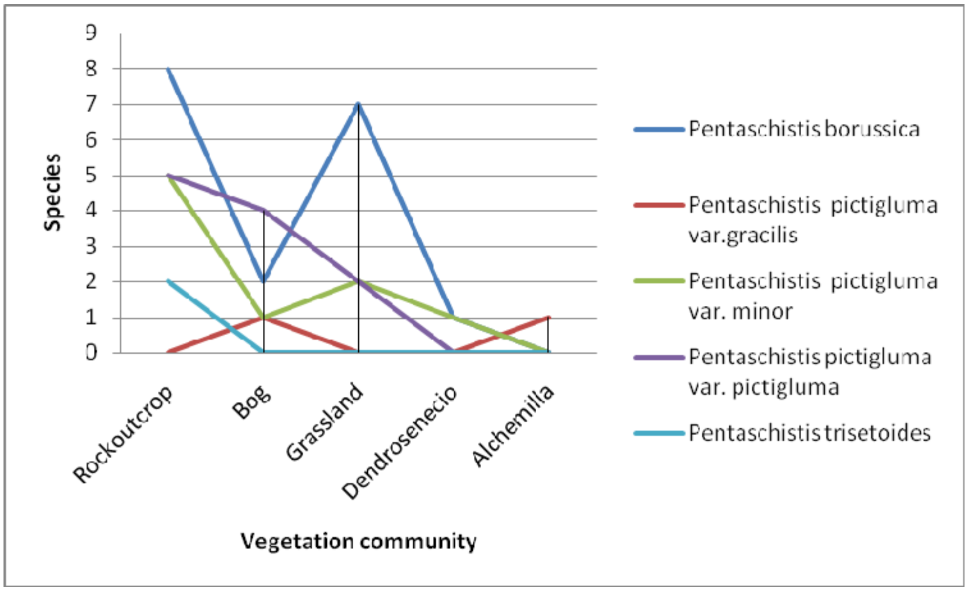


Figure 24: Showing the occurrence and prevalence of five *Pentaschistis* species across five vegetation types in East Africa and Ethiopian mountains

3.3.4 Molecular Analysis

The final matrix used for the phylogenetic analysis consisted of a total of 2032 plastid and nuclear DNA sequence characters. Trimming at both ends of the dataset was done due to some variations of some sequence length between the newly sequenced samples (current study) and the retrieved sequences from the gene bank (previous studies). The lengths of the sequences of *trn*L-F and rpL-16 regions are 693 bp and 767 bp respectively after the trimming. For the aligned sequences of trnL-F the number of variable characters was 164(24.0%) of which 66 (9.5%) were parsimony-informative sites. A GTR+G substitution model was selected for both partitions of the two plastids. The length of the ITS sequences was 572 bp out of which were 180 (31.5%) variable sites and 93(16.3%) parsimony informative sites. The best fit model for the ITS was GTR+ G + I.

From the Bayesian analysis, a consensus tree with fairly moderately resolved phylogenetic tree (figure 25) is obtained which recovers most of the clades of the previous phylogenetic analysis of Galley and Linder (2007). From this tree, the Afroalpine species from Eastern Africa are grouped into two widely separated and distantly related clades that will form the basis of the discussion below. The first Afroalpine species to form a clear sub-clade are the two species *P. borussica* and *P. pictigluma* including all the four varieties of *P. pictigluma* (*P. pictigluma* var. *pictigluma*, *P. pictigluma* var. *minor*, *P. pictigluma* var. *gracilis* and *P. pictigluma* var. *mannii*).

Like in the previous phylogeny of Galley and Linder (2007) the sequence association or grouping between these two species somewhat varied in that some accessions from one species aggregate with another accession from the other species rather than an accession from its own species (Sub-clade 1 figure 25). All the sequence accessions from Afroalpine species are from this study but interestingly the same pattern is observed in the previous phylogenetic analysis. The monophyly of both sub–clades are strongly supported.

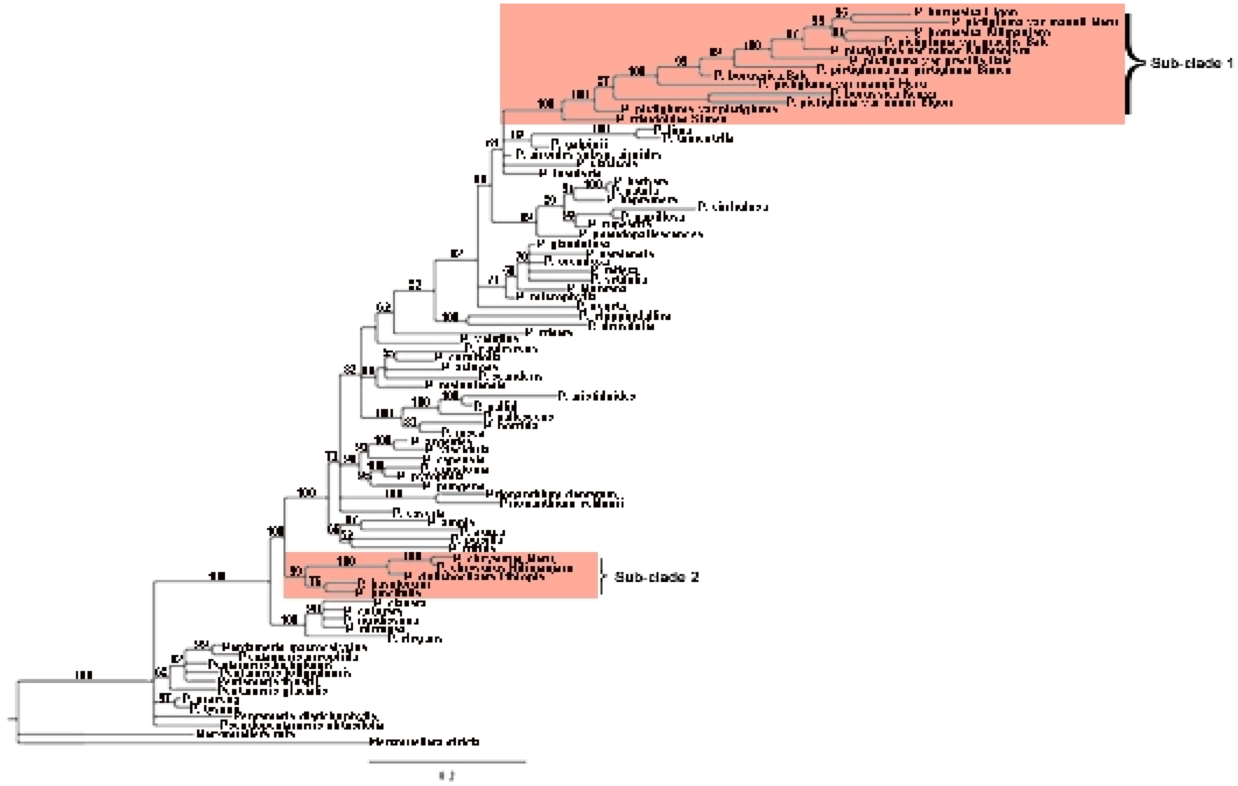


Figure 25 Phylogenetic tree inferred from Bayesian analysis of the plastid DNA (*trn*L–F & *rpL-16*) and ITS data set of *Pentaschistis* species. Posterior probability values are indicated above the branches

3.4 DISCUSSION AND CONCLUSION

3.4.1 Phenetic and morphological analysis

The results from the morphological variation within and between the populations study conducted in the Afroalpine zone of the Eastern Africa including morphometric analysis of 37 specimens for 38 characters of the species of *Pentaschistis* broadly indicates the existence of two major groupings. The first of these groupings is the two widely distributed species viz: *P. borussica* and the *P. pictigluma* species complex as well as two narrow endemics: *P. dolichochaeta* and *P. chrysurus*. The two narrow endemic species are morphologically more similar, as indicated by both the CA and the PCA. Study of herbarium specimens as well as phenetic analysis (CA & PCA) also indicate that *P. natalensis* exhibit superficial morphological similarity to the two vicariant narrow endemic taxa: *P. chrysurus* and *P. dolichochaeta* that are endemic to Tanzania (Mt. Kilimanjaro and Meru) and Central Ethiopian highland (Shewa region) respectively. *Pentaschistis natalensis* is the most widely distributed species of the genus occurring from South Africa to southern Tanzania highland and Madagascar. However, phylogenetic analysis of the *Pentaschistis* clade (*Pentaschistis*, *Pentameris* Beauv. and *Prionanthium* Desvaux) based on the cpDNA characters by Galley & Linder (2007) indicate that *P. natalensis* is not related to the tropical African *Pentaschistis* and thus the morphological resemblance between *P. natalensis* and the two narrow endemics is superficial.

Similarly comparative gross morphological study of *P. pictigluma*, *P. minor*, *P. mannii* and *P. gracilis* indicate that there is overlap of characters among these taxa and hence are phenetically not clearly distinct as revealed by both CA and PCA of the current study. About 19 characters are particularly important in separating well the taxa under study. These are: culm length, leaf length and width, panicle length, number of spikelets, spikelet length, glume length & indumentums, anther length & colour, awn length, apical bristle length, lemma length and indumentums, palea length, floret length and indumentums. However in the field, subtle morphological differences between these taxa can be observed that distinguishes between them. For example *P. pictigluma* var. *pictigluma* has characteristic golden yellow panicles while *P. pictigluma* var. *gracilis* has silvery grey panicles and soft glandular leaves. *Pentaschistis pictigluma* var. *minor* can be easily recognised by its short stature, few grey spikelets and folded tough leaves.

The habitat preference and distribution of *Pentaschistis* species vary. *Pentaschistis borussica* was the most widely distributed species as well as the most abundant species occurring in all the mountains except Mt. Simen. This species frequently occur in rock outcrop and grass vegetation communities but has also been recorded from bogs. It is rare in *Dendrosenecio* and *Alchemilla* vegetation communities. *Pentaschistis pictigluma* var. *minor* was also widely distributed occurring in four out of the six mountains sampled but was restricted largely on rock outcrop vegetation community, most often in the mountain summits. *Pentaschistis pictigluma* var. *pictigluma*, *P. pictigluma* var. *gracilis* and *P. trisetoides* are endemic to Ethiopian Mountains including Bale and Simen. *Pentaschistis pictigluma* var. *mannii*. *P. chrysurus* and *P. dolichochaeta* have been recorded from outside the plots. *Pentaschistis chrysurus* is endemic to Tanzania while *P. dolichochaeta* is endemic to Shewa region of Ethiopia.

Phenetically and morphologically there were significant differences between the broadly distributed species (*P. borussica*–*P. pictigluma*) and the two narrow endemics (*P. chrysurus* and *P. dolichochaeta*) thus rejecting the null hypothesis earlier stated in the hypothesis section of the second chapter (hypothesis one). Habitat preference between these two groupings was also quite distinct as the narrow endemics are essentially forest (non-alpine species) while the distribution range of the broadly distributed species was largely alpine zone. Thus the two loose groupings exhibited altitudinal separation.

3.4.2 Phylogenetic analysis

A fairly moderately resolved phylogenetic tree of the *Pentaschistis* clade was obtained revealing two colonization events of the Afroalpine species in East Africa and Ethiopian Mountains. Consequently the earlier view held of single colonization event of tropical African *Pentaschistis* is rejected (null hypothesis two of the second chapter). The *Pentaschistis* clade consists of three genera viz: *Pentameris*, *Pentaschistis* and *Prionanthium*, and was so named by Barker *et al.* (2000) following the phylogenetic analysis of the DNA of *Danthonioideae* grasses. The groupings of these three genera are supported by morphological characters such as spikelet similarities-presence of multicellular glands, having two fertile florets per spikelet and rachilla extension. They also share weak development (loss of) haustorial synergids, fine granular or lack of starch in the synergids compared to the presence of globular starch in other *Danthonioid* genera, insertion of the lemma setae in the sinuses between the lateral lobes and the median awn. In addition, these three genera have basic chromosome number of x= 7.

This morphological and cytological evidence is strengthened by the recent phylogenetic analysis of Galley and Linder (2007) as well as this study that showed the two genera of *Pentameris* and *Prionanthium* are nested within the *Pentaschistis* clade. However, since the scope of this study is limited to tropical African Mountains, this discussion will focus on the Afroalpine sub-clades of the genus *Pentaschistis* that constitute the bulk of the species of the *Pentaschistis* clade. Although most of the clades described in Galley & Linder (2007) are recovered in the resulting phylogenetic tree, the discussion will only focus on the clades nesting the Afroalpine sub-clades.

As revealed by the phylogenetic tree, the Afroalpine species of *Pentaschistis* grouped into two distantly related clades with high support of posterior probability (PP= 100). This provides strong evidence of two independent events of colonization of *Pentaschistis* species in the Afroalpine zones of tropical East Africa and Ethiopian Mountains from the source region (Cape Floristic Region and South Africa). The first Afroalpine species sub–clade are grouped with the large "summer rainfall clade" (VII). Basically this first group consists of the two broadly distributed species: *P. borussica* and *P. pictigluma* and the only annual species *P. trisetoides* that is sister to the *P. pictigluma–P. borussica* sub-clade. Other members of the "summer rainfall clade" apart from the Afroalpine species are: *P. lima*, *P. aristifolia*, *P. tomentella*, *P. airoides* ssp. *airoides*, *P. pseudopallescens*, *P. veneta*, *P. tomentella*, *P. oreodoxa*, *P. glandulosa*, *P. natalensis*, and *P. insularis* among others. All the variations of *P. pictigluma* (var. *pictigluma*, var. *minor*, var. *mannii* and var. *gracilis*) are all represented as well as the different collections of *P. borussica* from East Africa and Ethiopian Mountains.

Both the morphological and morphometric analysis of the current study as well as previous morphological variation study indicate almost lack of distinct morphological characters that separates the *P. pictigluma* varieties and to a lesser extent between *P. pictigluma* varieties and *P. borussica*. Similar trends where sequences from *P. borussica* and *P. pictigluma* are grouped together in the internal nodes are observed. From these observed trends and the wide distribution of these two species, it can therefore be inferred that these (*P. borussica* and *P. pictigluma*) are young taxa undergoing rapid diversification following their introduction in the Afroalpine zone as well as lineage sorting.

The second sub-clade of Afroalpine species includes the two narrow endemics viz: *P. chrysurus* and *P. dolichochaeta* that aggregate with *P. basutorum* and *P. juncifolia* which form a grade with strong support (PP= 99; sub-clade 2). *Pentaschistis chrysurus* and *P. dolichochaeta* share a number of morphological characteristics such as robustness (size), relatively broad leaves, long culms, large spikelets and florets, long awns and lack glands. These two species occur in similar habitats (forest or thicket) and occupy between forest zone and sub-alpine zone (2500m to 3400 m). Phillips (1995) in Flora Ethiopia and Eritrea similarly noted the close morphological affinities between these species. Both *Pentaschistis dolichochaeta* and *P. chrysurus* are endemic to Ethiopia and Tanzania respectively where the former is limited to Shewa region specifically in Ancober and Wafwasha natural forest while the latter is limited to Mt. Kilimanjaro, Mt. Meru and has been cited from Mt. Hannang all in northern Tanzania (Phillips, 1995).

Generally speaking species after their introduction to new suitable habitats tend to spread, diversify and occupy as large area as possible depending on the success of any given species before it starts shrinking its range due to natural or anthropogenic factors, natural evolutionary process that ultimately lead to extinction. Since rarity precedes extinction, the species continue to decline in terms of population density and geographic range until it ultimately disappears altogether (becomes extinct). From biogeographical point of view therefore, these two species are undergoing range shrinkage where their habitat is diminishing implying they are old taxa on road to extinction compared to *P. pictigluma* and *P. borussica* that are undergoing rapid diversification and colonizing available Afroalpine habitats in East African and Ethiopian Mountains. Hence these two species are perhaps vulnerable to extinction since their habitats (forest/thickets) in the lower zones of the high mountains are experiencing anthropogenic induced destructions and fragmentation that is causing loss of biodiversity.

The current phenetic study, gross morphology and DNA sequences of tropical African *Pentaschistis* reveal the distinctness of *P. chrysurus*, *P. dolichochaeta* from the rest of the taxa and the close morphological affinities between them. *Pentaschistis borussica* can be easily distinguished from the four varieties of *P. pictigluma* by its raised glands and is also phenetically distinct from these taxa. The phenetic analysis results (and sequence similarities) among *P. pictigluma*, *P. minor*, *P. gracilis* and *P. minor* indicate that these taxa are not distinct from each other. Hence this study proposes the retention of the current taxonomic treatment. It also further recommends population genetic studies among the populations of *P. pictigluma* species complex and between the two narrow endemics, *P. dolichochaeta* and *P. chrysurus* to reveal the existence of any cryptic speciation and possible hybridization.

3.4.3 Key to *Pentaschistis* species occurring in African high mountains

This section gives dichotomous key that shows the species circumscription adopted by this study after the various analysis.

1. Plant annual; lacking rhizomes/stolons…………………...................*Pentaschistis trisetoides*

Plant perennial; rhizomes/stolons mostly present………………………..........................2

2. Inflorescence loose and/or open; 3–17 cm wide……………………………........................4

Inflorescence loosely contracted to linear/spiciform; 0.8–2.5 cm wide……........................3

3. Culm length 60–120 cm; lamina length 40−60 cm; spikelet length 8–9 mm; endemic to Shewa region of Ethiopia………………………………......................*P. dolichochaeta*

Culms length 6−40 cm; Lamina length 3−20 cm; spikelet length 4–7 mm long, widespread in tropical African Mountains……………………................................*P. pictigluma*

4. Leaf margins and inflorescence glandular; florets glabrous, 2.5–3 mm; widespread in East Africa and Ethiopia…………………………………………………….........*P. borussica*

Leaf margins and inflorescence eglandular; florets densely hairy, 4 mm; restricted to Tanzania……………………………………………….......................................5

5. Panicle ovate to oblong, florets not intertwined; spikelet number over 200; glume apex acuminate……………………………………….................................*P. chrysurus*

Panicle pyramidal in shape, florets intertwined; spikelets 35–150; glume apex acute……………………………………………….............................*P. natalensis*

Varieties of *P. pictigluma*

a) Golden brown panicle; lamina flat or in−rolled, may or may not be glandular ……………………………... var. *pictigluma*

b) Grey or silvery panicles, not glandular; lamina linear, flat, margins usually glandular………………………..var. *gracilis*

c) Eglandular plants; panicles grey few spiculate; lamina narrowly linear or in−rolled to setaceous……………………...var. *minor*

d) Panicles grey, occasionally glands restricted to pedicels, raised crateriform, leaf sheaths white, shiny & persistent; ……………………...var. *mannii*

1. *Pentaschistis trisetoides* (Hochst. ex Steud.) Pilg. In Notizbl. Bot. Gt. Berlin 9:516 (1926); C.E. Hubb., F.T.A. 10: 131 (1937); Cufodontis, Enum. Ethiop. 1235 (1968); Linder & Ellis, Contrib. Bol. Herb. 12:50 (1990); S.M. Phillips, F.E. & E. (1995); Type: Ethiopia, near Debra Eski, *Schimper 109* (K, holo!, NH, ETH, iso!).

Synonym: *Danthonia trisetoides* Hochst. ex Steud., Pl. Glum. 1:244 (1854); K. Schum., Engl., Pflanzenw. Ost−Afrika C: 109 (1895). *Danthonia segetalis* Hochst. in Flora 38:276 (1855). *Pentaschistis segetalis* (Hochst.) Pilg. In Notizbl. Bot. Gt. Berlin 9:518 (1926). Type:

Ethiopia, near Debra Eski, *Schimper 24* (TUB, holo., K). *Danthonia trisetoides* Hochst. ex Steud. var. *tenuis* Engl., Hochgebirgsflora 131 (1892). *Pentaschistis trisetoides* (Hochst. ex Steud.) Pilg. var. *tenuis* (Engl.) Pilg. In Notizbl. Bot. Gt. Berlin 9:517 (1926). Type: Ethiopia, *Schimper 621* (B, holo., K), *Schimper 766*.

Slender annual glandular plant with simple culm, 6–35 cm tall. Leaf lamina soft linear, flat, glabrous above, pubescent below, 2–10 cm × 0.2 cm wide, margin scabrid. Inflorescence open or loosely contracted. Panicles glandular with raised, crateriform glands. Spikelets about 45–100, silvery grey with purple tinged, 3.5–5 mm long. Glumes lanceolate, acuminate greenish purple 3.5–5 mm long glabrous to scaberulous occasionally glandular. Florets glabrous, 2 mm long. Lemma pubescent, 1.5–2 mm long, awned and with two apical bristles. Apical bristles 1–2 mm long. Palea glabrous, 1.5−2 mm long. Awn 5–6.5 mm long, geniculate. Anthers brown 0.3–0.7 mm long.

Voucher specimen(s) cited: Ethiopia, Gondar region, Mt. Simen, Geech, *AFROALP II team*, *ET 220−3*, 25 October 2007.

Distribution: Bale, Simen & Ethiopian highlands (TU, BA, GD, SU, AR)

2. *Pentaschistis dolichochaeta* S.M. Phillips; Type: Ethiopia, SU, Ankober, *Lemma Selassie 887* (Eth holo.).

Perennial eglandular fairly robust plant with rhizomatous base. Culm 60–120 cm tall. Lamina 40–60 cm × 0.3−0.6 cm, flat occasionally inrolled 3–6 mm wide, margins scabrid, puberulous on the upper surface glabrous below. Panicle open to loosely contracted 10–16cm × 3–4 cm. Spikelets 180–200, pale greenish yellow 8–9.5 mm long. Glumes pale green, acuminate, glabrous or nearly so 8–9 mm long. Florets densely hairy, 4 mm long. Lemmas 3–3.5 mm long, pilose with two apical bristle 5–6 mm long arising from the lemma lobes, palea glabrous, 4−5 mm long. Awn 9–15 mm long, geniculate, column 1–2 mm long. Anther golden yellow, 2.5–2.7 mm long.

Ethiopia, Shewa region, Debre Sina, Wafwasha natural forest, 24 April 2009, *Ahmed A. Abdi ET−1604−1*, *ET−1604−6*, *ET−1604−7*, *ET− 1604−8*, 1 *ET−604−21*.

Distribution: Wafwasha forest and Ancober, Shewa (Ethiopia, SU). Not known elsewhere; 2920−3000 m.

3. *Pentaschistis borussica* (K. Schum.) Pilg. In Notizbl. Bot. Gt. Berlin 9: 517 (1926); Hubb., F.T.A. 10:128 (1937); Clayton, F.T.E.A. 1: 125 (1970); Linder & Ellis, Contrib. Bol. Herb. 12:55−56 (1990); *Danthonia borussica* K. Schum. In Eng., Pflanzenw. Ost−Afr. C: 109 (1895). Type: Tanzania, Mt. Kilimanjaro, *Volkens 1368* (EA. iso!, B, holo., BM, K).

Synonym: *Pentaschistis trisetoides* (Hochst. ex Steud.) Pilg. var. *expansa* Pilg. in Notizbl. Bot. Gt. Berlin 9: 516 (1926).

Pentaschistis expansa (Pilg.) C.E. Hubb. in F.T.A. 10:130 (1937). Type: Kenya, Mt. Kenya, *Fries 1200b* (B, holo.).

Pentaschistis effusa Peter in FDOA 1, Anh.: 97 t. 56/1 (1930). Type: Tanzania, Mt. Kilimanjaro, *Peter 46685* (B, holo.).

Pentaschistis meruensis C.E. Hubb. In Kew Bull. 1936:501 (1936); C.E. Hubb., F.T.A 10:127 (1937). Type: Tanzania, Arusha District, Mt. Meru, *Burtt 4062* (K, holo!, EA, iso!).

Pentaschistis ruwenzoriensis C.E. Hubb. In Kew Bull. 1936:500 (1936); C.E. Hubb., F.T.A 10:127 (1937). Type: Uganda, Toro District, Mt. Ruwenzori, *Taylor 2903* (K, holo., EA iso!)

Tufted perennial glandular plant with short rhizome. Culm, 11–60 cm tall. Leaf lamina linear, flat or folded, pubescent above, glabrous below 5–25 cm × 0.2−0.4 cm, margin smooth, sheath mouth villous. Inflorescences open with 20−70 spikelets. Panicles glandular with raised glands on the pedicels, branches, glumes and awns, 3−16 × 1−15 cm. Spikelets light to dark grey , (3.5)4–6(8) mm long. Glumes lanceolate−oblong, acute or acuminate greenish to pale yellow often purplish tinged 4–6 mm long glabrous to scaberulous occasionally glandular. Florets glabrous, 2.5−3 mm long. Lemma glabrous or pubescent, 2–3 mm long, awned and with two apical bristles. Awn geniculate, 5–9(11) mm long, apical bristles 2–3 mm long. Palea glabrous, 2−4 mm long. Anthers golden brown to purple 0.9–2.5 mm long.

Tanzania, Moshi, Arusha National Park, Mt Kilimanjaro, Shira, 6 November 2008, *Abdi, A., Abel G., Wondimu T., C. Masao & FellyT., TZ−116−4*; 10 November 2008, Karanga, *TZ−184−4*; Kenya, Kitale, Mt. Elgon, east of Koitobos, 27 January 2009, *Abdi et al. KN−251−3*, *KN−251−4*; Nyeri, Aberdares, Satima peak, 12 February 2009, *Abdi et al. KN−538−3.*

Distribution: Bale and southern highland, Ethiopia (BA, AR, SU), Mt. Kenya, Elgon, Aberdares, Kilimanjaro, Meru & Ruwenzori (U1−3, K3, 4; T2); 3000−4680 m.

3. *Pentaschistis chrysurus* (K. Schum.) Peter in Fedde Repert. Beih. 40.1:303(1931); Hubb., F.T.A. 10:125 (1937); Clayton, F.T.E.A. 1: 124 (1970); Linder & Ellis, Contrib. Bol. Herb. 12:105(1990).

Synonym: *Danthonia chrysurus* K. Schum. In Eng., Pflanzenw. Ost−Afr. C: 110 (1895). Type: Tanzania, Mt. Kilimanjaro, *Volkens 1826a* (B, holo., EA. iso!,K, photo).

Robust perennial eglandular plant with rhizome. Culm, 84−150 cm tall. Leaf lamina tough, linear, flat, glabrous above, pubescent below 43–56 cm × 0.7−1.0 cm, margin smooth and/or folded, sheath mouth villous. Inflorescences open with 200−250 spikelets. Panicles open, glabrous, dense, much branched,10−32 × 3−8 cm. Spikelets light to dark brown,7.5–10 mm long, ultimate pedicels (1)4−8 mm. Glumes acuminate light yellow to golden yellow, purple tinged, glabrous 7.5–10 mm long. Florets pubescent, 4 mm long. Lemmas pubescent, 3–5 mm long, awned and with two apical bristles. Awn geniculate, 8–15 mm long, apical bristles 3–6 mm long, column1−2 mm, slightly twisted . Palea glabrous, 4.5−5 mm long. Anthers golden brown 2–2.5 mm long.

Distribution: Mt. Kilimanjaro, Meru & Hanang (Tanzania, T2); 2598−3594 m.Tanzania, T2, Moshi, Mt. Kilimanjaro, 19 November 2008, *Abdi, A., Abel G., Wondimu, T., Masao, C. & Felly, T. TZ−348−4*; Mt. Kilimanjaro, 26 February 1934, *Greenway 3801*; 2 December 1972, *Vesey−FitzGerald D. 7506*; Arusha National Park, Mt. Meru, 24 September 1967, *Gilbert, V.C. 2249*; Meru crater, 28 December 1965, Vesey−*FitzGerald D. 4853*.

4. *Pentaschistis pictigluma* (Steud.) Pilg. In Notizbl. Bot. Gt. Berlin 9:517 (1926); C.E. Hubb., F.T.A. 10: 133 (1937); Cufodontis, Enum. Ethiop. 12343 (1968); S.M. Phillips, F.E. &E. 7:70−71 (1995); Linder & Ellis, Contrib. Bol. Herb. 12:63−64 (1990).

Synonym: *Aira pictigluma* Steud., Pl. Glum. 1: 221 (1854). Type: Ethiopia, *Schimper*; *Danthonia anothoxanthiformis* Hochst. (1855) nom. Superfl.−Type: Ethiopia without precise locality, *Schimper* s.n. (P, holo.).

Danthonia thumbergii sensu A. Rich. Non Kunth; based on Quartin Dillon & Petit s.n. (P); *Danthonia uberior* Hotchst. In Flora 38:279 (1855). Types: Ethiopia, Simien, mt. Bachit, *Scimper 112* (K, P); *Schimper 541* (K);

Danthonia nana Engl., Hochgebirgsflora 131 (1892). Type: Ethiopia, on Mt. Guna, *Schimper 1561* (B, holo., BM, K);

Danthonia trisetoides Hochst. ex Steud. var. *schimperi* Engl., Hochgebirgsflora 130 (1892). *Pentaschistis trisetoides* (Hochst. ex Steud.) Pilg. var. *Schimperi* (Engl.) Pilg. In Notizbl. Bot. Gt. Berlin 9:517(1926). Type: Ethiopia, Amba Hedscha, *Schimper 1005*(B, holo.,K).

Tufted very variable perennial plant with or without glands with short rhizome. Culm, 7−50 cm tall. Leaf lamina filiform and inrolled to soft and flat, glabrous or pilose 4–20 cm × 0.2−0.4 cm, margin scabrid, sheath mouth villous, basal leaf sheath whitish and papery. Inflorescences contracted or loosely contracted to spiciform with 10−100 spikelets. Panicles elliptic to narrowly oblong, glabrous to puberulous, 2−13 × 0.5−0.8 cm. Spikelets golden brown or grey to silvery grey,4–7 mm long, ultimate pedicels 2−3 mm. Glumes obtuse or acute or acuminate grey green to pale yellow, purple tinged, glabrous to scaberulous 4–7 mm long. Florets pubescent, 2−3 mm long. Lemmas pubescent, 2–2.5 mm long, awned and with two apical bristles. Awn geniculate, 3.0–7 mm long, apical bristles (1)1.5–3 mm long, column1−3 mm, twisted . Palea glabrous, 2−3 mm long. Anthers golden brown or yellow brown, 0.3–1.2 mm long.

(a) *P. pictigluma* var. *pictigluma*

Characteristic golden brown panicles; spikelets (4.5) 5.5−7(7.7) mm long; awns (4) 5−7 mm long; leaf blades flat or more often inrolled.

Ethiopia, Bale, Bale Mountain National Park, Sannati plateau, Konte, 19 November 2007, *AFROALP II Team ET−902−3*; 12 November, *AFROALP II Team ET−647−3*; Garba Guracha, 15 November 2007, *AFROALP II Team ET−763−3*; Angasu, 20 November 2007, *AFROALP II Team ET−813−3*; Gondar region, Simen, Simen Mountain National Park, Chenek, 28 October 2007, AFROALP *II Team ET−366−1*.

Distribution: Bale, Simen and Ethiopian highlands above 3500 m(Ethiopia, GD, BA, AR, SU, GJ,TU); 3700−4200 m.

(b) *P. pictigluma* var. *gracilis* (S.M. Phillips) S.M. Phillips in Proc. 13th AETFAT Congress: 372 (1994); Synonym: *P. gracilis* S.M. Phillips in Kew Bull. 41: 1028(1986); Linder & Ellis, Contrib. Bol. Herb. 12:64−65 (1990); Type: Ethiopia, SU, Entoto hill, *Friis et al. 1303* (K, holo.).

Silvery grey panicles; spikelets(3.5)4−6 mm long; awns 3−5 mm long; leaf blade linear, flat and soft, margins usually glandular.

Ethiopia, Bale, Bale Mountain National Park, Sannati plateau, Angasu, 23 November 2007, *AFROALP II Team ET−1009−3*; Garba Guracha, 15 November 2007, *AFROALP II Team ET−717−1*.

Distribution: Mt Bale and South & Central highlands (Ethiopia, BA, SU, KF); Elgon (Kenya/Uganda, T3).

(c) *P. pictigluma* var. *minor* (Ballard & C.E. Hubb.) S.M. Phillips in Proc. 13th AETFAT Congress:371 (1994); Synonym: *P. borussica* (K. Schum.) Pilg. *var. minor* Ballard & C.E. Hubb. In Kew Bull. 1930: 121 (1930); P. minor (Ballard & C.E. Hubb.) Ballard & C.E. Hubb. In F.T.A. 10: 132 (1937); Cufodontis, Conspec. Fl.Aeth. 1234 (1968); Clayton, F.T.E.A. 1:127 (1970); Linder & Ellis, Contrib. Bol. Herb. 12:62 (1990); Type: Tanzania, Mt. Kilimanjaro, *Cotton & Hitchcock 64* (K, holo.!).

Eglandular plants, comparatively short perennial variety; panicles grey few spiculate; spikelets 3.6−5 (6) mm long; awn 2.5−5 (6) mm; leaf blade narrowly linear, folded to setaceous.

Kenya, Kitale, K5, Mt. Elgon, eastern slopes, 3 March 1956, *Bogdan, A. AB 4123*; Upper heath zone, 1 January 1957, *Bogdan, A. AB 4499*; Mt. Elgon, December 1933, *Dale, I.R. R3189*; Ethiopia, Bale, Bale Mountain National Park, Sannati plateau, 12 November 2007, *AFROALP II Team ET−946−3*; Tanzania, T2, Moshi, Mt. Kilimanjaro, Shira,4 November 2008, *Abdi, A., Abel G., Wondimu, T., Masao, C. & Felly, T. TZ−48−4*.

Distribution: Bale (Ethiopia, TU, AR & BA); Mt. Kenya, Elgon (Kenya &Uganda, K5, 4, U3); Kilimanjaro (Tanzania, T2); 3000−4800 m.

(d) *P. pictigluma* var. *mannii* (Stapf ex C.E. Hubb.) S.M. Phillips in Kew Bull. 1936: 501 (1936); C.E. Hubb. In F.T.W.A. 2: 528 (1936); F.T.A. 10: 134 (1937); Clayton, F.T.E.A. 1:127 (1970); Linder & Ellis, Contrib. Bol. Herb. 12:62 (1990); Type: Cameroun, Mt. Cameroun, *Mann 1351* (K, holo.!)

Panicles grey, occasionally glands restricted to pedicels; spikelets 6−8 mm long; awn 5−7 mm long; leaf blade flat or folded, leaf sheaths white, shiny & persistent.

Tanzania, T2, Arusha National Park, Mt. Meru, 28 November 2008, Gilbert, *Abdi et al. TZ−453−4*; *TZ−452−4*; *TZ−454−5*; western slopes above Olkakola estate, 27 October 1948, *Hedberg, O. 2301*; Cameroun, Mt. Cameroun, 10 April 1955, *Thresh, J.M. JMT 4*.

Distribution: Mt. Elgon, Moruongole (Uganda, U1, 3); Meru (Tanzania, T2); Mt. Cameroun (Cameroun); 2600−4500 m.

CHAPTER FOUR: SUMMARY DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary discussion

Afroalpine "Sky Islands" of tropical Eastern Africa forms an excellent natural laboratory to study the biodiversity dynamics and the influence of abiotic and possibly biotic factors that ultimately cause diversification of Afroalpine species following successful dispersal from the source region. A total of 46 vascular plant families consisting of 124 genera and 278 species were recorded and sampled from five vegetation communities rock outcrops, bogs, grassland, *Dendrosenecio* forest or woodland and *Alchemilla* across six high mountains viz: Mt Kenya, Elgon, Kilimanjaro and Ruwenzori, Bale and Simen. Interestingly, the result indicates the dominance of few families over the majority in the colonization and occurrence of their species and genera in the sampled vegetation types and Mountains while 65% of the Afroalpine families have monotypic genera that are mostly represented by one or two species. For instance Asteraceae and Poaceae, the two dominant families have 21 and 17 genera respectively and account for more than a third (38%) of all the species of Afroalpine collected from the sampled plots while families like Rubiaceae, Asphodolaceae, Juncaceae, Geraniaceae, Commelinaceae and Callitrichaceae among others (30 families) are each represented by only one genus that has one or less often two species.

A number of factors could have contributed to the success of Asteraceae and Poaceae such as morphological adaptations including development of tiny light seeds especially grasses and parachute structures like most of the members of Asteraceae that enable the species to be well adapted for long distant dispersal by wind. This is because wind dispersal is thought to be one of the main mechanisms effecting long distance dispersal for Afroalpine plants (Troll, 1952; Hedberg, 1964b &1970; Coe, 1967) since all the Afroalpine enclaves are effectively isolated from other flora of the surrounding vegetation and from each other by the high elevation. In addition, wind dispersal or *anemochory* is characteristic of pioneer vegetation and virgin habitats like newly formed volcanoes or after receding of glaciers or oceanic islands (Van der Pijl, 1969) and its significance is directly proportional to the altitudinal height of the mountains (Hedberg, 1970). Strong winds and occasionally wind storms like cyclones are prevalent in Afroalpine zones of the high mountains and are capable of blowing large amount of light and tiny seeds between the mountain Afroalpine enclaves and even from far distant areas in the Northern and Southern Hemispheres with alpine climate. Other factors such as fire (especially favours grass community), physiological and genetic adaptations could be playing role in the dominance and rapid diversification of some families over others but is out of scope of the current study (Wesche *et al*., 2000).

The Afroalpine plant communities prevalent in the five vegetation types sampled were dominated by one or few keystone genera and species. The following are the main combination of the keystone genera and species that best describes the communities in the vegetation type: *Carex runssoroensis−C. monostachya−Deschampsia caespitosa* dominated bogs, *Festuca abyssinica−F. simensis−Pentaschistis* dominated grassland communities, *Dendrosenecio−Alchemilla* species dominated *Dendrosenecio* forest/woodland, *Alchemilla argyrophylla−A. johnstonii−A. haumannii* dominated shrubby *Alchemilla* communities and *Helichrysum−Festuca−Koeleria−Pentaschistis* dominated rock outcrop communities.

In the rock outcrop vegetation type, the species combination of the dominant genera like *Helichrysum*, *Festuca, Pentaschistis* and *Deschampsia* generally varies from mountain to mountain but the trend was that East Africa Mountains like Mt. Kenya, Elgon and Kilimanjaro (all on the eastern arm of the rift valley) share common species combination compared to the Ethiopian Mountains or those mountains occurring along the western arm of the rift valley. Some genera in the rock outcrop were mountain specific and include *Rytidosperma* (*R. subulata*), *Colpodium* (*C. hedbergii*), *Plantago* (*P. afra*), *Cotula* (C. *abyssinica*), *Gnaphalium unionis*, *Vulpia bromoides*, *Crepis rueppellii* and *Lychnis abyssinica* in Simen; *Cineraria deltoidea*, *Crassula* sp. in Bale; *Dendrosenecio keniodendron* in Mt Kenya and *Isolepis* sp. in Kilimanjaro.

Unlike in the rock outcrop communities, bog vegetation types were more homogenous in the generic composition. Mount Rwenzori, the wettest mountain differs from the rest of the mountains with respect to species composition of the most dominant taxa. For example the tussock forming species of *Carex runsoroensis* was the dominant species in all the four plots of bog sampled from Ruwenzori while the rest of the mountains were dominated by *Carex monostachya* in association with various members of other genera like *Ranunculus* (mostly *R. oreophytus*), *Haplocarpha* (usually *H. rueppellii*) and *Isolepis* among others. Frequently present in the tussocks of *C. runnsoroensis* are *Hydrocotylee sibthorpioides*, *Isolepis fluitans*, *Helichrysum stuhlmannii*, *H. formosissimum* and *Alchemilla argyrophylla* ssp. *argyrophylloides*.

The genera and species of the family Poaceae form the dominant species in terms of cover in grassland community. Species of *Festuca* (*F. abyssinica* in EA Mountains and *F. simensis* in Ethiopian Mountains) dominated the species composition of the sampled plots across the mountains. Other dominant grass genera in East Africa Mountains include *Koeleria*, (*K. capensis*) *Pennisetum* (*P. humile*), *Colpodium*, *Pentaschistis* (*P. borussica*) and *Poa*. In Ethiopian Mountains, *Festuca* (*F. simensis*), *Pentaschistis* (*P. pictigluma*), *Andropogon* (A. *lima*) and *Helictotrichon* (*H. elegantum*) dominated grassland species

The *Dendrosenecio* is not found in Ethiopia, as a result only three East Africa countries viz., Mt Kenya, Elgon (Kenya/Uganda) and Ruwenzori were covered. However in Mt Kilimanjaro, the *Dendrosenecio* vegetation type was not well developed as only scattered trees were found in the Afroalpine zone which could not form continuous plot of *Dendrosenecio* community comparable to other mountains for sampling and analysis. Mount Kenya, Elgon and Ruwenzori each had an endemic vicariant species of *Dendrosenecio* as the dominant species associated frequently and/or co−dominated occasionally with other woody (*Lobelia*) or shrubby *Alchemilla* species. For example, in Mt Elgon *D. elgonensis* was the dominant species while *D. keniodendron* dominates Mt Kenya *Dendrosenecio* woodland. In Ruwenzori, *Dendrosenecio* vegetation type was well developed often forming dense moist forest dominated by *D. advinalis* ssp. *advinalis* and *D. advinalis* var. *petiolatus*.

Alchemilla community was the least extensively developed vegetation type in the whole of the study area although well represented by many species across the entire mountains. As such only eight plots were sampled from two mountains (Bale in Ethiopia and Ruwenzori in East Africa) and the other mountains lacked sizable plots for sampling and analysis. In Ruwenzori the *Alchemilla* communities were dominated in terms of species cover and presence by *A. argyrophylla* ssp. *argyrophylloides* and *A. johnstonii* with frequent association of *A. triphylla*. On the other hand, *A. haumanii* was basically the sole dominant species in Bale often with cover of over 84%. In one plot however, *A. micrbetula*, *A. pedata* and *Isolepis fluitans* (all frequently found in bogs) dominated the *Alchemilla* community.

Rock outcrop and grassland vegetation types were the most similar (J’ value of 52) sharing a total of 118 species. The other pairs that share relatively higher degree of similarity were bogs and grassland (J’=44.0; common−96; different 122) and rock outcrop and bog (J=41.0;

common−101; different−143). On the other hand there were marked dissimilarity between grassland and *Dendrosenecio* vegetation types (J=22.0; common−40; different−145) and/or rock outcrop and *Alchemilla* (J=26.0; common−55; different−145). Light, water and temperature play significant role in the occurrence and distribution of species in the vegetation types. Shade loving species frequently occur in *Dendrosenecio* and *Alchemilla* vegetation types since the dense forest or sclerophyllous shrubby *Alchemilla* provide cover to the undergrowth species.

Analysis of similarities (R value) reveals the differences between the five vegetation types i.e. can be easily recognized from each other. However the heterogeneity of the vegetation types was blurred by overlap in terms of species composition. For instance vegetation types such as rock outcrop vs. grassland were barely separable at all ($R< 0.25$) while rock outcrop vs *Dendrosenecio*, rock outcrop vs *Alchemilla*, bog vs *Alchemilla*, bog vs grassland, grassland vs *Alchemilla*, and *Dendrosenecio* vs *Alchemilla* were overlapping but fairly separable. However, rock outcrop vs bog and bog vs *Dendrosenecio* are overlapping but clearly separable ($R > 0.5$).

The rock outcrop vegetation type was the most species rich compared to both *Dendrosenecio* and *Alchemilla* vegetation types. This was also true between bogs and *Dendrosenecio* vegetation types where single factor ANOVA tests gives a marked differences between these two vegetation types.

Comparative analysis of the species composition and community ecological analysis revealed a general pattern of similarity and/or differences between the six mountains based on several parameters such as geographical location, age, geological history (nature of formation), climatic and edaphic or soil factors. Consequently East Africa Mountains that occur along eastern arm of the rift valley such Mt. Kenya, Kilimanjaro and Elgon have high degree of similarity compared to Ethiopian Mountains and Ruwenzori. Hence Mt Kenya, Kilimanjaro, and Elgon share many common species and are floristically similar. Mount Kenya and Kilimanjaro, the two closest mountains in East Africa show the high degree of similarity (Jaccard's similarity index: 44.4). Similarly Bale and Simen have higher Jaccard's similarity index than between any other pair for the same reason (J' 47.05). Apart from geographical proximity, age, nature of formation and climatic factors such as rainfall explains the observed pattern. East Africa Mountains are volcanic, young and bimodal rainfall pattern while the Ethiopian Mountains were mostly forming by doming, are much older and have unimodal pattern of rainfall.

The phenetic study, gross morphology and phylogenetic analysis based on two chloroplast DNA (TrnL-F and rpL-16) and one nuclear DNA (ITS) reveal and confirm the existence of two broadly distributed species viz: *P. pictigluma* and *P. borussica* and two narrow endemics, namely *P. chrysurus* and *P. dolichochaeta*. *Pentaschistis trisetoides* is sister to the *P. pictigluma– P. borussica* sub–clade. In addition the phylogenetic analysis of the *Pentaschistis* clade provides a robust support for the two sub–clades of *P. borussica–P. pictigluma* and *P. chrysurus–P. dolichochaeta* that indicate two events of independent colonization by these two groups. *Pentaschistis borussica* can be easily distinguished from *P. pictigluma*, *P. minor*, *P. gracilis* and *P. mannii* by its raised glands and open panicles. Both DNA sequence similarity analyses as well as morphometric analysis among *P. pictigluma*, *P. minor*, *P. gracilis* and *P. minor* indicate that these taxa are not distinct from each other and agree with similar results obtained by S. M. Phillips. Hence this study proposes the retention of the current taxonomic treatment that recognizes five species: *P. borussica*, *P. pictigluma* (including the four varieties), *P. trisetoides*, *P. chrysurus* and *P. dolichochaeta*

.

4.2 Conclusions

The study supports the current taxonomic treatment that reduces *P. minor, P. mannii, P. gracilis* to variety rank under *P. pictigluma*. The two narrow endemics similarly show close morphological affinities, are older taxa undergoing range contraction and could be vulnerable to natural and anthropogenic disturbances due to their limited distribution. They are also distantly related to the two broadly distributed species, P. *borussica* and *P. pictigluma. Pentaschistis borussica and P. pictigluma* species are young taxa that are undergoing rapid diversification as is evident from their wide distribution range. Afroalpine vegetation types are distinct and recognizable from each other but largely overlapping. Age, geographical position, geological history, climate and edaphic factors account for the similarities and disparities in species composition of the mountains and vegetation types studied.

4.3 Recommendations

This study recommends that;

- Further population genetic studies be carried out among the populations of *P. pictigluma* species complex and between the two narrow endemics as well as conduct anatomical studies on leaf and glands to help further distinguish between the populations of the broadly distributed and narrow endemic species.
- Conservation programmes be initiated for the Afroalpine endemics since they are vulnerable to anthropogenic disturbance and climate change.
- Further research be carried out to determine why few families dominate the Afroalpine vegetation communities.

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Appendix 1a: Data matrix of 12 plots of Mt Kenya showing presence/absence scores for all species sampled

Species	**KER P1**	**KER P2**	**KER P3**	**KER P4**	**KEB P1**	**KEB P2**	**KEB P3**	**KEB P4**	**KED P1**	**KED P2**	**KED P3**	**KED P4**
Adiantum thalictroides	0	0	0	0	0	0	0	0	0	0	0	0
Aeonium leucoblepharum	0	0	0	0	0	0	0	0	0	0	0	0
Agrocharis melanantha	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis gracilifolia ssp. *gracilifolia*	0	0	0	0	0	0	1	0	0	0	1	0
Agrostis quinqueseta	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis sclerophylla	0	1	0	0	0	0	1	1	0	0	0	0
Agrostis trachyphylla	0	0	0	0	0	0	0	1	0	0	0	0
Agrostis volkensii	0	0	1	0	0	0	0	0	0	0	0	0
Aira caryophyllea	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla argyrophylla	1	1	1	0	1	1	0	1	1	1	0	1
Alchemilla haumannii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla johnstonii	0	0	0	0	0	0	0	0	0	0	0	1
Alchemilla microbetula	1	1	0	0	1	1	1	1	1	1	0	0
Alchemilla pedata	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla subnivalis	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla triphylla	1	0	0	0	0	0	0	0	0	0	0	0
Alopecurus baptarrhenius	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis serpens ssp. *meyeri-johannis*	0	0	0	0	0	0	0	0	0	0	0	0
Andropogon amethystinus	0	0	0	0	0	0	0	0	0	0	0	0

Andropogon lima	0	0	0	0	0	0	0	0	0	0	0	0
Anemone thomsonii var. *thomsonii*	0	0	0	0	0	0	0	1	0	0	0	0
Anogramma leptophylla	1	0	0	0	0	0	0	0	1	0	0	0
Anthemis tigrensis	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum nivale	1	1	1	0	1	1	0	1	1	1	0	1
Aphanes bachitii	0	0	0	0	0	0	0	0	0	0	0	0
Arabidopsis thaliana	0	0	0	0	0	0	0	0	0	0	0	0
Arabis alpine	1	1	1	1	0	0	0	0	1	0	1	1
Argyrolobium schimperianum	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia afra	0	0	0	0	0	0	0	1	0	0	0	0
Asplenium abyssinicum	1	0	0	0	0	0	0	0	0	0	0	0
Asplenium aethiopicum	0	0	0	1	0	0	0	0	0	0	0	0
Asplenium buttneri	0	0	1	0	0	0	0	0	0	0	0	0
Barbarea intermedia	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia decurva	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia longiflora ssp. *longiflora*	0	0	0	0	0	0	0	0	0	0	0	0
Bromus leptoclados	0	0	0	0	0	0	0	0	0	0	0	0
Callitriche oreophila	0	0	0	0	0	0	0	1	0	0	0	0
Callitriche vulcanicola	0	0	0	0	0	0	0	0	0	0	0	0
Campanula edulis	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine hirsuta	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine obliqua	0	1	0	0	0	0	0	1	1	0	0	1
Carduus chamaecephalus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus keniensis	0	1	0	1	0	0	0	1	1	1	0	1
Carduus leptacanthus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus macracanthus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus ruwenzoriensis	0	0	0	0	0	0	0	0	0	0	0	0

Carduus schimperi	1	1	1	1	0	1	1	1	1	1	1	1
Carex bequaerttii	0	0	0	0	0	0	0	0	0	0	0	0
Carex monostachya	0	0	0	0	1	1	1	1	0	0	0	0
Carex runssoroensis var. *aberdarensis*	0	0	0	0	0	0	0	0	0	0	0	0
Carex simensis	0	0	0	0	0	0	0	0	0	0	0	0
Carex conferta	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium octandrum	1	1	0	1	0	1	0	1	1	1	1	0
Cheilanthes farinosa	0	0	0	0	0	0	0	0	0	0	0	0
Cineraria abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Cineraria deltoidea	0	0	0	0	0	0	0	0	0	0	0	0
Colpodium chionogeiton	0	1	1	0	0	0	0	0	0	1	0	0
Colpodium hedbergii	0	0	0	0	0	1	0	1	0	0	0	1
Conyza spinosa	0	0	0	0	0	0	0	0	0	0	0	0
Conyza subscaposa	1	1	0	0	1	0	0	0	1	1	0	0
Cotula abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Cotula cryptocephala	0	0	0	0	0	0	0	0	0	0	0	0
Crassula granvikii	0	1	0	0	1	1	1	1	0	0	0	0
Crassula schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Crassula sp.	0	0	0	0	0	0	0	0	0	0	0	0
Crepis dianthoseris	1	1	1	1	1	0	0	1	0	0	1	0
Crepis foetida	0	0	0	0	0	0	0	0	0	0	0	0
Crepis rueppellii	0	0	0	0	0	0	0	0	0	0	0	0
Cyanotis barbata	0	0	0	0	0	0	0	0	0	0	0	0
Cyanotis polyrrhiza	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus elegantulus	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus plateilema	0	0	0	0	0	0	0	0	0	0	0	0

Cystopteris fragilis	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium macrocentrum	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium wellbyi	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio adnivalis ssp. *adnivalis* var. *adnivalis*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio battiscombei	0	0	0	1	0	0	0	0	0	0	0	0
Dendrosenecio elgonensis ssp. *barbatipes*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio erici-rosenii ssp. *erici-rosenii*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis	1	1	0	0	1	1	1	1	0	1	0	0
Dendrosenecio keniensis × *keniodendron*	0	0	0	0	0	0	0	0	0	1	0	0
Dendrosenecio keniodendron	1	1	1	1	1	1	1	1	1	1	1	1
Dendrosenecio kilimanjari ssp. *cottonii*	0	0	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	0	0	0	0	0	0	0	0
Deschampsia flexuosa var. *afromontana*	1	0	1	0	0	0	0	0	0	0	1	0
Dianthus longiglumis	0	0	0	0	0	0	0	0	0	0	0	0
Dichrocephala chrysanthemifolia	0	0	0	0	0	0	0	0	0	0	0	0
Dierama cupuliflorum	0	0	0	0	0	0	0	0	0	0	0	0
Dipsacus pinnatifidus	0	0	0	0	0	0	0	0	0	0	0	0
Disa stairsii	0	0	0	0	0	0	0	0	0	0	0	0
Echinops buhaitensis	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium stereophyllum var. *stereophyllum*	0	0	0	0	0	0	0	0	0	0	0	0
Erica arborea	1	1	1	0	0	0	0	0	0	0	0	0
Erica johnstonii	0	0	0	0	0	0	0	0	0	0	0	0
Erica tenuipilosa ssp. *spicata*	0	0	0	0	0	0	0	0	0	0	0	0
Erica trimera ssp. *keniensis*	1	1	1	0	0	0	0	0	0	0	0	0

Erigeron alpinus	0	0	0	0	0	0	0	0	0	0	0	0
Eriocaulon schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Erophila verna	0	0	0	0	0	0	0	0	0	0	0	0
Euryops dacrydioides	0	0	0	0	0	0	0	0	0	0	0	0
Euryops elgonensis	0	0	0	0	0	0	0	0	0	0	0	0
Euryops prostratus	0	0	0	0	0	0	0	0	0	0	0	0
Festuca abyssinica	0	0	0	0	0	0	1	1	0	0	0	1
Festuca macrophylla	0	0	0	0	0	0	0	0	0	0	0	0
Festuca pilgeri	1	0	0	0	1	1	0	1	1	1	1	0
Festuca richardii	0	0	0	0	0	0	0	0	0	0	0	0
Festuca simensis	0	0	0	0	0	0	0	0	0	0	0	0
Galium acrophyum	1	1	0	1	1	0	1	0	1	1	1	0
Galium ruwenzoriense	0	0	1	1	0	0	0	0	0	0	1	1
Galium simense	0	1	0	0	0	0	0	0	0	0	0	0
Galium ossirwaense var. *glabrum*	0	0	0	0	0	0	0	0	0	0	0	0
Galium thunbergianum	0	0	0	0	0	0	0	0	0	0	0	0
Geranium arabicum	0	0	0	0	0	0	0	1	0	0	0	0
Geranium sp.nov.=Miehe 3002	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium unionis	0	0	0	0	0	0	0	0	0	0	0	0
Haplocarpha rueppellii	0	1	0	0	1	1	1	1	0	0	0	0
Haplocarpha schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Haplosciadium abyssinicum	0	1	0	0	1	1	1	1	0	0	0	0
Hebenstretia angolensis	0	0	1	1	0	0	0	0	0	0	0	0
Helichrysum brownei var. *brownei*	0	1	0	0	0	0	0	0	0	0	0	0
Helichrysum citrispinum	1	0	1	1	0	0	0	0	0	0	0	0
Helichrysum foetidum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum formosissimum	0	0	1	0	0	1	0	0	0	1	0	0

Helichrysum forskahlii	1	0	1	0	1	0	0	1	0	0	1	0
Helichrysum globosum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum gofense	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum horridum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum kilimanjari	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum newii	1	0	0	0	0	0	0	1	0	0	0	0
Helichrysum ambylyphyllum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum argyranthum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum splendidum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon elongatum	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon cf *umbrosum*	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum abyssincum	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum elgonense	0	0	0	0	0	0	0	0	0	1	0	0
Herniaria abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Hesperantha petitiana	0	0	0	0	0	0	0	0	0	0	0	0
Huperzia saururus	0	1	0	0	1	0	0	1	0	0	0	0
Hydrocotylee sibthorpioides	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum peplidifolium	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum revolutum	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis costata	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis fluitans	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis setacea	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia foliosa	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia isoetifolia	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia thomsonii	0	0	0	0	0	0	0	0	0	0	0	0

Koeleria capensis	0	0	0	0	0	0	0	1	0	0	0	0
Lactuca inermis	0	0	0	0	0	0	0	0	0	0	0	0
Limosella major	0	0	0	0	1	1	0	1	0	0	0	0
Lithospermum afromontanum	0	0	1	1	0	0	0	0	1	0	1	0
Lobelia aberdarica	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia bequaertii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia deckenii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia gregoriana	0	0	0	0	1	1	1	1	0	1	0	1
Lobelia lindblomii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia rhynchopetalum	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia telekii	1	1	1	1	0	0	1	1	1	1	1	0
Lobelia wollastonii	0	0	0	0	0	0	0	0	0	0	0	0
Luzula abyssinica	0	1	0	0	1	1	1	1	0	0	0	0
Luzula johnstonii	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis rotundifolia	0	0	0	0	0	0	0	0	0	0	0	0
Malva verticillata	0	0	0	0	0	0	0	0	0	0	0	0
Merendera schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Minuartia filifolia	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis keniensis	1	0	0	0	0	0	0	0	0	0	0	0
Myosotis vestergrenii	0	0	0	0	0	0	0	0	0	0	0	0
Oreophyton falcatum	1	1	1	0	0	0	0	1	0	0	1	0
Oxalis corniculata	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis obliquifolia	0	0	0	0	0	0	0	0	0	0	0	0
Parietaria debilis	0	0	0	0	0	0	0	0	0	0	0	0
Paronychia bryoides	0	0	0	0	0	0	0	0	0	0	0	0

Pennisetum humile	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis borussica	1	0	0	1	0	0	0	1	0	0	0	1
Pentaschistis pictigluma var *gracilis*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *minor*	0	1	1	0	0	0	0	0	0	0	1	0
Pentaschistis pictigluma var. *pictigluma*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis trisetoides	0	0	0	0	0	0	0	0	0	0	0	0
Peucedanum kerstenii	0	0	0	0	0	1	0	0	0	0	0	0
Phagnalon abyssinicum	0	0	0	0	0	0	0	0	0	0	0	0
Pimpinella oreophila	0	0	0	0	0	0	0	0	0	0	0	0
Pimpinella pimpinelloides	0	0	0	0	0	0	0	0	0	0	0	0
Plantago afra var. *stricta*	0	0	0	0	0	0	0	0	0	0	0	0
Poa annua	0	0	0	0	0	0	0	1	1	1	0	0
Poa leptoclada	0	0	0	0	0	0	0	0	0	0	0	0
Poa schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Polygala steudneri	0	0	0	0	0	0	0	0	0	0	0	0
Polypogon schimperianus	0	0	0	0	0	0	0	0	0	0	0	0
Polystichum magnificum	0	0	0	0	0	0	0	0	0	0	0	0
Polystichum setiferum	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus distrias	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oligocarpus	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oreophytus	0	0	0	0	1	1	1	1	0	1	0	0
Ranunculus stagnalis	0	0	0	0	0	0	0	1	0	0	0	0
Ranunculus trichophyllus	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus volkensii	0	0	0	0	0	0	0	0	0	0	0	0
Rhabdotosperma scrophulariifolia	0	0	0	0	0	0	0	0	0	0	0	0
Romulea fischeri	0	0	0	0	1	1	1	0	0	0	0	0
Rosularia semiensis	0	0	0	0	0	0	0	0	0	0	0	0

Rumex nepalensis	0	0	0	0	0	0	0	0	0	0	0	0
Rytidosperma grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0
Rytidosperma subulata	0	0	0	0	0	0	0	0	0	0	0	0
Sagina abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Sagina afroalpina	1	1	1	0	1	1	1	1	1	1	0	1
Salvia nilotica	0	0	0	0	0	0	0	0	0	0	0	0
Satureja abyssinica	0	0	0	0	0	0	0	0	0	0	1	0
Satureja imbricata	0	0	0	0	0	0	0	0	0	0	0	0
Satureja kilimandschari	0	0	0	0	0	0	0	0	0	0	0	0
Satureja pseudosimensis	0	0	0	0	0	0	0	0	0	0	0	0
Satureja punctata ssp. *punctata*	0	0	0	0	0	0	0	0	0	0	0	0
Satureja simensis	0	0	0	0	0	0	0	0	0	0	0	0
Satureja uhligii var. *obtusifolium*	0	0	0	0	0	0	0	0	0	0	0	0
Saxifraga hederifolia	0	0	0	0	0	0	0	0	0	0	0	0
Scabiosa columbaria	0	0	0	0	0	0	0	0	0	0	0	0
Sedum crassularia	0	0	0	0	0	0	0	0	0	0	0	0
Sedum meyeri-johannis	1	0	0	1	0	0	0	0	0	0	0	0
Sedum mooneyi	0	0	0	0	0	0	0	0	0	0	0	0
Senecio balensis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio farinaceus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio fresenii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio jacksonii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio nanus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio polyadenus	0	0	0	0	0	0	0	0	0	1	0	0
Senecio purtschelleri	0	0	0	0	1	1	1	0	0	0	0	0
Senecio rhammatophyllus	0	0	0	0	0	0	0	0	0	0	0	1

Senecio schultzii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio schweinfurthii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio subsessilis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio telekii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *major*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *sycephyllus*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio unionis	0	0	0	0	0	0	0	0	0	0	0	0
Silene burchellii var. *burchellii*	0	0	0	0	0	0	0	0	0	0	0	0
Silene flammulifolia	0	0	0	0	0	0	0	0	0	0	0	0
Silene macrosolen	0	0	0	0	0	0	0	0	0	0	0	0
Silene melanolepis	0	0	0	0	0	0	0	0	0	0	0	0
Sonchus melanolepis	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria media	0	0	0	0	0	0	0	0	0	0	0	0
Stoebe kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0
Subularia monticola	0	0	0	0	1	1	1	1	0	0	0	0
Swertia abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Swertia crassiuscula	0	0	0	0	0	0	0	1	1	0	0	1
Swertia engleri	0	0	0	0	0	0	0	0	0	0	0	0
Swertia kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0
Swertia pumila	0	0	0	0	0	0	0	0	0	0	0	0
Swertia subnivalis	0	0	0	0	0	0	0	0	0	0	0	0
Swertia uniflora	0	0	0	0	0	0	0	0	0	0	0	0
Swertia volkensii	1	1	1	0	0	0	0	1	1	0	0	0
Thymus schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Thymus serrulatus	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium acaule	0	0	0	0	0	0	0	0	0	0	0	0

Trifolium calocephalum	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium cryptopodium	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium elgonense	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium multinerve	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium rueppellianum	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium simense	0	0	0	0	0	0	0	0	0	0	0	0
Umbilicus botryoides	0	0	0	0	0	0	0	0	0	0	0	0
Ursinia nana	0	0	0	0	0	0	0	0	0	0	0	0
Valerianella microcarpa var. *microcarpa*	0	0	0	0	0	0	0	0	0	0	0	0
Verbascum sedgwickianum	0	0	0	0	0	0	0	0	0	0	0	0
Veronica anagallis-aquatica	0	0	0	0	0	0	0	0	0	0	0	0
Veronica arvensis	0	0	0	0	0	0	0	0	0	0	0	0
Veronica glandulosa	0	1	0	1	0	1	0	1	0	1	1	0
Veronica gunae	0	0	0	0	0	0	0	0	0	0	0	0
Viola eminii	0	0	0	0	0	0	0	0	0	0	0	0
Vulpia bromoides	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b: Data matrix of 11 plots of Mt Elgon showing presence/absence scores for all species sampled

Species	**ERP 1**	**ERP 2**	**ERP 3**	**ERP 4**	**EGP 1**	**EGP 2**	**EGP 3**	**EGP 4**	**EDP 1**	**EDP 2**	**EDP 3**
Adiantum thalictroides	0	0	0	0	0	0	0	0	0	0	0
Aeonium leucoblepharum	0	0	0	0	0	0	0	0	0	0	0
Agrocharis melanantha	0	0	0	0	0	0	0	0	0	0	0
Agrostis gracilifolia ssp. *gracilifolia*	0	1	1	0	0	1	1	0	0	1	1
Agrostis quinqueseta	0	0	0	0	0	0	0	0	0	0	0
Agrostis schimperiana	0	0	0	0	0	0	0	0	0	0	0
Agrostis sclerophylla	0	0	0	0	0	0	0	0	0	0	0
Agrostis trachyphylla	0	0	0	0	0	0	0	0	0	0	0
Agrostis volkensii	0	0	0	0	1	0	0	1	0	0	0
Aira caryophyllea	0	0	0	0	0	0	0	0	0	0	0
Alchemilla abyssinica	0	0	0	0	0	0	0	0	0	0	0
Alchemilla argyrophylla	0	1	1	0	0	0	0	0	1	1	1
Alchemilla haumannii	0	0	0	0	0	0	0	0	0	0	0
Alchemilla johnstonii	0	1	1	0	0	1	0	0	1	1	0
Alchemilla microbetula	0	0	1	0	0	0	0	0	0	0	0
Alchemilla pedata	0	0	0	0	0	0	0	0	0	0	0
Alchemilla subnivalis	0	0	0	0	0	0	0	0	0	0	0
Alchemilla stuhlmannii	0	0	0	0	0	0	0	0	0	0	0
Alchemilla triphylla	0	0	0	0	0	0	0	0	0	0	0
Alopecurus baptarrhenius	0	0	0	0	0	0	0	0	0	0	0
Anagallis serpens ssp. *meyeri-johannis*	0	0	0	0	0	0	0	1	0	0	0
Andropogon amethystinus	0	0	0	0	0	0	0	0	0	0	0

Andropogon lima	0	0	0	1	1	0	0	1	0	0	0
Anemone thomsonii var. *thomsonii*	0	0	0	0	0	0	0	1	0	0	0
Anogramma leptophylla	0	0	0	0	0	0	0	0	0	0	0
Anthemis tigrensis	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum nivale	1	0	1	0	0	1	1	0	1	1	1
Aphanes bachitii	0	0	0	0	0	0	0	0	0	0	0
Arabidopsis thaliana	0	0	0	0	0	0	0	0	0	0	0
Arabis alpina	1	1	1	1	0	0	0	0	0	0	0
Argyrolobium schimperianum	0	0	0	0	0	0	0	0	0	0	0
Artemisia afra	0	0	0	1	1	1	1	1	1	0	0
Asplenium abyssinicum	0	0	0	0	0	0	0	0	0	0	0
Asplenium aethiopicum	1	1	1	1	0	0	0	0	0	0	0
Asplenium buttneri	0	0	0	0	0	0	0	0	0	0	0
Barbarea intermedia	0	0	0	0	0	0	0	0	0	0	0
Bartsia decurva	1	0	0	0	1	0	0	0	0	0	0
Bartsia longiflora ssp. *longiflora*	0	1	1	1	0	0	0	0	0	1	0
Bromus leptoclados	0	0	0	0	0	0	0	0	0	0	0
Callitriche oreophila	0	0	0	0	0	0	0	0	0	0	0
Callitriche vulcanicola	0	0	0	0	0	0	0	0	0	0	0
Campanula edulis	0	0	0	0	0	0	0	0	0	0	0
Cardamine hirsuta	0	0	0	0	0	0	0	0	0	0	0
Cardamine obliqua	0	1	1	0	0	0	0	0	0	0	1
Carduus chamaecephalus	0	0	0	0	0	0	0	0	0	0	0
Carduus keniensis	0	0	1	0	0	1	0	1	1	1	1
Carduus leptacanthus	0	0	0	0	0	0	0	0	0	0	0
Carduus macracanthus	0	0	0	0	0	0	0	0	0	0	0
Carduus ruwenzoriensis	0	0	0	0	0	0	0	0	0	0	0

Carduus schimperi	0	0	0	0	0	1	0	1	0	0	0
Carex bequaerttii	1	0	0	0	0	0	0	0	0	0	0
Carex monostachya	0	0	0	0	0	0	0	0	0	0	0
Carex runssoroensis var. *aberdarensis*	0	0	0	0	0	0	0	0	0	0	0
Carex simensis	0	1	0	0	0	0	1	0	0	0	0
Carex conferta	0	0	1	0	0	0	0	0	0	0	0
Cerastium afromontanum	0	0	0	0	0	0	0	0	0	0	0
Cerastium octandrum	1	1	1	0	1	0	0	0	0	1	1
Cheilanthes farinosa	0	1	0	0	0	0	0	0	0	0	0
Cineraria abyssinica	0	0	0	0	0	0	0	0	0	0	0
Cineraria deltoidea	1	0	0	1	1	0	0	0	0	0	0
Colpodium chionogeiton	0	0	0	0	1	0	0	0	0	1	0
Colpodium hedbergii	0	0	0	0	0	0	0	0	0	0	0
Conyza spinosa	0	0	0	0	0	0	0	0	0	0	0
Conyza subscaposa	0	0	0	0	1	1	1	1	1	0	0
Cotula abyssinica	0	0	0	0	0	0	0	0	0	0	0
Cotula cryptocephala	0	0	0	0	0	0	0	0	0	0	0
Crassula granvikii	0	0	0	0	0	0	0	0	0	0	0
Crassula schimperi	0	0	1	1	0	0	0	0	0	0	0
Crassula sp.	0	0	0	0	0	0	0	0	0	0	0
Crepis dianthoseris	0	1	0	0	0	1	0	1	1	0	1
Crepis foetida	0	0	0	0	0	0	0	0	0	0	0
Crepis rueppellii	0	0	0	0	0	0	0	0	0	0	0
Cyanotis barbata	0	0	0	0	0	0	0	0	0	0	0
Cyanotis polyrrhiza	0	0	0	0	0	0	0	0	0	0	0
Cyperus elegantulus	0	0	0	0	0	0	0	0	0	0	0
Cyperus plateilema	0	0	0	0	1	0	1	1	0	0	0

Cystopteris fragilis	0	0	0	0	0	0	0	0	0	0	0
Delphinium macrocentrum	0	0	0	0	1	0	0	0	0	0	0
Delphinium wellbyi	0	0	0	1	0	0	0	0	0	0	0
Dendrosenecio adnivalis ssp. *adnivalis* var. *adnivalis*	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio battiscombei	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio elgonensis ssp. *barbatipes*	1	1	1	0	0	0	0	1	1	1	1
Dendrosenecio erici-rosenii ssp. *erici-rosenii*	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis × keniodendron	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniodendron	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio kilimanjari ssp. *cottonii*	0	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	0	0	0	0	0	0	0
Deschampsia flexuosa var. *afromontana*	0	1	1	1	0	1	0	0	1	0	0
Dianthus longiglumis	0	0	0	0	0	0	0	0	0	0	0
Dichrocephala chrysanthemifolia	0	0	0	0	0	0	0	1	0	0	0
Dierama cupuliflorum	0	0	0	0	0	0	0	1	0	0	0
Dipsacus pinnatifidus	0	0	0	0	0	0	0	0	0	0	0
Disa stairsii	0	0	0	0	0	0	0	0	0	0	0
Echinops buhaitensis	0	0	0	0	0	0	0	0	0	0	0
Epilobium stereophyllum var. stereophyllum	0	0	0	0	0	0	0	0	0	0	0
Erica arborea	0	0	0	1	1	0	1	0	0	0	0
Erica johnstonii	0	0	0	0	0	0	0	0	0	0	0
Erica tenuipilosa ssp. *spicata*	0	0	0	0	0	0	0	0	0	0	0
Erica trimera ssp. *keniensis*	0	0	0	0	0	0	0	0	0	0	0
Erigeron alpinus	0	0	0	0	0	0	0	0	0	0	0
Eriocaulon schimperi	0	0	0	0	0	0	0	0	0	0	0
Erophila verna	0	0	0	0	0	0	0	0	0	0	0

Euryops dacrydioides	0	0	0	0	0	0	0	0	0	0	0
Euryops elgonensis	1	0	0	0	0	0	0	0	1	0	0
Euryops prostratus	0	0	0	0	0	0	0	0	0	0	0
Festuca abyssinica	0	1	1	0	1	1	0	0	1	1	1
Festuca macrophylla	0	0	0	0	0	0	0	0	0	0	0
Festuca pilgeri	0	0	0	0	0	0	1	1	0	0	0
Festuca richardii	0	0	0	0	0	0	0	0	0	0	0
Festuca simensis	0	0	0	0	0	0	0	0	0	0	0
Galium acrophyum	0	1	0	0	0	0	0	0	0	1	0
Galium ruwenzoriense	1	1	1	1	1	1	1	1	1	0	1
Galium simense	0	0	0	0	0	0	0	0	0	0	0
Galium ossirwaense var. *glabrum*	0	0	0	0	0	0	0	1	0	0	0
Galium thunbergianum	0	0	0	0	0	0	0	0	0	0	0
Geranium arabicum	0	0	0	0	1	1	1	1	1	1	1
Geranium sp.nov.=Miehe 3002	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium unionis	0	0	0	0	0	0	0	0	0	0	0
Haplocarpha rueppellii	1	1	1	0	0	1	1	0	0	0	1
Haplocarpha schimperi	0	0	0	0	0	0	0	0	0	0	0
Haplosciadium abyssinicum	1	0	1	0	0	0	0	0	0	0	0
Hebenstretia angolensis	1	0	0	1	0	0	0	1	0	0	0
Helichrysum brownei var. *brownei*	0	0	0	0	0	0	0	0	0	0	0
Helichrysum citrispinum	1	1	0	0	0	0	0	0	0	0	0
Helichrysum foetidum	0	0	0	0	0	0	0	0	0	0	0
Helichrysum formosissimum	1	1	1	1	1	0	1	1	1	1	1
Helichrysum forskahlii	1	0	1	0	0	0	1	1	1	1	1
Helichrysum globosum	0	0	0	0	0	0	0	0	0	0	0
Helichrysum gofense	0	0	0	0	0	0	0	0	0	0	0

Helichrysum horridum	0	0	0	0	0	0	0	0	0	0	0
Helichrysum kilimanjari	1	0	0	1	1	0	0	1	0	0	0
Helichrysum newii	1	0	0	0	0	0	1	0	0	0	0
Helichrysum ambylyphyllum	0	1	1	0	0	0	0	0	0	1	1
Helichrysum argyranthum	0	0	0	0	1	0	0	0	0	0	0
Helichrysum splendidum	0	0	0	0	0	0	0	0	0	0	0
Helichrysum stuhlmannii	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon elongatum	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon cf umbrosum	0	0	0	0	0	0	0	0	0	0	0
Heracleum abyssincum	0	0	0	0	0	0	0	0	0	0	0
Heracleum elgonense	1	1	1	1	0	0	0	0	0	1	1
Herniaria abyssinica	0	0	0	0	0	0	0	0	0	0	0
Hesperantha petitiana	0	0	0	0	0	0	0	0	0	0	0
Huperzia saururus	0	0	0	0	0	0	0	0	0	0	0
Hydrocotylee sibthorpioides	0	1	0	0	0	0	0	0	1	0	0
Hypericum peplidifolium	0	0	0	0	1	0	0	0	0	0	0
Hypericum revolutum	0	0	0	0	1	0	0	0	0	0	0
Hypericum afromontanum	0	0	0	0	1	0	0	0	0	0	0
Isolepis costata	0	0	0	0	0	0	0	0	0	0	0
Isolepis fluitans	0	0	0	0	0	0	0	0	0	0	0
Isolepis setacea	0	0	0	0	0	0	0	0	0	0	0
Kniphofia foliosa	0	0	0	0	0	0	0	0	0	0	0
Kniphofia isoetifolia	0	0	0	0	0	0	0	0	0	0	0
Kniphofia thomsonii	1	0	0	1	1	0	1	1	0	0	0
Koeleria capensis	1	0	0	1	1	1	1	1	1	0	1
Lactuca inermis	0	0	0	0	0	0	0	0	0	0	0
Limosella major	0	0	0	0	0	0	0	0	0	0	0

Lithospermum afromontanum	0	1	1	0	0	0	0	0	0	1	1
Lobelia aberdarica	0	0	0	0	0	0	0	1	0	0	0
Lobelia bequaertii	0	0	0	0	0	0	0	0	0	0	0
Lobelia deckenii	0	0	0	0	0	0	0	0	0	0	0
Lobelia gregoriana	0	0	0	0	0	0	0	0	1	0	0
Lobelia lindblomii	0	0	0	1	1	1	1	1	0	0	0
Lobelia rhynchopetalum	0	0	0	0	0	0	0	0	0	0	0
Lobelia stuhlmannii	0	0	0	0	0	0	0	0	0	0	0
Lobelia telekii	1	1	1	1	1	0	0	0	0	1	1
Lobelia wollastonii	0	0	0	0	0	0	0	0	0	0	0
Luzula abyssinica	1	1	1	1	1	1	1	1	0	1	0
Luzula johnstonii	0	0	1	0	0	0	0	0	0	0	0
Lychnis abyssinica	0	0	0	0	0	0	0	0	0	0	0
Lychnis rotundifolia	0	0	0	0	0	0	0	0	0	0	0
Malva verticillata	0	0	0	0	0	0	0	0	0	0	0
Merendera schimperiana	0	0	0	0	0	0	0	0	0	0	0
Minuartia filifolia	0	0	0	0	0	0	0	0	0	0	0
Myosotis keniensis	0	0	0	0	0	0	0	0	0	0	0
Myosotis vestergrenii	1	0	1	0	0	0	0	0	0	0	0
Oreophyton falcatum	0	1	1	0	0	0	0	0	0	0	0
Oxalis corniculata	0	0	0	0	0	0	0	0	0	0	0
Oxalis obliquifolia	0	0	0	0	0	0	0	0	0	0	0
Parietaria debilis	0	1	1	0	0	0	0	0	0	0	0
Paronychia bryoides	0	0	0	0	0	0	0	0	0	0	0
Pennisetum humile	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis borussica	1	1	0	1	1	1	1	0	0	0	0
Pentaschistis pictigluma var. *gracilis*	0	0	0	0	0	0	0	0	0	0	0

Pentaschistis pictigluma var. *minor*	0	0	1	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *pictigluma*	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis trisetoides	0	0	0	0	0	0	0	0	0	0	0
Peucedanum kerstenii	0	0	0	0	1	1	1	1	1	0	1
Phagnalon abyssinicum	0	0	0	0	0	0	0	0	0	0	0
Pimpinella oreophila	0	0	0	0	0	0	0	1	0	0	0
Pimpinella pimpinelloides	0	0	0	0	0	0	0	0	0	0	0
Plantago afra var. *stricta*	0	0	0	0	0	0	0	0	0	0	0
Poa annua	0	0	0	0	0	0	0	0	0	0	0
Poa leptoclada	0	0	0	0	0	0	0	0	0	0	0
Poa schimperiana	0	0	0	0	0	0	0	0	0	0	0
Polygala steudneri	0	0	0	0	0	0	0	0	0	0	0
Polypogon schimperianus	0	0	0	0	0	0	0	0	0	0	0
Polystichum magnificum	0	0	0	0	0	0	0	0	0	0	0
Polystichum setiferum	0	0	0	0	0	0	0	0	0	0	0
Ranunculus districs	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oligocarpus	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oreophytus	0	0	0	0	0	0	0	0	0	0	0
Ranunculus stagnalis	0	0	0	0	0	0	0	0	0	0	0
Ranunculus trichophyllus	0	0	0	0	0	0	0	0	0	0	0
Ranunculus volkensii	0	0	0	0	0	0	0	0	0	0	0
Rhabdotosperma scrophulariifolia	0	0	0	0	0	0	0	0	0	0	0
Romulea fischeri	0	0	0	0	0	0	0	0	0	0	0
Rosularia semiensis	0	0	0	0	0	0	0	0	0	0	0
Rumex nepalensis	0	0	0	0	0	0	0	0	0	0	0
Rytidosperma grandiflorum	0	0	0	0	0	0	0	0	0	0	0
Rytidosperma subulata	0	0	0	0	0	0	0	0	0	0	0

Sagina abyssinica	0	0	0	0	0	0	0	1	0	0	0
Sagina afroalpina	1	1	1	1	0	0	0	0	0	0	0
Salvia nilotica	0	0	0	0	0	0	0	0	0	0	0
Satureja abyssinica	1	0	0	0	1	1	0	1	1	0	0
Satureja imbricata	0	0	0	0	0	0	0	0	0	0	0
Satureja kilimandschari	0	0	0	0	0	0	1	0	0	0	0
Satureja pseudosimensis	0	0	0	0	0	0	0	0	0	0	0
Satureja punctata ssp. *punctata*	1	0	0	0	0	0	0	0	0	0	0
Satureja simensis	0	0	0	0	0	0	0	0	0	0	0
Satureja uhligii var. *obtusifolium*	0	0	0	1	0	0	0	0	0	0	0
Saxifraga hederifolia	0	0	0	0	0	0	0	0	0	0	0
Scabiosa columbaria	1	0	0	1	1	0	1	1	0	0	0
Sedum crassularia	1	1	1	0	0	0	0	0	0	0	0
Sedum meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0
Sedum mooneyi	0	0	0	0	0	0	0	0	0	0	0
Senecio balensis	0	0	0	0	0	0	0	0	0	0	0
Senecio farinaceus	0	0	0	0	0	0	0	0	0	0	0
Senecio fresenii	0	0	0	0	0	0	0	0	0	0	0
Senecio jacksonii	1	1	1	0	0	0	0	0	0	0	0
Senecio meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0
Senecio nanus	0	0	0	0	0	0	0	0	0	0	0
Senecio polyadenus	0	0	0	0	0	0	0	0	0	0	0
Senecio purtschelleri	0	0	0	0	0	0	0	0	0	0	0
Senecio rhammatophyllus	0	0	1	0	0	0	0	0	1	0	1
Senecio schultzii	0	0	0	0	0	0	0	0	0	0	0
Senecio schweinfurthii	0	0	0	0	0	0	0	0	0	0	0
Senecio subsessilis	0	0	0	0	0	0	0	0	0	0	0

Senecio telekii	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus	0	0	0	0	0	0	0	0	0	1	0
Senecio transmarinus var. *major*	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *sycephyllus*	0	0	0	0	0	0	0	0	0	0	0
Senecio unionis	0	0	0	0	0	0	0	0	0	0	0
Silene burchellii var. *burchellii*	1	0	0	1	0	0	1	0	0	0	0
Silene flammulifolia	0	0	0	0	0	0	0	0	0	0	0
Silene macrosolen	0	0	0	0	0	0	0	0	0	0	0
Silene melanolepis	0	0	0	0	0	0	0	0	0	0	0
Sonchus melanolepis	0	0	0	0	0	0	0	0	0	0	0
Stellaria media	0	0	0	0	0	0	0	0	0	0	0
Stoebe kilimandscharica	1	0	0	1	1	0	0	1	0	0	0
Subularia monticola	0	0	0	0	0	0	0	0	0	0	0
Swertia abyssinica	0	0	0	0	0	0	0	0	0	0	0
Swertia crassiuscula	0	0	0	0	0	1	1	1	0	0	0
Swertia engleri	0	0	0	0	0	0	0	0	0	0	0
Swertia kilimandscharica	0	0	0	0	1	0	0	0	0	0	0
Swertia pumila	0	0	0	0	0	0	0	0	0	0	0
Swertia subnivalis	0	1	0	0	0	0	0	0	0	1	0
Swertia uniflora	0	0	0	0	0	0	0	0	0	1	1
Swertia volkensii	0	0	0	0	0	0	0	0	0	0	0
Thymus schimperi	0	0	0	0	0	0	0	0	0	0	0
Thymus serrulatus	0	0	0	0	0	0	0	0	0	0	0
Trifolium acaule	0	0	0	0	0	1	0	0	0	0	0
Trifolium calocephalum	0	0	0	0	0	0	0	0	0	0	0
Trifolium cryptopodium	0	0	0	0	1	0	0	1	0	0	0
Trifolium elgonense	0	0	0	0	0	0	0	0	0	0	0

Trifolium multinerve	0	0	0	0	0	0	0	0	0	0	0
Trifolium rueppellianum	0	0	0	0	0	0	0	0	0	0	0
Trifolium simense	0	0	0	0	0	0	0	0	0	0	0
Umbilicus botryoides	0	0	0	0	0	0	0	0	0	0	0
Ursinia nana	0	0	0	0	0	0	0	0	0	0	0
Valerianella microcarpa var. *microcarpa*	0	0	0	0	0	0	0	0	0	0	0
Verbascum sedgwickianum	0	0	0	0	0	0	0	0	0	0	0
Veronica anagallis-aquatica	0	0	0	0	0	0	0	0	0	0	0
Veronica arvensis	0	0	0	0	0	0	0	0	0	0	0
Veronica glandulosa	0	0	0	0	0	0	0	1	1	0	0
Veronica gunae	0	0	0	0	0	0	0	0	0	0	0
Viola eminii	0	0	0	0	0	0	0	0	0	0	0
Vulpia bromoides	0	0	0	0	0	0	0	0	0	0	0

Appendix 1c **:**Data matrix of 12 plots of Mt Kilimanjaro showing presence/absence scores for all species sampled

Species	**KIR P1**	**KIR P2**	**KIR P3**	**KIR P3**	**KIB P1**	**KIB P2**	**KIB P3**	**KIB P4**	**KIG P1**	**KIG P2**	**KIG P3**	**KIG P4**
Adiantum thalictroides	0	0	0	0	0	0	0	0	0	0	0	0
Aeonium leucoblepharum	0	0	0	0	0	0	0	0	0	0	0	0
Agrocharis melanantha	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis gracilifolia ssp. *gracilifolia*	0	0	0	0	0	0	0	0	0	1	0	0
Agrostis quinqueseta	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis sclerophylla	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis trachyphylla	0	0	0	0	0	1	1	0	0	0	0	0
Agrostis volkensii	1	1	1	0	1	1	0	0	0	0	0	0
Aira caryophyllea	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla argyrophylla	1	1	1	0	1	0	1	0	1	1	0	0
Alchemilla haumannii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla johnstonii	1	1	1	1	0	1	1	1	0	0	0	0
Alchemilla microbetula	0	0	0	0	1	0	0	0	1	0	0	0
Alchemilla pedata	0	0	0	0	0	1	0	0	0	0	0	0
Alchemilla subnivalis	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla triphylla	0	0	0	0	0	0	0	0	0	0	0	0
Alopecurus baptarrhenius	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis serpens ssp. *meyeri-johannis*	0	0	1	0	1	1	0	1	1	0	0	0
Andropogon amethystinus	0	0	0	0	0	0	0	0	0	0	0	0

Andropogon lima	0	0	0	0	0	0	0	0	0	0	0	0
Anemone thomsonii var. *thomsonii*	0	0	0	0	1	0	0	0	0	0	1	1
Anogramma leptophylla	0	0	0	0	0	0	0	0	0	0	0	0
Anthemis tigrensis	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum nivale	1	1	1	0	1	0	1	1	0	0	0	0
Aphanes bachitii	0	0	0	0	0	0	0	0	0	0	0	0
Arabidopsis thaliana	0	0	0	0	0	0	0	0	0	0	0	0
Arabis alpina	0	0	1	0	0	0	0	0	0	0	0	0
Argyrolobium schimperianum	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia afra	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium abyssinicum	0	0	0	1	0	0	0	0	0	0	0	0
Asplenium aethiopicum	0	0	1	1	0	0	0	0	0	0	0	0
Asplenium buttneri	0	0	0	0	0	0	0	0	0	0	0	0
Barbarea intermedia	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia decurva	0	0	0	1	0	0	0	0	0	0	0	1
Bartsia longiflora ssp. *longiflora*	0	0	0	0	0	0	0	0	0	0	0	0
Bromus leptoclados	0	0	0	0	0	0	0	0	0	0	0	0
Callitriche oreophila	0	0	0	0	0	0	0	0	0	0	0	0
Callitriche vulcanicola	0	0	0	0	0	0	0	0	0	0	0	0
Campanula edulis	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine hirsuta	0	0	0	0	1	0	0	0	0	0	0	0
Cardamine obliqua	0	0	0	0	0	1	1	1	0	0	0	0
Carduus chamaecephalus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus keniensis	1	1	1	0	1	1	1	0	1	1	0	0
Carduus leptacanthus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus macracanthus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus ruwenzoriensis	0	0	0	0	0	0	0	0	0	0	0	0

Carduus schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Carex bequaerttii	0	0	0	0	0	0	0	0	0	0	0	0
Carex monostachya	0	0	0	0	1	1	1	1	0	0	0	0
Carex runssoroensis var. *aberdarensis*	0	0	0	0	0	0	0	0	0	0	0	0
Carex simensis	0	0	0	0	0	0	0	0	0	0	0	0
Carex conferta	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium octandrum	0	0	1	0	0	0	0	0	1	1	1	1
Cheilanthes farinosa	0	0	1	0	0	0	0	0	0	0	0	0
Cineraria abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Cineraria deltoidea	0	0	0	1	0	0	0	0	0	0	0	0
Colpodium chionogeiton	0	0	0	0	0	0	1	0	0	0	0	0
Colpodium hedbergii	0	0	0	0	0	0	0	0	0	0	0	0
Conyza spinosa	0	0	0	0	0	0	0	0	0	0	0	0
Conyza subscaposa	1	1	1	1	1	1	0	0	0	1	1	0
Cotula abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Cotula cryptocephala	0	0	0	0	0	0	0	0	0	0	0	0
Crassula granvikii	0	0	0	0	1	1	1	1	0	0	0	0
Crassula schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Crassula sp.	0	0	0	0	0	0	0	0	0	0	0	0
Crepis dianthoseris	0	0	1	1	0	1	0	0	0	1	0	0
Crepis foetida	0	0	0	0	0	0	0	0	0	0	0	0
Crepis rueppellii	0	0	0	0	0	0	0	0	0	0	0	0
Cyanotis barbata	0	0	0	0	0	0	0	0	0	0	0	0
Cyanotis polyrrhiza	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus elegantulus	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus plateilema	0	0	0	0	0	0	0	0	0	0	0	0

Cystopteris fragilis	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium macrocentrum	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium wellbyi	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio adnivalis ssp. *adnivalis* var. *adnivalis*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio battiscombei	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio elgonensis ssp. *barbatipes*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio erici-rosenii ssp. *erici-rosenii*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis × *keniodendron*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniodendron	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio kilimanjari ssp. *cottonii*	0	0	1	0	0	0	1	1	0	0	0	0
Deschampsia caespitosa	0	0	0	0	1	0	0	0	0	0	0	0
Deschampsia flexuosa var. *afromontana*	0	1	0	0	0	0	0	0	0	1	1	1
Dianthus longiglumis	0	0	0	0	0	0	0	0	0	0	0	0
Dichrocephala chrysanthemifolia	0	0	0	0	1	0	0	0	0	0	0	0
Dierama cupuliflorum	0	0	0	0	0	0	0	0	0	0	0	0
Dipsacus pinnatifidus	0	0	0	0	0	0	0	0	0	0	0	0
Disa stairsii	0	0	0	0	0	0	0	0	0	0	0	1
Echinops buhaitensis	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium stereophyllum var. *stereophyllum*	0	0	0	0	0	0	0	0	0	0	0	0
Erica arborea	1	1	1	1	1	1	1	1	1	1	1	0
Erica johnstonii	0	0	0	1	0	0	0	0	0	1	1	1
Erica tenuipilosa ssp. *spicata*	0	0	0	0	0	0	0	0	0	0	0	0
Erica trimera ssp. *keniensis*	1	0	1	1	0	0	0	0	0	0	0	0
Erigeron alpinus	0	0	0	0	0	0	0	0	0	0	0	1

Eriocaulon schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Erophila verna	0	0	0	0	0	0	0	0	0	0	0	0
Euryops dacrydioides	1	1	1	1	1	0	1	1	1	1	0	0
Euryops elgonensis	0	0	0	0	0	1	0	0	0	0	0	0
Euryops prostratus	0	0	0	0	0	0	0	0	0	0	0	0
Festuca abyssinica	1	0	1	0	1	1	0	0	1	1	0	0
Festuca macrophylla	0	0	0	0	0	0	0	0	0	0	0	0
Festuca pilgeri	0	0	0	0	0	0	0	0	0	0	0	0
Festuca richardii	0	0	0	0	0	0	0	0	0	0	0	0
Festuca simensis	0	0	0	0	0	0	0	0	0	0	0	0
Galium acrophyum	0	0	0	0	0	1	0	1	0	0	0	0
Galium ruwenzoriense	0	0	0	0	0	0	1	0	0	0	0	0
Galium simense	0	0	0	0	0	0	0	0	0	0	0	0
Galium ossirwaense var. *glabrum*	0	0	0	0	0	0	0	0	0	0	0	0
Galium thunbergianum	0	0	0	0	0	0	0	0	0	0	0	0
Geranium arabicum	0	0	0	1	1	0	0	1	0	0	1	0
Geranium sp.nov.=Miehe 3002	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium unionis	0	0	0	0	0	0	0	0	0	0	0	0
Haplocarpha rueppellii	0	0	0	0	0	1	0	1	0	0	0	0
Haplocarpha schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Haplosciadium abyssinicum	1	1	1	0	1	1	0	0	1	1	0	0
Hebenstretia angolensis	0	0	0	1	1	0	1	0	0	0	1	0
Helichrysum brownei var. *brownei*	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum citrispinum	1	1	1	0	0	1	1	0	0	1	0	0
Helichrysum foetidum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum formosissimum	0	0	1	0	0	0	0	0	0	0	1	1
Helichrysum forskahlii	1	1	1	1	1	1	1	1	1	1	0	0

Helichrysum globosum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum gofense	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum horridum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum kilimanjari	0	1	0	1	0	0	0	0	0	0	0	0
Helichrysum newii	1	1	1	1	1	1	1	1	1	1	0	0
Helichrysum ambylyphyllum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum argyranthum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum splendidum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon elongatum	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon cf *umbrosum*	0	0	0	0	1	0	0	0	0	0	0	0
Heracleum abyssincum	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum elgonense	0	0	0	0	0	0	0	0	0	0	0	0
Herniaria abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Hesperantha petitiana	0	0	0	0	0	0	0	0	0	0	0	0
Huperzia saururus	0	0	0	0	0	0	0	0	0	0	0	0
Hydrocotylee sibthorpioides	0	0	0	0	1	0	0	0	0	0	0	0
Hypericum peplidifolium	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum revolutum	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum afromontanum	0	0	0	0	0	0	0	0	0	0	0	1
Isolepis costata	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis fluitans	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis setacea	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia foliosa	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia isoetifolia	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia thomsonii	0	0	0	0	0	0	0	0	0	0	0	1
Koeleria capensis	1	0	1	0	1	1	0	0	1	1	1	1

Lactuca inermis	0	0	0	0	0	0	0	0	0	0	0	0
Limosella major	0	0	0	0	0	1	0	1	0	0	0	0
Lithospermum afromontanum	0	0	0	0	1	0	1	0	0	0	0	0
Lobelia aberdarica	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia bequaertii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia deckenii	1	1	1	0	0	1	0	0	1	0	1	1
Lobelia gregoriana	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia lindblomii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia rhynchopetalum	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia telekii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia wollastonii	0	0	0	0	0	0	0	0	0	0	0	0
Luzula abyssinica	1	1	1	0	1	1	0	0	1	1	1	1
Luzula johnstonii	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis rotundifolia	0	0	0	0	1	0	0	0	1	0	0	0
Malva verticillata	0	0	0	0	0	0	0	0	0	0	0	0
Merendera schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Minuartia filifolia	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis vestergrenii	0	0	0	0	1	0	0	0	0	0	0	0
Oreophyton falcatum	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis corniculata	0	0	0	0	1	0	0	0	0	0	0	0
Oxalis obliquifolia	0	0	0	0	0	0	0	0	0	0	0	0
Parietaria debilis	0	0	0	0	0	0	0	0	0	0	0	0
Paronychia bryoides	0	0	0	0	0	0	0	0	0	0	0	0
Pennisetum humile	0	0	0	0	0	0	0	0	0	0	0	0

Pentaschistis borussica	1	1	0	1	1	0	0	0	1	1	1	1
Pentaschistis pictigluma var *gracilis*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *minor*	0	0	1	0	1	0	0	0	1	1	0	0
Pentaschistis pictigluma var. *pictigluma*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis trisetoides	0	0	0	0	0	0	0	0	0	0	0	0
Peucedanum kerstenii	1	0	0	0	1	0	1	1	0	1	0	0
Phagnalon abyssinicum	0	0	0	0	0	0	0	0	0	0	0	0
Pimpinella oreophila	0	0	0	0	0	0	0	0	0	0	0	0
Pimpinella pimpinelloides	0	0	0	0	0	0	0	0	0	0	0	0
Plantago afra var. *stricta*	0	0	0	0	0	0	0	0	0	0	0	0
Poa annua	0	0	0	0	0	0	0	0	0	0	0	0
Poa leptoclada	0	0	0	0	0	0	0	0	1	0	0	0
Poa schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Polygala steudneri	0	0	0	0	0	0	0	0	0	0	0	0
Polypogon schimperianus	0	0	0	0	0	0	0	0	0	0	0	0
Polystichum magnificum	0	0	0	0	0	0	0	0	0	0	0	0
Polystichum setiferum	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus distrias	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oligocarpus	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oreophytus	0	1	1	0	0	1	1	1	1	0	0	0
Ranunculus stagnalis	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus trichophyllus	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus volkensii	0	0	0	0	1	1	0	1	0	0	0	0
Rhabdotosperma scrophulariifolia	0	0	0	0	0	0	0	0	0	0	0	0
Romulea fischeri	0	0	0	0	0	0	0	0	0	0	0	0
Rosularia semiensis	0	0	0	0	0	0	0	0	0	0	0	0
Rumex nepalensis	0	0	0	0	0	0	0	0	0	0	0	0

Rytidosperma grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0
Rytidosperma subulata	0	0	0	0	0	0	0	0	0	0	0	0
Sagina abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Sagina afroalpina	0	0	1	0	1	1	0	1	0	0	0	0
Salvia nilotica	0	0	0	0	0	0	0	0	1	0	0	0
Satureja abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Satureja imbricata	0	0	0	0	0	0	0	0	0	0	0	0
Satureja kilimandschari	0	0	1	0	1	0	0	0	0	1	0	0
Satureja pseudosimensis	0	0	0	0	0	0	0	0	0	0	0	0
Satureja punctata ssp. *punctata*	0	0	0	0	0	0	0	0	0	0	0	0
Satureja simensis	0	0	0	0	0	0	0	0	0	0	0	0
Satureja uhligii var. *obtusifolium*	0	0	0	1	0	0	0	0	1	0	0	0
Saxifraga hederifolia	0	0	0	0	0	0	0	0	0	0	0	0
Scabiosa columbaria	0	0	0	1	0	0	0	0	0	0	0	0
Sedum crassularia	0	0	0	0	0	0	0	0	0	0	0	0
Sedum meyeri-johannis	0	0	1	0	0	0	0	0	0	0	0	0
Sedum mooneyi	0	0	0	0	0	0	0	0	0	0	0	0
Senecio balensis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio farinaceus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio fresenii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio jacksonii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio meyeri-johannis	1	1	1	0	1	1	0	0	1	1	0	0
Senecio nanus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio polyadenus	1	0	0	0	0	0	0	0	0	0	0	0
Senecio purtschelleri	0	0	0	0	0	0	0	0	0	0	0	0
Senecio rhammatophyllus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio schultzii	0	0	0	0	0	0	0	0	0	0	0	0

Senecio schweinfurthii	1	1	1	0	0	1	0	0	0	0	0	0
Senecio subsessilis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio telekii	1	0	0	0	0	0	0	0	0	1	0	0
Senecio transmarinus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *major*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *sycephyllus*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio unionis	0	0	0	0	0	0	0	0	0	0	0	0
Silene burchellii var. *burchellii*	0	0	0	0	0	0	0	0	0	0	0	0
Silene flammulifolia	0	0	0	0	0	0	0	0	0	0	0	0
Silene macrosolen	0	0	0	0	0	0	0	0	0	0	0	0
Silene melanolepis	0	0	0	0	0	0	0	0	0	0	0	0
Sonchus melanolepis	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria media	0	0	0	0	0	0	0	0	0	0	0	0
Stoebe kilimandscharica	0	0	0	1	0	0	0	0	0	0	0	0
Subularia monticola	0	0	1	0	0	1	0	1	0	0	0	0
Swertia abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Swertia crassiuscula	1	0	1	0	1	0	1	0	0	0	0	0
Swertia engleri	0	0	0	0	0	0	0	0	0	0	0	0
Swertia kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0
Swertia pumila	0	0	0	0	0	0	0	0	0	0	0	0
Swertia subnivalis	0	0	0	0	0	0	0	0	0	0	0	0
Swertia uniflora	0	0	0	0	0	0	0	0	0	0	0	0
Swertia volkensii	1	1	1	0	0	1	0	0	1	0	1	0
Thymus schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Thymus serrulatus	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium acaule	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium calocephalum	0	0	0	0	0	0	0	0	0	0	0	0

Trifolium cryptopodium	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium elgonense	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium multinerve	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium rueppellianum	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium simense	0	0	0	0	0	0	0	0	0	0	0	0
Umbilicus botryoides	0	0	0	0	0	0	0	0	0	0	0	0
Ursinia nana	0	0	0	0	0	0	0	0	0	0	0	0
Valerianella microcarpa var. *microcarpa*	0	0	0	0	0	0	0	0	0	0	0	0
Verbascum sedgwickianum	0	0	0	0	0	0	0	0	0	0	0	0
Veronica anagallis-aquatica	0	0	0	0	0	0	0	0	0	0	0	0
Veronica arvensis	0	0	0	0	0	0	0	0	0	0	0	0
Veronica glandulosa	0	0	0	0	1	0	0	0	0	0	0	0
Veronica gunae	0	0	0	0	0	0	0	0	0	0	0	0
Viola eminii	0	0	0	0	0	0	0	0	0	0	0	0
Vulpia bromoides	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1d: Data matrix of 12 plots of Mt Rwenzori showing presence/absence scores for all species sampled

Species	**RBP 1**	**RBP 2**	**RBP 3**	**RBP 3**	**RDP 1**	**RDP 2**	**RDP 3**	**RDP 4**	**RAP 1**	**RAP 2**	**RAP 3**	**RAP 4**
Adiantum thalictroides	0	0	0	0	0	0	0	0	0	0	0	0
Aeonium leucoblepharum	0	0	0	0	0	0	0	0	0	0	0	0
Agrocharis melanantha	1	0	0	0	0	0	0	0	0	0	0	0
Agrostis gracilifolia ssp. *gracilifolia*	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis quinqueseta	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis schimperiana	1	1	0	0	0	0	0	0	0	0	0	1
Agrostis sclerophylla	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis trachyphylla	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis volkensii	0	0	0	0	0	0	0	0	0	0	0	0
Aira caryophyllea	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla argyrophylla	1	1	1	1	1	1	0	1	1	1	1	1
Alchemilla haumannii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla johnstonii	1	1	1	1	1	0	0	1	1	1	1	1
Alchemilla microbetula	0	1	1	0	1	0	0	0	0	1	1	1
Alchemilla pedata	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla subnivalis	0	0	0	0	0	0	1	0	0	0	0	0
Alchemilla stuhlmannii	0	0	0	0	1	1	0	1	0	0	0	1
Alchemilla triphylla	0	0	0	0	1	0	0	1	0	1	1	1
Alopecurus baptarrhenius	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis serpens ssp. *meyeri-johannis*	0	0	0	0	0	0	0	0	0	0	0	0
Andropogon amethystinus	0	0	0	0	0	0	0	0	0	0	0	0
Andropogon lima	0	0	0	0	0	0	0	0	0	0	0	0

Anemone thomsonii var. thomsonii	0	0	0	0	0	0	0	0	0	0	0	0
Anogramma leptophylla	0	0	0	0	0	0	0	0	0	0	0	0
Anthemis tigrensis	0	0	0	0	0	0	0	0	0	0	0	0
Anthoxanthum nivale	1	1	0	0	0	0	0	0	0	0	0	0
Aphanes bachitii	0	0	0	0	0	0	0	0	0	0	0	0
Arabidopsis thaliana	0	0	0	0	0	0	0	0	0	0	0	0
Arabis alpina	1	0	0	0	1	1	1	1	0	0	1	1
Argyrolobium schimperianum	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia afra	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium abyssinicum	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium aethiopicum	1	0	0	0	1	1	0	0	1	1	0	1
Asplenium buttneri	0	0	0	0	0	0	0	0	0	0	0	0
Barbarea intermedia	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia decurva	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia longiflora ssp. *longiflora*	0	0	0	0	0	0	0	0	1	0	0	0
Bromus leptoclados	1	0	0	0	0	0	0	0	0	0	0	0
Callitriche oreophila	0	0	0	0	0	0	0	0	0	0	0	0
Callitriche vulcanicola	0	0	0	1	0	0	0	0	0	0	0	0
Campanula edulis	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine hirsuta	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine obliqua	1	1	1	1	1	1	1	1	1	1	1	1
Carduus chamaecephalus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Carduus leptacanthus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus macracanthus	0	0	0	0	0	0	0	0	0	0	0	0
Carduus ruwenzoriensis	0	0	0	0	0	0	0	0	1	0	0	0
Carduus schimperi	0	0	0	0	0	0	0	0	0	0	0	0

Carex bequaerttii	1	0	0	0	0	0	0	0	0	0	0	0
Carex monostachya	0	0	0	0	0	0	0	0	0	0	0	0
Carex runssoroensis var. *aberdarensis*	1	1	1	1	0	0	0	0	0	0	0	0
Carex simensis	0	0	0	0	0	0	0	0	0	0	0	0
Carex conferta	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium octandrum	1	1	0	0	1	1	1	1	0	1	1	1
Cheilanthes farinosa	1	1	1	0	1	1	0	0	1	1	0	1
Cineraria abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Cineraria deltoidea	0	0	0	0	0	0	0	0	0	0	0	0
Colpodium chionogeiton	1	0	1	0	1	1	1	0	1	0	1	0
Colpodium hedbergii	0	1	0	0	0	0	0	1	0	0	0	1
Conyza spinosa	0	0	0	0	0	0	0	0	0	0	0	0
Conyza subscaposa	0	0	0	0	0	0	0	0	0	0	0	0
Cotula abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Cotula cryptocephala	0	0	0	0	0	0	0	0	0	0	0	0
Crassula granvikii	1	0	0	1	0	0	0	1	0	0	0	0
Crassula schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Crassula sp.	0	0	0	0	0	0	0	0	0	0	0	0
Crepis dianthoseris	0	0	0	0	0	0	0	0	0	0	0	0
Crepis foetida	0	0	0	0	0	0	0	0	0	0	0	0
Crepis rueppellii	0	0	0	0	0	0	0	0	0	0	0	0
Cyanotis barbata	0	0	0	0	0	0	0	0	0	0	0	0
Cyanotis polyrrhiza	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus elegantulus	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus plateilema	0	0	0	0	0	0	0	0	0	0	0	0
Cystopteris fragilis	0	0	0	0	0	0	0	0	0	0	0	0

Delphinium macrocentrum	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium wellbyi	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio adnivalis ssp. *adnivalis* var. *adnivalis*	1	1	1	1	1	1	1	1	1	1	0	1
Dendrosenecio battiscombei	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio elgonensis ssp. *barbatipes*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio erici-rosenii ssp. *erici-rosenii*	0	0	1	0	0	0	0	0	1	1	0	0
Dendrosenecio keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis × *keniodendron*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniodendron	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio kilimanjari ssp. *cottonii*	0	0	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	1	1	0	1	0	0	0	0	0	1	1	0
Deschampsia flexuosa var. *afromontana*	1	0	0	0	0	0	0	0	0	0	0	1
Dianthus longiglumis	0	0	0	0	0	0	0	0	0	0	0	0
Dichrocephala chrysanthemifolia	0	0	0	0	0	0	0	0	0	0	0	0
Dierama cupuliflorum	0	0	0	0	0	0	0	0	0	0	0	0
Dipsacus pinnatifidus	0	0	0	0	0	0	0	0	0	0	0	0
Disa stairsii	1	1	1	0	0	0	0	0	0	0	0	0
Echinops buhaitensis	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium stereophyllum var. *stereophyllum*	0	0	0	0	0	0	0	0	0	0	0	0
Erica arborea	1	1	0	0	0	0	0	0	0	0	0	0
Erica johnstonii	0	0	0	0	0	0	0	0	0	0	0	0
Erica tenuipilosa ssp. *spicata*	0	0	0	0	0	0	0	0	0	0	0	0
Erica trimera ssp. *keniensis*	0	0	0	0	0	0	0	0	0	0	0	0
Erigeron alpinus	0	0	0	0	0	0	0	0	0	0	0	0
Eriocaulon schimperi	0	0	0	0	0	0	0	0	0	0	0	0

Erophila verna	0	0	0	0	0	0	0	0	0	0	0	0
Euryops dacrydioides	0	0	0	0	0	0	0	0	0	0	0	0
Euryops elgonensis	0	0	0	0	0	0	0	0	0	0	0	0
Euryops prostratus	0	0	0	0	0	0	0	0	0	0	0	0
Festuca abyssinica	1	1	0	0	1	1	1	1	0	0	0	1
Festuca macrophylla	0	0	0	0	0	0	0	0	0	0	0	0
Festuca pilgeri	0	0	0	0	0	0	0	0	0	0	0	0
Festuca richardii	0	0	0	0	0	0	0	0	0	0	0	0
Festuca simensis	0	0	0	0	0	0	0	0	0	0	0	0
Galium acrophyum	0	0	0	0	0	0	0	0	0	0	0	0
Galium ruwenzoriense	1	1	0	0	1	1	1	1	1	1	1	1
Galium simense	0	0	0	0	0	0	0	0	1	1	0	0
Galium ossirwaense var. *glabrum*	0	0	0	0	0	0	0	0	0	0	0	0
Galium thunbergianum	0	0	0	0	0	0	0	0	0	0	0	0
Geranium arabicum	1	0	0	0	0	0	0	0	0	0	0	0
Geranium sp.nov.=Miehe 3002	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium unionis	0	0	0	0	0	0	0	0	0	0	0	0
Haplocarpha rueppellii	0	0	0	0	0	0	0	0	0	0	0	0
Haplocarpha schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Haplosciadium abyssinicum	0	0	0	0	0	0	0	0	0	0	0	0
Hebenstretia angolensis	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum brownei var. *brownei*	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum citrispinum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum foetidum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum formosissimum	1	0	0	0	0	1	0	0	1	1	0	0
Helichrysum forskahlii	1	0	0	0	0	0	0	0	0	0	0	0
Helichrysum globosum	0	0	0	0	0	0	0	0	0	0	0	0

Helichrysum gofense	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum horridum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum kilimanjari	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum newii	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum ambylyphyllum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum argyranthum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum splendidum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum stuhlmannii	1	1	1	0	1	1	1	1	1	1	1	1
Helictotrichon elongatum	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon cf umbrosum	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum abyssincum	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum elgonense	0	0	0	0	0	0	0	0	0	0	0	0
Herniaria abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Hesperantha petitiana	0	0	0	0	0	0	0	0	0	0	0	0
Huperzia saururus	1	1	0	0	0	0	0	0	0	0	0	0
Hydrocotylee sibthorpioides	1	1	0	0	1	0	0	0	0	1	0	0
Hypericum peplidifolium	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum revolutum	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis costata	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis fluitans	1	1	0	1	0	0	0	0	0	0	0	0
Isolepis setacea	1	0	0	0	0	0	0	0	0	0	0	0
Kniphofia foliosa	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia isoetifolia	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia thomsonii	0	0	0	0	0	0	0	0	0	0	0	0
Koeleria capensis	0	0	0	0	0	0	0	0	0	0	0	0
Lactuca inermis	0	0	0	0	0	0	0	0	0	0	0	0

Limosella major	1	0	0	1	0	0	0	0	0	0	0	0
Lithospermum afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia aberdarica	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia bequaertii	1	1	0	0	0	0	0	0	1	1	0	0
Lobelia deckenii ssp. *deckenii,* ssp. *burttii*	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia gregoriana ssp. elgonensis	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia lindblomii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia rhynchopetalum	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia stuhlmannii	0	0	1	0	0	0	0	0	1	1	0	0
Lobelia telekii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia wollastonii	0	0	1	1	1	1	1	1	1	0	1	1
Luzula abyssinica	1	1	0	0	1	0	0	0	0	0	0	1
Luzula johnstonii	1	1	1	0	1	1	0	0	1	1	0	1
Lychnis abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis rotundifolia	0	0	0	0	0	0	0	0	0	0	0	0
Malva verticillata	0	0	0	0	0	0	0	0	0	0	0	0
Merendera schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Minuartia filifolia	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis vestergrenii	0	0	0	0	0	0	0	0	0	0	0	0
Oreophyton falcatum	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis corniculata	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis obliquifolia	0	0	0	0	0	0	0	0	0	0	0	0
Parietaria debilis	0	0	0	0	0	0	0	0	0	0	0	0
Paronychia bryoides	0	0	0	0	0	0	0	0	0	0	0	0
Pennisetum humile	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis borussica	0	0	0	0	0	0	0	0	0	0	0	0

Pentaschistis pictigluma var. *gracilis*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *minor*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *pictigluma*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis trisetoides	0	0	0	0	0	0	0	0	0	0	0	0
Peucedanum kerstenii	1	1	0	0	1	0	0	1	1	1	1	1
Phagnalon abyssinicum	0	0	0	0	0	0	0	0	0	0	0	0
Pimpinella oreophila	0	0	0	0	0	0	0	0	0	0	0	0
Pimpinella pimpinelloides	0	0	0	0	0	0	0	0	0	0	0	0
Plantago afra var. *stricta*	0	0	0	0	0	0	0	0	0	0	0	0
Poa annua	0	0	0	0	0	0	0	0	0	0	0	0
Poa leptoclada	0	0	0	0	0	0	0	0	0	0	0	0
Poa schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Polygala steudneri	0	0	0	0	0	0	0	0	0	0	0	0
Polypogon schimperianus	0	0	0	0	0	0	0	0	0	0	0	0
Polystichum magnificum	0	0	0	0	0	0	0	0	0	0	0	0
Polystichum setiferum	1	0	0	0	0	1	0	0	0	0	0	0
Ranunculus distrias	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oligocarpus	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oreophytus	1	1	1	0	0	1	0	0	0	1	1	1
Ranunculus stagnalis	1	0	0	0	0	0	0	0	0	0	0	0
Ranunculus trichophyllus	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus volkensii	0	0	0	0	0	0	0	0	0	0	0	0
Rhabdotosperma scrophulariifolia	0	0	0	0	0	0	0	0	0	0	0	0
Romulea fischeri	0	0	0	0	0	0	0	0	0	0	0	0
Rosularia semiensis	0	0	0	0	0	0	0	0	0	0	0	0
Rumex nepalensis	1	0	0	0	0	0	0	0	0	0	0	0
Rytidosperma grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0

Rytidosperma subulata	0	0	0	0	0	0	0	0	0	0	0	0
Sagina abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Sagina afroalpina	0	0	0	0	0	0	0	0	0	0	0	0
Salvia nilotica	0	0	0	0	0	0	0	0	0	0	0	0
Satureja abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Satureja imbricata	0	0	0	0	0	0	0	0	0	0	0	0
Satureja kilimandschari	0	0	0	0	0	0	0	0	0	0	0	0
Satureja pseudosimensis	0	0	0	0	0	0	0	0	0	0	0	0
Satureja punctata ssp. *punctata*	0	0	0	0	0	0	0	0	0	0	0	0
Satureja simensis	0	0	0	0	0	0	0	0	0	0	0	0
Satureja uhligii var. *obtusifolium*	0	0	0	0	0	0	0	0	0	0	0	0
Saxifraga hederifolia	0	0	0	0	0	0	0	0	0	0	0	0
Scabiosa columbaria	0	0	0	0	0	0	0	0	0	0	0	0
Sedum crassularia	0	0	0	0	0	0	0	0	0	0	0	0
Sedum meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0	0
Sedum mooneyi	0	0	0	0	0	0	0	0	0	0	0	0
Senecio balensis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio farinaceus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio fresenii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio jacksonii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio nanus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio polyadenus	1	0	0	0	0	0	0	0	0	0	0	0
Senecio purtschelleri	0	0	0	0	0	0	0	0	0	0	0	0
Senecio rhammatophyllus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio schultzii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio schweinfurthii	0	0	0	0	0	0	0	0	0	0	0	0

Senecio subsessilis	0	0	0	0	0	1	0	0	0	0	0	0
Senecio telekii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus	0	1	0	0	0	0	0	0	1	1	0	0
Senecio transmarinus var. *major*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *sycephyllus*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio unionis	0	0	0	0	0	0	0	0	0	0	0	0
Silene burchellii var *burchellii*	0	0	0	0	0	0	0	0	0	0	0	0
Silene flammulifolia	0	0	0	0	0	0	0	0	0	0	0	0
Silene macrosolen	0	0	0	0	0	0	0	0	0	0	0	0
Silene melanolepis	0	0	0	0	0	0	0	0	0	0	0	0
Sonchus melanolepis	0	0	0	0	0	0	0	0	0	0	0	0
Stellaria media	0	0	0	0	0	0	0	0	0	0	0	0
Stoebe kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0
Subularia monticola	1	1	0	1	0	0	0	0	0	0	0	0
Swertia abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Swertia crassiuscula	0	0	0	0	0	0	0	0	0	0	0	0
Swertia engleri var. *engleri*	0	0	0	0	0	0	0	0	0	0	0	0
Swertia kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0
Swertia pumila	0	0	0	0	0	0	0	0	0	0	0	0
Swertia subnivalis	0	0	0	0	0	0	0	0	0	0	0	0
Swertia uniflora	0	0	0	0	0	0	0	0	0	0	0	0
Swertia volkensii	0	0	0	0	0	0	0	0	0	0	0	0
Thymus schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Thymus serrulatus	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium acaule	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium calocephalum	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium cryptopodium	0	0	0	0	0	0	0	0	0	0	0	0

Trifolium elgonense	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium multinerve	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium rueppellianum	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium simense	0	0	0	0	0	0	0	0	0	0	0	0
Umbilicus botryoides	0	0	0	0	0	0	0	0	0	0	0	0
Ursinia nana	0	0	0	0	0	0	0	0	0	0	0	0
*Valerianella microcarpa,*var. *microcarpa*	0	0	0	0	0	0	0	0	0	0	0	0
Verbascum sedgwickianum	0	0	0	0	0	0	0	0	0	0	0	0
Veronica anagallis-aquatica	0	0	0	0	0	0	0	0	0	0	0	0
Veronica arvensis	0	0	0	0	0	0	0	0	0	0	0	0
Veronica glandulosa	1	0	0	0	0	0	0	0	0	0	0	0
Veronica gunae	0	0	0	0	0	0	0	0	0	0	0	0
Viola eminii	1	1	0	0	0	0	0	0	0	0	0	0
Vulpia bromoides	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1e: Data matrix of 16 plots of Mt Bale showing presence/absence scores for all species sampled

Species	**BRP 1**	**BRP 2**	**BRP 3**	**BRP 4**	**BBP 1**	**BBP 2**	**BBP 3**	**BBP 4**	**BGP 1**	**BGP 2**	**BGP 3**	**BGP 4**	**BAP 1**	**BAP 2**	**BAP 3**	**BAP 4**
Adiantum thalictroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aeonium leucoblepharum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrocharis melanantha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis gracilifolia ssp. *gracilifolia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis quinqueseta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis schimperiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis sclerophylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis trachyphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis volkensii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aira caryophyllea	1	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
Alchemilla abyssinica	1	1	1	1	0	1	0	0	1	0	0	0	1	0	0	0
Alchemilla argyrophylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla haumannii	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Alchemilla johnstonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla microbetula	1	1	1	1	0	1	1	0	1	0	0	1	1	0	0	0
Alchemilla pedata	0	0	0	0	1	1	0	1	0	1	1	0	0	0	1	1
Alchemilla subnivalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla triphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alopecurus baptarrhenius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis serpens ssp. *meyeri-johannis*	0	0	1	0	0	1	1	0	0	0	0	1	1	0	0	0
Andropogon amethystinus	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Andropogon lima	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Anemone thomsonii var. *thomsonii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anogramma leptophylla	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Anthemis tigrensis	1	1	1	0	0	1	0	0	0	0	0	0	1	0	0	0
Anthoxanthum nivale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aphanes bachitii	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arabidopsis thaliana	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Arabis alpina	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Argyrolobium schimperianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Artemisia afra	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Asplenium abyssinicum	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium aethiopicum	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium buttneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barbarea intermedia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia decurva	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Bartsia longiflora ssp. *longiflora*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bromus leptoclados	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Callitriche oreophila	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Callitriche vulcanicola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Campanula edulis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cardamine hirsuta	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Cardamine oblique	0	0	0	0	1	1	1	0	0	0	0	1	1	0	0	0
Carduus chamaecephalus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carduus keniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carduus leptacanthus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carduus macracanthus	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0

Carduus ruwenzoriensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carduus schimperi	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0
Carex bequaerttii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex monostachya	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Carex runssoroensis var. *aberdarensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex simensis	0	1	1	1	0	0	1	0	0	1	1	1	1	0	1	1
Carex conferta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium afromontanum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium octandrum	1	1	1	1	1	1	1	1	1	0	0	1	1	0	0	0
Cheilanthes farinosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cineraria abyssinica	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	0
Cineraria deltoidea	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0
Colpodium chionogeiton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colpodium hedbergii	0	1	1	1	0	1	1	1	1	0	1	0	1	1	0	1
Conyza spinosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conyza subscaposa	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cotula abyssinica	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Cotula cryptocephala	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Crassula granvikii	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Crassula schimperi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crassula sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crepis dianthoseris	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Crepis foetida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crepis rueppellii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyanotis barbata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Cyanotis polyrrhiza	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus elegantulus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Cyperus plateilema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cystopteris fragilis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium macrocentrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium wellbyi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio adnivalis ssp. *adnivalis* var. *adnivalis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio battiscombei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio elgonensis ssp. *barbatipes*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio erici-rosenii ssp. erici-rosenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis × *keniodendron*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniodendron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio kilimanjari ssp. cottonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
Deschampsia flexuosa var. *afromontana*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianthus longiglumis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichrocephala chrysanthemifolia	1	1	1	1	0	1	0	1	1	1	1	1	0	0	1	1
Dierama cupuliflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dipsacus pinnatifidus	0	0	0	1	0	0	0	0	1	0	0	1	0	1	0	0
Disa stairsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinops buhaitensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epilobium stereophyllum var. *stereophyllum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Erica arborea	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Erica johnstonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erica tenuipilosa ssp. *spicata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erica trimera ssp. *keniensis*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erigeron alpines	1	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0
Eriocaulon schimperi	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Erophila verna	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Euryops dacrydioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euryops elgonensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euryops prostrates	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Festuca abyssinica	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
Festuca macrophylla	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca pilgeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca richardii	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Festuca simensis	0	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0
Galium acrophyum	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	1
Galium ruwenzoriense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium simense	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium ossirwaense var. *glabrum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galium thunbergianum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Geranium arabicum	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0
Geranium sp.nov.=Miehe 3002	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0
Gnaphalium unionis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Haplocarpha rueppellii	1	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1
Haplocarpha schimperi	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Haplosciadium abyssinicum	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0
Hebenstretia angolensis	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Helichrysum brownei var. *brownei*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum citrispinum	1	1	1	1	0	1	0	0	1	1	0	0	1	1	0	0
Helichrysum foetidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum formosissimum	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Helichrysum forskahlii	1	1	0	1	0	1	0	0	1	1	0	0	1	1	0	0
Helichrysum globosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum gofense	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Helichrysum horridum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum kilimanjari	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum newii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum ambylyphyllum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum argyranthum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum splendidum	0	1	0	0	0	1	0	0	1	1	0	0	1	1	0	0
Helichrysum stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon elongatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon cf *umbrosum*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum abyssincum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum elgonense	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Herniaria abyssinica	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hesperantha petitiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Huperzia saururus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrocotylee sibthorpioides	0	0	0	0	1	1	1	1	0	0	0	0	1	1	0	0
Hypericum peplidifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum revolutum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypericum afromontanum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Isolepis costata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis fluitans	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1
Isolepis setacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia foliosa	0	1	1	1	0	0	0	0	0	0	1	1	0	0	1	1
Kniphofia isoetifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kniphofia thomsonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Koeleria capensis	0	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0
Lactuca inermis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Limosella major	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Lithospermum afromontanum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia aberdarica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia bequaertii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia deckenii ssp. *deckenii,* ssp. *burttii*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia gregoriana ssp. *elgonensis, gregoriana*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia lindblomii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia rhynchopetalum	1	1	1	1	0	1	0	1	1	0	0	0	0	1	0	0
Lobelia stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia telekii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia wollastonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Luzula abyssinica	0	1	1	1	1	1	1	1	0	0	0	0	1	1	0	0
Luzula johnstonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis abyssinica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lychnis rotundifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malva verticillata	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Merendera schimperiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Minuartia filifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis keniensis	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1
Myosotis vestergrenii	0	0	1	1	0	1	0	1	0	0	0	0	1	0	0	0
Oreophyton falcatum	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis corniculata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis obliquifolia	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Parietaria debilis	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Paronychia bryoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pennisetum humile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Pentaschistis borussica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *gracilis*	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Pentaschistis pictigluma var. *minor*	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *pictigluma*	0	1	1	1	0	1	0	1	1	0	0	0	0	0	0	0
Pentaschistis trisetoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peucedanum kerstenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phagnalon abyssinicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pimpinella oreophila	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pimpinella pimpinelloides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago afra var. *stricta*	1	1	0	0	0	0	0	0	1	0	1	1	0	0	1	1
Poa annua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa leptoclada	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poa schimperiana	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Polygala steudneri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Polypogon schimperianus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polystichum magnificum	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Polystichum setiferum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus distrias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus oligocarpus	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Ranunculus oreophytus	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Ranunculus stagnalis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Ranunculus trichophyllus	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ranunculus volkensii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhabdotosperma scrophulariifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Romulea fischeri	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Rosularia semiensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rumex nepalensis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Rytidosperma grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rytidosperma subulata	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Sagina abyssinica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sagina afroalpina	1	1	1	0	0	0	1	1	1	1	0	0	1	1	0	0
Salvia nilotica	0	0	0	1	0	0	0	0	1	0	1	1	0	0	1	1
Satureja abyssinica	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Satureja imbricate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Satureja kilimandschari	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0
Satureja pseudosimensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Satureja punctata ssp. *punctata*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Satureja simensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Satureja uhligii var. *obtusifolium*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saxifraga hederifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scabiosa columbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Sedum crassularia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedum meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sedum mooneyi	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio balensis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio farinaceous	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio fresenii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio jacksonii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio nanus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio polyadenus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio purtschelleri	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio rhammatophyllus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio schultzii	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Senecio schweinfurthii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio subsessilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio telekii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *major*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *sycephyllus*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senecio unionis	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Silene burchellii var. *burchellii*	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene flammulifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene macrosolen	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silene melanolepis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sonchus melanolepis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Stellaria media	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stoebe kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subularia monticola	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Swertia abyssinica	0	1	0	1	0	0	0	0	1	0	1	1	1	1	1	1
Swertia crassiuscula	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Swertia engleri var. *engleri*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Swertia kilimandscharica	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
Swertia pumila	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Swertia subnivalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Swertia uniflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Swertia volkensii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Thymus schimperi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thymus serrulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium acaule	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Trifolium calocephalum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium cryptopodium	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Trifolium elgonense	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Trifolium multinerve	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium rueppellianum	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Trifolium simense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Umbilicus botryoides	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ursinia nana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Valerianella microcarpa var. *microcarpa*	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0
Verbascum sedgwickianum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veronica anagallis-aquatica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veronica arvensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veronica glandulosa	1	0	1	1	0	0	1	1	1	0	0	0	1	1	0	0

Veronica gunae	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Viola eminii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vulpia bromoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1f: Data matrix of 12 plots of Mt Simen showing presence/absence scores for all species sampled

Species	**SRP1**	**SRP2**	**SRP3**	**SRP3**	**SBP1**	**SBP2**	**SBP3**	**SBP4**	**SGP1**	**SGP2**	**SGP3**	**SGP4**
Adiantum thalictroides	1	0	0	0	0	0	0	0	0	0	0	0
Aeonium leucoblepharum	1	0	0	0	0	0	0	0	0	0	1	0
Agrocharis melanantha	1	0	0	0	1	0	0	0	1	1	0	1
Agrostis gracilifolia ssp. *gracilifolia*	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis quinqueseta	0	0	0	0	1	0	0	0	1	1	1	1
Agrostis schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis sclerophylla	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis trachyphylla	0	0	0	0	0	0	0	0	0	0	0	0
Agrostis volkensii	0	0	0	0	0	0	0	0	0	0	0	0
Aira caryophyllea	1	0	0	1	0	0	0	0	0	0	1	0
Alchemilla abyssinica	0	0	0	0	1	1	1	1	1	1	0	0
Alchemilla argyrophylla	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla haumannii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla johnstonii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla microbetula	1	1	1	1	0	0	1	0	1	1	1	1
Alchemilla pedata	0	0	0	0	0	1	0	1	0	0	0	0
Alchemilla subnivalis	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Alchemilla triphylla	0	0	0	0	0	0	0	0	0	0	0	0
Alopecurus baptarrhenius	0	0	0	0	0	1	0	1	0	0	0	0
Anagallis serpens ssp. *meyeri-johannis*	0	0	0	0	1	1	1	1	0	0	0	1
Andropogon amethystinus	0	0	0	0	0	0	0	0	1	0	0	0
Andropogon lima	1	1	1	0	0	0	0	0	1	0	0	0

Anemone thomsonii var. *thomsonii*	0	0	0	0	0	0	0	0	0	0	0	0
Anogramma leptophylla	1	1	0	0	0	0	0	0	0	0	0	0
Anthemis tigrensis	0	0	0	0	0	0	0	0	0	1	0	1
Anthoxanthum nivale	0	0	0	0	0	0	0	0	0	0	0	0
Aphanes bachitii	0	0	0	0	0	0	0	0	0	0	0	0
Arabidopsis thaliana	1	1	0	0	0	0	0	0	0	0	0	0
Arabis alpine	1	0	0	1	0	0	0	0	0	0	1	0
Argyrolobium schimperianum	0	0	0	0	0	0	0	0	1	0	0	0
Artemisia afra	0	0	0	0	1	0	0	0	0	0	0	0
Asplenium abyssinicum	0	1	1	0	0	0	0	0	0	1	0	0
Asplenium aethiopicum	1	1	1	1	0	0	0	0	0	0	1	0
Asplenium buttneri	0	0	0	0	0	0	0	0	0	0	0	0
Barbarea intermedia	0	0	0	0	0	0	0	0	0	0	0	0
Bartsia decurva	0	0	1	0	0	0	0	0	1	1	1	1
Bartsia longiflora ssp. *longiflora*	1	0	0	0	0	0	0	0	0	0	0	0
Bromus leptoclados	0	1	1	1	0	0	0	0	0	1	0	1
Callitriche oreophila	0	0	0	0	0	1	1	1	0	0	0	0
Callitriche vulcanicola	0	0	0	0	0	0	0	0	0	0	0	0
Campanula edulis	1	1	1	1	0	0	0	0	0	0	0	0
Cardamine hirsuta	1	1	1	1	0	0	0	0	0	0	0	0
Cardamine obliqua	0	0	0	0	1	1	1	1	0	0	0	0
Carduus chamaecephalus	0	0	0	0	0	0	0	0	0	1	0	0
Carduus keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Carduus leptacanthus	0	0	0	0	1	0	0	0	0	0	0	0
Carduus macracanthus	0	0	0	0	0	1	1	0	0	0	0	0
Carduus ruwenzoriensis	0	0	0	0	0	0	0	0	0	0	0	0
Carduus schimperi	0	1	0	1	1	1	1	1	1	0	0	0

Carex bequaerttii	0	0	0	0	0	0	0	0	0	0	0	0
Carex monostachya	0	0	0	0	1	1	1	1	0	0	1	1
Carex runssoroensis var. *aberdarensis*	0	0	0	0	0	0	0	0	0	0	0	0
Carex simensis	0	0	0	0	0	1	1	0	0	0	0	0
Carex conferta	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium afromontanum	0	0	0	0	0	0	0	0	0	0	1	0
Cerastium octandrum	1	1	1	1	0	1	1	1	1	1	1	1
Cheilanthes farinosa	0	0	0	0	0	0	0	0	0	0	0	0
Cineraria abyssinica	0	0	0	0	0	0	0	0	0	0	1	0
Cineraria deltoidea	1	0	1	0	0	0	0	0	0	0	1	0
Colpodium chionogeiton	0	0	0	0	0	0	0	0	0	0	0	0
Colpodium hedbergii	1	1	1	1	1	1	1	1	1	1	1	1
Conyza spinosa	1	0	0	0	0	0	0	0	0	0	1	0
Conyza subscaposa	0	0	0	0	0	0	0	0	0	0	0	0
Cotula abyssinica	0	1	0	1	1	0	1	0	1	0	0	0
Cotula cryptocephala	0	0	0	0	0	1	0	1	0	0	0	0
Crassula granvikii	1	1	1	1	1	1	1	1	0	1	0	0
Crassula schimperi	1	1	1	1	0	0	0	0	0	0	0	0
Crassula sp.	0	0	0	0	0	0	0	0	0	0	0	0
Crepis dianthoseris	1	1	0	1	1	1	0	0	1	0	1	1
Crepis foetida	0	1	0	0	0	0	0	0	0	0	0	0
Crepis rueppellii	1	0	0	1	0	0	0	0	0	0	0	0
Cyanotis barbata	0	0	0	0	0	0	0	0	1	0	0	0
Cyanotis polyrrhiza	1	0	0	0	0	0	0	0	0	0	0	0
Cyperus elegantulus	0	0	0	0	0	0	1	1	0	0	0	0
Cyperus plateilema	0	0	0	0	0	0	0	0	0	0	0	0
Cystopteris fragilis	0	0	0	1	0	0	0	0	0	0	0	0

Delphinium macrocentrum	0	0	0	0	0	0	0	0	0	0	0	0
Delphinium wellbyi	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio adnivalis ssp. *adnivalis* var. *adnivalis*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio battiscombei	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio elgonensis ssp. *barbatipes*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio erici-rosenii ssp. *erici-rosenii*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniensis × *keniodendron*	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio keniodendron	0	0	0	0	0	0	0	0	0	0	0	0
Dendrosenecio kilimanjari ssp. *cottonii*	0	0	0	0	0	0	0	0	0	0	0	0
Deschampsia caespitosa	0	0	0	0	1	0	0	0	0	0	0	0
Deschampsia flexuosa var. *afromontana*	0	0	0	0	0	0	0	0	0	0	0	0
Dianthus longiglumis	1	0	0	0	0	0	0	0	0	0	0	0
Dichrocephala chrysanthemifolia	1	1	0	1	0	0	0	0	1	0	0	0
Dierama cupuliflorum	0	0	0	0	0	0	0	0	0	0	0	0
Dipsacus pinnatifidus	0	0	1	0	1	0	0	0	0	0	1	1
Disa stairsii	0	0	0	0	0	0	0	0	0	0	0	0
Echinops buhaitensis	0	1	0	0	0	0	0	0	0	0	0	0
Epilobium stereophyllum var. *stereophyllum*	0	0	0	0	1	1	1	1	0	0	0	0
Erica arborea	1	0	0	0	0	0	0	0	1	0	1	0
Erica johnstonii	0	0	0	0	0	0	0	0	0	0	0	0
Erica tenuipilosa ssp. *spicata*	0	0	1	0	0	0	0	0	0	1	1	1

Erica trimera ssp. *keniensis*	0	0	0	0	0	0	0	0	0	0	0	0
Erigeron alpines	0	0	0	0	0	0	0	0	0	0	0	0
Eriocaulon schimperi	0	0	0	0	0	0	0	0	0	0	0	0
Erophila verna	0	0	0	0	0	0	0	0	0	0	0	0
Euryops dacrydioides	0	0	0	0	0	0	0	0	0	0	0	0
Euryops elgonensis	0	0	0	0	0	0	0	0	0	0	0	0
Euryops prostrates	0	0	0	0	0	0	0	0	0	0	0	0
Festuca abyssinica	0	0	0	0	0	0	0	0	1	0	0	0
Festuca macrophylla	0	0	1	0	0	1	1	1	0	0	0	1
Festuca pilgeri	0	0	0	0	0	0	0	0	0	0	0	0
Festuca richardii	0	0	0	0	0	0	0	0	0	0	0	0
Festuca simensis	1	1	1	1	1	0	0	0	1	1	1	1
Galium acrophyum	1	0	1	1	1	0	0	0	0	1	1	1
Galium ruwenzoriense	0	0	0	0	0	0	0	0	0	0	0	0
Galium simense	0	0	1	0	0	0	0	0	0	0	1	0
Galium ossirwaense var. *glabrum*	0	0	0	0	0	0	0	0	0	0	0	0
Galium thunbergianum	1	0	0	1	0	0	0	0	0	0	1	0
Geranium arabicum	0	1	0	1	1	0	0	0	1	1	0	0
Geranium sp.nov.=Miehe 3002	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium unionis	1	1	0	0	0	0	0	0	0	0	0	0
Haplocarpha rueppellii	0	0	1	0	1	1	1	1	0	0	0	0
Haplocarpha schimperi	0	0	0	0	0	0	1	1	0	0	0	0
Haplosciadium abyssinicum	0	0	0	0	0	0	0	0	1	0	0	0
Hebenstretia angolensis	0	0	0	1	0	0	0	0	0	0	0	0
Helichrysum brownei var. *brownei*	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum citrispinum	1	1	1	1	0	0	0	0	0	0	1	1
Helichrysum foetidum	1	0	0	0	0	0	0	0	0	0	0	0

Helichrysum formosissimum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum forskahlii	0	0	0	0	1	0	0	0	1	1	1	0
Helichrysum globosum	0	0	0	0	0	1	0	0	0	1	0	0
Helichrysum gofense	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum horridum	1	1	0	0	0	0	0	0	0	0	0	0
Helichrysum kilimanjari	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum newii	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum ambylyphyllum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum argyranthum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum splendidum	0	0	0	0	0	0	0	0	0	0	0	0
Helichrysum stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon elongatum	1	0	0	0	0	0	0	0	0	0	0	0
Helictotrichon cf *umbrosum*	0	0	0	0	0	0	0	0	0	0	0	0
Heracleum abyssincum	1	0	0	1	0	0	1	0	0	0	0	0
Heracleum elgonense	0	0	0	0	0	0	0	0	0	0	0	0
Herniaria abyssinica	1	1	0	1	0	0	0	0	0	0	1	0
Hesperantha petitiana	1	0	0	0	0	0	0	0	1	0	1	0
Huperzia saururus	0	0	0	0	0	0	0	0	0	0	0	0
Hydrocotylee sibthorpioides	0	0	0	0	1	1	1	1	0	1	0	0
Hypericum peplidifolium	0	0	0	0	0	1	1	0	1	0	0	0
Hypericum revolutum	0	1	0	0	0	0	0	0	1	0	0	0
Hypericum afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis costata	0	0	0	0	1	0	0	1	0	0	0	0
Isolepis fluitans	0	0	0	0	0	0	1	1	0	0	0	0
Isolepis setacea	1	0	0	0	0	0	0	0	0	0	0	0
Kniphofia foliosa	1	0	0	0	0	1	0	0	0	0	0	0
Kniphofia isoetifolia	0	0	0	0	0	0	0	0	1	0	0	0

Kniphofia thomsonii	0	0	0	0	0	0	0	0	0	0	0	0
Koeleria capensis	0	0	0	0	1	0	0	0	1	1	0	0
Lactuca inermis	0	0	0	0	0	0	0	0	0	1	0	1
Limosella major	0	0	0	0	1	1	1	1	0	0	0	0
Lithospermum afromontanum	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia aberdarica	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia bequaertii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia deckenii ssp. *deckenii*/ ssp. *burttii*	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia gregoriana ssp.*elgonensis*/ ssp.*gregoriana*	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia lindblomii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia rhynchopetalum	0	0	1	1	1	1	1	1	0	1	1	1
Lobelia stuhlmannii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia telekii	0	0	0	0	0	0	0	0	0	0	0	0
Lobelia wollastonii	0	0	0	0	0	0	0	0	0	0	0	0
Luzula abyssinica	0	0	1	0	1	0	0	0	0	1	1	1
Luzula johnstonii	0	0	0	0	0	0	0	0	0	0	0	0
Lychnis abyssinica	0	1	0	1	1	0	0	0	1	0	0	0
Lychnis rotundifolia	0	0	0	0	0	0	0	0	0	0	0	0
Malva verticillata	0	0	0	0	0	0	0	0	0	0	0	0
Merendera schimperiana	0	1	0	0	0	0	0	0	0	0	0	0
Minuartia filifolia	1	1	0	0	0	0	0	0	0	0	0	0
Myosotis keniensis	0	0	0	0	0	0	0	0	0	0	0	0
Myosotis vestergrenii	1	1	0	1	0	0	0	0	1	0	0	0
Oreophyton falcatum	0	0	1	1	0	0	0	0	0	0	0	0
Oxalis corniculata	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis obliquifolia	0	0	0	0	0	0	0	0	0	0	0	0

Parietaria debilis	0	1	1	1	0	0	0	0	0	0	0	0
Paronychia bryoides	0	0	0	1	0	0	0	0	0	0	1	1
Pennisetum humile	0	0	0	0	0	1	1	1	0	0	0	0
Pentaschistis borussica	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *gracilis*	0	0	0	0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *minor*	0	0		0	0	0	0	0	0	0	0	0
Pentaschistis pictigluma var. *pictigluma*	1	1	0	0	1	1	0	0	0	1	0	0
Pentaschistis trisetoides	0	1	0	1	0	0	0	0	0	0	0	0
Peucedanum kerstenii	0	0	0	0	0	0	0	0	0	0	0	0
Phagnalon abyssinicum	0	1	0	0	0	0	0	0	0	0	0	0
Pimpinella oreophila	0	0	0	0	0	1	0	0	0	0	0	0
Pimpinella pimpinelloides	0	0	1	1	0	0	1	0	0	0	0	0
Plantago afra var. *stricta*	1	1	0	0	0	0	0	0	1	0	0	0
Poa annua	0	0	0	0	1	0	1	1	0	0	0	0
Poa leptoclada	0	0	0	0	0	0	0	0	0	0	0	0
Poa schimperiana	0	0	0	0	0	0	0	0	0	0	0	0
Polygala steudneri	0	0	0	0	0	0	0	0	1	0	1	1
Polypogon schimperianus	0	0	0	0	1	1	0	0	1	0	0	0
Polystichum magnificum	0	0	1	0	0	0	0	1	0	0	0	0
Polystichum setiferum	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus distrias	0	0	0	0	1	0	0	0	0	0	0	0
Ranunculus oligocarpus	0	0	0	0	1	1	1	1	0	1	0	0
Ranunculus oreophytus	0	0	0	0	1	1	1	1	1	1	0	1
Ranunculus stagnalis	0	0	0	0	1	1	1	1	0	1	0	0
Ranunculus trichophyllus	0	0	0	0	0	0	1	0	0	0	0	0
Ranunculus volkensii	0	0	0	0	0	0	0	0	0	0	0	0

Rhabdotosperma scrophulariifolia	1	0	0	0	0	0	0	0	0	0	0	0
Romulea fischeri	0	1	1	0	1	0	0	0	1	1	0	0
Rosularia semiensis	1	0	1	1	0	0	0	0	0	0	0	0
Rumex nepalensis	0	0	0	0	0	1	1	1	0	1	0	0
Rytidosperma grandiflorum	0	0	0	1	0	0	0	0	0	0	0	0
Rytidosperma subulata	0	1	1	1	1	0	0	0	1	1	1	1
Sagina abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Sagina afroalpina	1	1	1	1	1	0	1	1	0	1	1	1
Salvia nilotica	0	1	0	0	0	0	0	0	1	0	0	0
Satureja abyssinica	0	0	0	0	0	0	0	0	0	0	0	0
Satureja imbricata	0	0	1	0	0	0	0	0	0	0	0	0
Satureja kilimandschari	0	0	0	0	0	0	0	0	0	0	0	0
Satureja pseudosimensis	0	1	0	0	1	0	0	0	1	1	1	1
Satureja punctata ssp. *punctata*	0	0	0	0	0	0	0	0	0	0	0	0
Satureja simensis	0	0	0	0	0	0	0	0	0	0	0	0
Satureja uhligii var. *obtusifolium*	0	0	0	0	0	0	0	0	0	0	0	0
Saxifraga hederifolia	1	0	1	1	0	0	0	0	0	0	0	0
Scabiosa columbaria	0	0	0	0	0	0	0	0	1	0	0	0
Sedum crassularia	0	0	0	0	0	0	0	0	0	0	0	0
Sedum meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0	0
Sedum mooneyi	0	0	0	0	0	0	0	0	0	0	0	0
Senecio balensis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio farinaceous	0	0	1	0	0	1	1	0	0	0	1	0
Senecio fresenii	0	0	0	0	1	1	0	0	0	0	0	0
Senecio jacksonii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio meyeri-johannis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio nanus	1	0	1	0	0	0	0	0	0	1	0	0

Senecio polyadenus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio purtschelleri	0	0	0	0	0	0	0	0	0	0	0	0
Senecio rhammatophyllus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio schultzii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio schweinfurthii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio subsessilis	0	0	0	0	0	0	0	0	0	0	0	0
Senecio telekii	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *major*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio transmarinus var. *sycephyllus*	0	0	0	0	0	0	0	0	0	0	0	0
Senecio unionis	0	1	0	0	0	0	0	0	0	0	0	0
Silene burchellii var. *burchellii*	1	0	0	1	0	0	0	0	1	1	1	0
Silene flammulifolia	1	0	0	1	0	0	0	0	0	0	1	0
Silene macrosolen	0	0	1	0	0	0	0	0	0	0	0	0
Silene melanolepis	1	1	1	0	0	0	0	0	0	0	1	0
Sonchus melanolepis	0	1	1	1	0	0	0	0	0	0	1	0
Stellaria media	0	0	0	1	0	0	0	0	0	0	0	0
Stoebe kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0
Subularia monticola	0	0	0	0	0	0	0	0	0	0	0	0
Swertia abyssinica	0	1	0	1	1	0	0	0	1	1	1	1
Swertia crassiuscula ssp.*crassiuscula,* ssp. *robusta*	0	0	0	0	0	0	0	0	0	0	0	0
Swertia engleri var. *engleri (*ssp. *engleri,*ssp. *woodii)*	0	0	1	0	1	0	1	0	0	1	1	1
Swertia kilimandscharica	0	0	0	0	0	0	0	0	0	0	0	0
Swertia pumila	1	0	0	0	0	0	0	0	0	1	1	1
Swertia subnivalis	0	0	0	0	0	0	0	0	0	0	0	0

Swertia uniflora	0	0	0	0	0	0	0	0	0	0	0	0
Swertia volkensii var. *baleensis,*var *volkensii*	0	0	0	0	0	0	0	0	0	0	0	0
Thymus schimperi	1	0	0	0	0	0	0	0	1	0	0	0
Thymus serrulatus	1	1	0	1	0	0	0	0	0	0	1	0
Trifolium acaule	0	0	0	0	0	0	1	1	0	1	1	1
Trifolium calocephalum	0	0	0	0	0	0	1	1	0	0	0	0
Trifolium cryptopodium	1	0	1	0	1	0	1	0	1	1	1	1
Trifolium elgonense	0	0	0	0	0	1	0	0	0	0	0	0
Trifolium multinerve	0	1	1	0	1	1	0	1	1	1	1	0
Trifolium rueppellianum	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium simense	0	0	0	0	0	0	0	0	1	0	0	0
Umbilicus botryoides	1	1	1	1	0	0	0	0	0	0	0	0
Ursinia nana	0	1	0	0	0	0	0	0	0	0	0	0
Valerianella microcarpa var. *microcarpa*	0	1	0	1	0	0	0	0	0	0	0	0
Verbascum sedgwickianum	0	1	0	0	0	0	0	0	0	0	0	0
Veronica anagallis-aquatica	0	0	0	0	0	1	1	1	0	0	0	0
Veronica arvensis	1	0	0	1	0	0	0	0	0	0	0	0
Veronica glandulosa	0	0	0	0	0	0	0	0	1	0	0	0
Veronica gunae	0	0	0	0	0	0	0	0	0	0	0	0
Viola eminii	0	0	0	0	0	0	0	0	0	0	0	0
Vulpia bromoides	1	1	1	1	0	0	1	0	1	0	0	0

Appendix 2a: Data Matrix of the species of *Pentaschistis* for Phenetic Analysis

Specimens (OTUs)	CL(cm)	LF	GLLV	LVW (mm)	PAL(cm)	PAW (cm)	INFL(cm)	SPC	No. SP	SPL (mm)	GLPA	GLUC	ASGLU	GLUT	SHINF	ANTC	AWL (mm)	APL(mm)
ET−1604−8	65	0	0	6	10	4	8.5	0	200	8	0	1	0	1	1	0	9	5
ET−1604−21	120	0	0	6	16	3.5	18	0	200	8	0	1	0	1	1	0	12	6
ET−1604−7	80	0	0	8	13	2	8	0	180	8	0	1	0	1	1	0	10	5
ET−1604−1	60	0	0	6	13	4	15	0	180	9	0	1	0	1	1	0	10	5
ET−1604−6	75	0	0	6	12	3	12	0	160	9	0	1	0	1	1	0	10	5
ET−1009−3	6	0	1	2	3	0.3	1	1	23	6	1	1	2	0	0	1	3	2
ET−717−1	8.5	0	1	3	5	1	1	1	80	6	1	1	2	0	0	1	3	1.2
ET−220−3	5.5	0	0	2	3	0.7	1	1	45	5	1	4	1	0	1	3	6	1
TZ−116−4	11	0	0	3	8.5	6	4	2	55	6	1	3	3	0	1	2	6	2
KN−251−4	17	0	0	2.5	9	5.5	11	2	65	6	1	3	3	0	1	2	6	2.5
KN−538−3	14	0	0	2.5	7.5	4	5	2	70	6	1	3	3	0	1	2	7	3
TZ−184	13.5	0	0	3	7	4	8	2	60	6	1	3	3	0	1	2	5.5	2
KN−251−3	18	0	0	2.5	8.5	4	12.5	2	60	6	1	3	3	0	1	2	6	2
ET−366−1	21	0	0	4	4	0.9	5	3	50	6	0	3	0	0	0	0	5	2
ET−763−3	33	0	0	3	6.5	1.1	9	3	100	6	0	3	0	0	0	0	6	2.5
ET−902−3	30	0	0	3	7	1.2	6.5	3	90	7	0	3	0	0	0	0	7	3
ET−647−3	28.5	0	0	3	6	1.5	3.5	3	85	7	0	3	0	0	0	0	7	2.5
ET−813−3	23	0	0	2	6	1.1	4	3	100	6	0	3	0	0	0	0	6	2.5
A. Bogdan AB 4123	9	1	0	1	2	0.2	2	2	10	4	0	3	0	0	0	0	3.5	1.5
A. Bogdan AB 44499	11	1	0	1	3	0.5	3	2	12	4	0	3	0	0	0	0	4	1.8
I.R. Dale 1933	17	1	0	3	3.3	1.2	4	2	60	6	0	3	0	0	0	0	6	3
TZ−48	25	1	0	1	6.5	0.4	3	2	17	4	0	3	0	0	0	0	3.5	1.5
ET−946−3	7	1	0	1	3	0.3	5	2	21	4	0	3	0	0	0	0	4	2
TZ−453−4	25	0	0	2	6	0.6	9	2	25	6	0	2	1	0	0	0	5	3
O. Hedberg 4208	17.5	0	0	3	4.5	1	2	2	30	8	1	2	1	0	0	0	7	3
O. Hedberg 2301	29	0	0	3	5	1.2	1.5	2	32	6	1	2	1	0	0	0	8	3
TZ−454−5	24	0	0	4	6.5	1	3	2	30	6	1	2	1	0	0	0	7	3
J.M. Thresh JMT 4	26	0	1	3	4	1	7	2	35	7	1	2	1	0	0	0	5	2.5
TZ−348−4	102	0	0	10	21	4.5	8	4	210	10	0	3	1	1	1	0	14	6

V. C. Gilbert 2249	107	0	0	10	32	6.5	7	4	220	10	0	3	1	1	1	0	11	5
Greenway 3801	140	0	0	10	21	5	14.5	4	200	8	0	3	1	1	1	0	10	5
D. Vesey Fitzgerald 4853	84	0	0	8	19	4.5	10	4	210	9	0	3	1	1	1	0	12	6
D. Vesey Fitzgerald 7506	87	0	0	8	19	5	10	4	250	10	0	3	1	1	1	0	8	3
O. Kerfoot 1734	55	0	0	4	15	3.5	8	5	150	8	0	5	0	2	1	4	9	5
R. Wingfield 350	88	0	0	4	19	5	31	5	100	7	0	5	0	2	1	4	8	3
W.H. Prins 341	84	0	0	5	17	14	24	5	120	7	0	5	0	2	1	4	9	4
P.J. Muller &J.C. Scheeper 145	50	0	0	3	8	3	9	5	34	7	0	5	0	2	1	4	8	3
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Appendix 2b: Data Matrix

Specimens (OTUs)	Habit	LEI	LESM	LEL	LEM	GLTYP	GLLOC	LEML	LEMI	GLAWN	PALEAL	PALEI	ANTL	ULPEDL	BPEDL	GLL	CRLINF	FLORL	FLORIND
ET−1604−8	1	1	1	45	1	0	0	3	1	0	4	0	2.7	4	4	8	0	4	2
ET−1604−21	1	1	1	50	1	0	0	3.5	1	0	4.5	0	2.6	4	4	8	0	4	2
ET−1604−7	1	1	1	45	1	0	0	3	1	0	4	0	2.5	2	4	8	0	4	2
ET−1604−1	1	1	1	53	1	0	0	3.5	1	0	5	0	2.7	4	4	9	0	4	2
ET−1604−6	1	1	1	40	1	0	0	3	1	0	4	0	2.6	3	4	9	0	4	2
ET−1009−3	1	1	1	3	1	2	2	2	0	0	2	1	0.5	2	4	6	4	2	0
ET−717−1	1	1	1	9	1	2	2	2	0	0	2	1	0.6	2	4	6	4	2	0
ET−220−3	0	1	0	7	1	1	1	2	1	0	1.5	0	0.7	2	4	5	4	2	0
TZ−116−4	1	1	1	12	0	1	1	2.2	0	1	1.5	0	1	8	16	6	3	3	0
KN−251−4	1	1	1	15	0	1	1	3	0	1	3	0	1.5	7	16	6	3	2.5	0
KN−538−3	1	1	1	10	0	1	1	2.5	0	1	3.5	0	2	9	17	6	3	3	0
TZ−184	1	1	1	9	0	1	1	3	0	1	3	0	1	7	12	6	3	2	0
KN−251−3	1	1	1	15	0	1	1	2.5	0	1	3	0	1.5	7	16	6	3	2.5	0
ET−366−1	1	1	1	17	1	0	0	2	0	0	3	0	0.5	2	4	6	1	2.5	1
ET−763−3	1	1	1	15	1	0	0	2	0	0	2	0	0.6	2	4	6	1	2.5	1
ET−902−3	1	1	1	20	1	0	0	2	0	0	2.5	0	0.7	2	4	7	1	2.5	1
ET−647−3	1	1	1	15	1	0	0	2	0	0	2	0	0.5	2	4	7	1	3	1
ET−813−3	1	1	1	20	1	0	0	2	0	0	2	0	0.6	2	4	6	1	2.5	1
A. Bogdan AB 4123	1	1	1	4	1	0	0	2	0	0	2	0	0.5	2	3	4	2	2	1
A. Bogdan AB 44499	1	1	1	6	1	0	0	2	0	0	2	0	0.6	2	3	4	2	2	1
I.R. Dale 1933	1	1	1	6	1	0	0	2	0	0	2	0	0.5	2	3	4	2	2	1
TZ−48	1	1	1	7	1	0	0	2	0	0	2	0	0.6	2	3	4	2	2	1
ET−946−3	1	1	1	5	1	0	0	2	0	0	2	0	0.5	2	3	4	2	2	1
TZ−453−4	1	1	1	13	1	1	3	2	0	0	2	0	0.7	2	6	6	2	3	1
O. Hedberg 4208	1	1	1	22	1	1	3	2.5	0	0	2.5	0	0.8	2	6	7	2	3	1
O. Hedberg 2301	1	1	1	24	1	1	3	2	0	0	2	0	0.9	2	6	6	2	3	1
TZ−454−5	1	1	1	15	1	1	3	1.8	0	0	2	0	0.7	2	6	6	2	3	1
J.M. Thresh JMT 4	1	1	1	16	1	1	3	2	0	0	2	0	0.7	3	5	7	2	3	1
TZ−348−4	1	0	1	56	0	0	0	3	1	0	4.5	0	2.5	4	11	10	1	4	2

V. C. Gilbert 2249	1	0	1	45	0	0	0	3.5	1	0	5	0	2.5	5	13	10	1	4	2
Greenway 3801	1	0	1	49	0	0	0	3	1	0	4.5	0	2.5	5	12	10	1	4	2
D. Vesey Fitzgerald 4853	1	0	1	45	0	0	0	3	1	0	4.5	0	2.3	5	11	10	1	4	2
D. Vesey Fitzgerald 7506	1	0	1	43	0	0	0	3.5	1	0	4.5	0	2.5	5	12	10	1	4	2
O. Kerfoot 1734	1	1	1	28	1	0	0	2	1	0	3.5	2	2	12	17	8	2	4	2
R. Wingfield 350	1	1	1	30	1	0	0	2.5	1	0	4	2	2	10	16	7	2	4	2
W.H. Prins 341	1	1	1	30	1	0	0	3	1	0	3.5	2	2	12	20	7	2	4	2
P.J. Muller &J.C. Scheeper 145	1	1	1	30	1	0	0	2.5	1	0	3.5	2	2	12	17	7	2	4	2
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Appendix 3: Species count for *Pentaschistis* species from five Vegetation types

Species	**Rock outcrop**	**Bog**	**Grassland**	***Dendrosenecio***	***Alchemilla***
Pentaschistis borussica	8	2	7	1	0
Pentaschistis pictigluma var *gracilis*	0	1	0	0	1
Pentaschistis pictigluma var. *minor*	5	1	2	1	0
Pentaschistis pictigluma var. *pictigluma*	5	4	2	0	0
Pentaschistis trisetoides	2	0	0	0	0

Appendix 4: Summary of the Family, genera and species sampled from Eastern Africa

No.	Family	No. of genera	Percentage (%)	No. of Species	Percentage (%)
1	Asteraceae	21	16.9	69	24.8
2	Poaceae	17	13.7	37	13.3
3	Caryophyllaceae	9	7.3	16	5.8
4	Lamiaceae	4	3.2	12	4.3
5	Cyperaceae	4	3.2	11	3.9
6	Rosaceae	2	1.6	10	3.6
7	Ranunculaceae	3	2.4	9	3.2
8	Lobeliaceae	1	0.8	9	3.2
9	Apiaceae	7	5.6	9	3.2
10	Scrophulariaceae	5	4.0	8	2.9
11	Gentianaceae	1	0.8	8	2.9
12	Fabaceae	2	1.6	8	2.9
13	Crassulaceae	5	4.0	8	2.9
14	Brassicaceae	5	4.0	6	2.2
15	Rubiaceae	1	0.8	4	1.4
16	Ericaceae	1	0.8	4	1.4
17	Adiantaceae	3	2.4	4	1.4
18	Iridaceae	3	2.4	3	1.0
19	Clusiaceae	1	0.8	3	1.0
20	Boraginaceae	2	1.6	3	1.0
21	Aspleniaceae	1	0.8	3	1.0
22	Asphodelaceae	1	0.8	3	1.0
23	Juncaceae	1	0.8	2	0.7
24	Geraniaceae	1	0.8	2	0.7
25	Dryopteridaceae	1	0.8	2	0.7
26	Dipsacaceae	2	1.6	2	
27	Commelinaceae	1	0.8	2	0.7
28	Callitrichaceae	1	0.8	2	0.7
29	Woodsiaceae	1	0.8	1	0.4
30	Violaceae	1	0.8	1	0.4
31	Valerianalaceae	1	0.8	1	0.4
32	Urticaceae	1	0.8	1	0.4
33	Saxifragaceae	1	0.8	1	0.4
34	Primulaceae	1	0.8	1	0.4
35	Polygonaceae	1	0.8	1	0.4
36	Polygalaceae	1	0.8	1	0.4
37	Plantaginaceae	1	0.8	1	0.4
38	Papaveraceae	1	0.8	1	0.4
39	Oxalidaceae	1	0.8	2	0.7
40	Orchidaceae	1	0.8	1	0.4

41	Onagraceae	1	0.8	1	0.4
42	Malvaceae	1	0.8	1	0.4
43	Lycopodiaceae	1	0.8	1	0.4
44	Eriocaulaceae	1	0.8	1	0.4
45	Colchicaceae	1	0.8	1	0.4
46	Campanulaceae	1	0.8	1	0.4

KK= Kenya Mt. Kenya; KE = Kenya Elgon; TK =Tanzania, Kilimanjaro; UR =Uganda, Ruwenzori; EB =Ethiopia, Bale; ES =Ethiopia, Simen; R= rock outcrop, B=bog, G= grassland, D =*Dendrosenecio*, A =*Alchemilla*.

Appendix 5: Comparison of Species Diversity & richness among the 75 plots from Eastern African mountains. The green colour indicates the most important factors that distinguish taxa

Plot No.	**Species Count**	**Margale'f (d)**	**Brillouin**	**H'(loge)**
KKRP1	28	8.10274397	2.424634	3.332205
KKRP2	30	8.52640901	2.488608	3.401197
KKRP3	23	7.016437756	2.243769	3.135494
KKRP4	17	5.647297982	1.970887	2.833213
KKBP1	23	7.016437756	2.243769	3.135494
KKBP2	24	7.23713355	2.282697	3.178054
KKBP3	20	6.342355813	2.116781	2.995732
KKBP4	41	10.77130032	2.781322	3.713572
KKDP1	19	6.113218894	2.07052	2.944439
KKDP2	22	6.793824516	2.203236	3.091042
KKDP3	17	5.647297982	1.970887	2.833213
KKDP4	16	5.410106403	1.916991	2.772589
KERP1	33	9.15198936	2.577408	3.496508
KERP2	32	8.944709254	2.548686	3.465736
KERP3	35	9.563058078	2.632462	3.555348
KERP4	26	7.673191911	2.356219	3.258097
KEGP1	32	8.944709254	2.548686	3.465736
KEGP2	21	6.569174775	2.160959	3.044522
KEGP3	24	7.23713355	2.282697	3.178054
KEGP4	35	9.563058078	2.632462	3.555348
KEDP1	22	6.793824516	2.203236	3.091042
KEDP2	22	6.793824516	2.203236	3.091042
KEDP3	22	6.793824516	2.203236	3.091042
TKRP1	25	7.456019215	2.320144	3.218876
TKRP2	21	6.569174775	2.160959	3.044522
TKRP3	35	9.563058078	2.632462	3.555348
TKRP4	20	6.342355813	2.116781	2.995732
TKBP1	38	10.17158038	2.709689	3.637586
TKBP2	31	8.736200287	2.519104	3.433987
TKBP3	21	6.569174775	2.160959	3.044522
TKBP4	20	6.342355813	2.116781	2.995732
TKGP1	23	7.016437756	2.243769	3.135494
TKGP2	23	7.016437756	2.243769	3.135494
TKGP3	14	4.926001362	1.799373	2.639057
TKGP4	14	4.926001362	1.799373	2.639057
URBP1	43	11.1666486	2.826351	3.7612
URBP2	28	8.10274397	2.424634	3.332205
URBP3	15	5.169771223	1.859951	2.70805

URBP4	12	4.426725648	1.665601	2.484907
URDP1	20	6.342355813	2.116781	2.995732
URDP2	18	5.881596356	2.021969	2.890372
URDP3	10	3.908650337	1.510441	2.302585
URDP4	15	5.169771223	1.859951	2.70805
URAP1	20	6.342355813	2.116781	2.995732
URAP2	22	6.793824516	2.203236	3.091042
URAP3	14	4.926001362	1.799373	2.639057
URAP4	22	6.793824516	2.203236	3.091042
EBRP1	28	8.10274397	2.424634	3.332205
EBRP2	34	9.358090238	2.605318	3.526361
EBRP3	42	10.96940184	2.804092	3.73767
EBRP4	32	8.944709254	2.548686	3.465736
EBBP1	21	6.569174775	2.160959	3.044522
EBBP2	39	10.37241998	2.734148	3.663562
EBBP3	25	7.456019215	2.320144	3.218876
EBBP4	29	8.315277722	2.457139	3.367296
EBGP1	30	8.52640901	2.488608	3.401197
EBGP2	20	6.342355813	2.116781	2.995732
EBGP3	19	6.113218894	2.07052	2.944439
EBGP4	20	6.342355813	2.116781	2.995732
EBAP1	27	7.888739964	2.39102	3.295837
EBAP2	19	6.113218894	2.07052	2.944439
EBAP3	16	5.410106403	1.916991	2.772589
EBAP4	20	6.342355813	2.116781	2.995732
ESRP1	57	13.85092503	3.094664	4.043051
ESRP2	51	12.71673891	2.988423	3.931826
ESRP3	43	11.1666486	2.826351	3.7612
ESRP4	48	12.14093504	2.930707	3.871201
ESBP1	44	11.36306691	2.84812	3.78419
ESBP2	37	9.969764163	2.684611	3.610918
ESBP3	40	10.5723162	2.758016	3.688879
ESBP4	34	9.358090238	2.605318	3.526361
ESGP1	45	11.55868168	2.869421	3.806662
ESGP2	40	10.5723162	2.758016	3.688879
ESGP3	45	11.55868168	2.869421	3.806662
ESGP4	31	8.736200287	2.519104	3.433987

Appendix 6: Factor coordinates of the variables, based on correlations (α=0.05) showing contribution of each character

Variables	**Factor 1**	**Factor 2**
Culm length (cm)	−0.931808	0.139898
Leaf form	0.402137	0.335374
Glands on leaf	0.341640	−0.061741
Leaf width (mm)	−0.879374	0.140551
Panicle length(cm)	−0.922147	−0.150105
Panicle width (cm)	−0.675553	−0.554726
Inflorescence stalk length (cm)	−0.653765	−0.238590
Spikelet colour	−0.359071	−0.362657
Number of spikelets	−0.921263	0.139919
Spikelet length (mm)	−0.847205	0.092779
Glands on panicle	0.518975	−0.550953
Glume colour	−0.142005	−0.526447
Apex shape of glume	0.240128	−0.703352
Glume indumentum	−0.846531	−0.169860
Shape of inflorescence	−0.743564	−0.477475
Anther colour	−0.123738	−0.830395
Awn length (mm)	−0.906432	0.052024
Apical bristle length (mm)	−0.883746	0.184985
Habit	−0.189322	0.149026
Leaf Indumentum	0.615114	−0.051794
Leaf sheath mouth	−0.189322	0.149026
Leaf length	−0.931239	0.221056
Leaf margin	0.333003	0.497351
Gland type	0.565486	−0.455049
Gland location	0.498750	−0.182795
Lemma length	−0.808909	−0.058095
Lemma indumentum	−0.881843	0.001280
Presence of glands on awn	0.182530	−0.697871
Palea length	−0.928655	0.012457
Palea indumentum	−0.244850	−0.471305
Anther length	−0.926487	−0.075016
Ultimate pedicel length	−0.477449	−0.770043
Basal Pedicel length	−0.454288	−0.843252

Glume length	−0.875207	0.059071
Colour of Inflorescence	0.628223	−0.682671
Floret length	−0.929760	0.006535
Floret indumentum	−0.832789	0.410002

Appendix 7: Data matrix for species richness of each vegetation community

Vegetation Community/Plot No.	**ROCK**	**BOG**	**GRASSLAND**	**DENDROSENECIO**	**ALCHEMILLA**
1	28	23	32	19	20
2	30	24	21	22	22
3	23	20	24	17	14
4	17	41	35	16	22
5	33	43	23	22	27
6	32	28	23	22	19
7	35	15	14	22	16
8	26	12	14	20	20
9	25	38	30	18	
10	21	31	20	10	
11	35	21	19	15	
12	20	20	20		
13	28	21	45		
14	34	39	40		
15	42	25	45		
16	32	29	31		
17	57	44			
18	51	37			
19	43	40			
20	48	34			

Appendix 8: Data matrix for species richness of each East African Mountain

Mountain/Plot No.	**Kenya**	**Elgon**	**Kilimanjaro**	**Rwenzori**	**Bale**	**Simen**
1	28	33	25	43	28	57
2	30	32	21	28	34	51
3	23	35	35	15	42	43
4	17	26	20	12	32	48
5	23	32	38	20	21	44
6	24	21	31	18	39	37
7	20	24	21	10	25	40
8	41	35	20	15	29	44
9	19	22	23	20	30	45
10	22	22	23	22	20	40
11	17	22	14	14	19	45
12	16		14	22	20	31
13					27	
14					19	
15					16	
16					20	

Appendix 9: Species checklist of Afroalpine Flora from Eastern Africa

Family	**Species**
Adiantaceae	*Adiantum thalictroides* Willd. ex Schlechtend.
Adiantaceae	*Cheilanthes farinosa* (Forssk.) Kaulf.
Apiaceae	*Agrocharis melanantha* Hochst.
Apiaceae	*Heracleum abyssincum* (Boiss.) Norman
Apiaceae	*Heracleum elgonense* (H.Wolff) Bullock
Apiaceae	*Peucedanum kerstenii* Engl.
Apiaceae	*Pimpinella oreophila* Hook.f.
Apiaceae	*Pimpinella pimpinelloides* H.Wolff
Apiaceae	*Haplosciadium abyssinicum* Hochst.
Araliaceae	*Hydrocotylee sibthorpioides* Lam.
Asphodelaceae	*Kniphofia foliosa* Hochst.
Asphodelaceae	*Kniphofia isoetifolia* A.Rich.
Asphodelaceae	*Kniphofia thomsonii* Baker
Aspleniaceae	*Asplenium abyssinicum* Fée
Aspleniaceae	*Asplenium aethiopicum* (Burm.f.) Bech
Aspleniaceae	*Asplenium buttneri* Hook.
Asteraceae	*Helichrysum citrispinum* Delile
Asteraceae	*Helichrysum foetidum* (L.) Cass.
Asteraceae	*Helichrysum formosissimum* Sch.Bip.
Asteraceae	*Helichrysum forskahlii* (J.F.Gmel.) Hilliard & B.L.Burtt
Asteraceae	*Helichrysum globosum* Sch.Bip.
Asteraceae	*Helichrysum gofense* Cufod.
Asteraceae	*Helichrysum horridum* Sch.Bip.
Asteraceae	*Helichrysum kilimanjari* Oliv.
Asteraceae	*Helichrysum newii* Oliv. & Hiern
Asteraceae	*Helichrysum ambylyphyllum* Mattf.
Asteraceae	*Helichrysum argyranthum* O.Hoffm.
Asteraceae	*Helichrysum splendidum* (Thunb.) Less.
Asteraceae	*Helichrysum stuhlmannii* O.Hoffm.
Asteraceae	*Anthemis tigrensis* A.Rich.
Asteraceae	*Artemisia afra* Jacq. ex Willd.
Asteraceae	*Carduus chamaecephalus* (Vatke) Oliv. & Hiern
Asteraceae	*Carduus keniensis* R.E.Fr.
Asteraceae	*Carduus leptacanthus* Fresen.
Asteraceae	*Carduus macracanthus* Kazmi
Asteraceae	*Carduus ruwenzoriensis* (Cortesi) Chiov.
Asteraceae	*Carduus schimperi* Sch. Bip.
Asteraceae	*Cineraria abyssinica* Sch.Bip. ex A.Rich.
Asteraceae	*Cineraria deltoidea* Sond.

Asteraceae	*Conyza spinosa* Sch.Bip. ex Oliv. & Hiern
Asteraceae	*Conyza subscaposa* O.Hoffm.
Asteraceae	*Cotula abyssinica* Sch.Bip.
Asteraceae	*Cotula cryptocephala* Sch.Bip. ex A.Rich
Asteraceae	*Crepis foetida* L.
Asteraceae	*Crepis rueppellii* Sch.Bip.
Asteraceae	*Dendrosenecio adnivalis* (Stapf) E.B.Knox ssp. adnivalis var. adnivalis
Asteraceae	*Dendrosenecio battiscombei* (R.E.Fr. & T.C.E.Fr.) E.B.Knox
Asteraceae	*Dendrosenecio elgonensis* (T.C.E.Fr.) E.B.Knox ssp. barbatipes
Asteraceae	*Dendrosenecio erici-rosenii* (R.E.Fr. & T.C.E.Fr.) E.B.Knox ssp. erici-rosenii
Asteraceae	*Dendrosenecio keniensis* (Baker f.) Mabb.
Asteraceae	*Dendrosenecio keniensis × D. keniodendron*
Asteraceae	*Dendrosenecio keniodendron* (r.e.fr. & t
Asteraceae	*Dendrosenecio kilimanjari* (Mildbr.) E.B.Knox ssp. cottonii
Asteraceae	*Dichrocephala chrysanthemifolia* (Blume) DC.
Asteraceae	*Echinops buhaitensis* Mesfin
Asteraceae	*Erigeron alpinus* L.
Asteraceae	*Euryops dacrydioides* Oliv.
Asteraceae	*Euryops elgonensis* Mattf.
Asteraceae	*Euryops prostratus* B.Nord.
Asteraceae	*Gnaphalium unionis* Sch.Bip. ex Oliv. & Hiern
Asteraceae	*Haplocarpha rueppellii* (Sch.Bip.) Beauverd
Asteraceae	*Haplocarpha schimperi* (Sch.Bip.) Beauverd
Asteraceae	*Helichrysum brownei* S.Moore var. brownei
Asteraceae	*Lactuca inermis* Forssk.
Asteraceae	*Oreophyton falcatum* (A.Rich.) O.E.Schulz
Asteraceae	*Phagnalon abyssinicum* Sch.Bip. ex Hochst.
Asteraceae	*Senecio balensis* S.Ortiz & Vivero
Asteraceae	*Senecio farinaceous* Sch.Bip. ex A.Rich.
Asteraceae	*Senecio fresenii* Sch.Bip.
Asteraceae	*Senecio jacksonii* S. Moore
Asteraceae	*Senecio meyeri-johannis* Engl.
Asteraceae	*Senecio nanus* Sch.Bip. ex A.Rich.
Asteraceae	*Senecio polyadenus* Hedberg
Asteraceae	*Senecio purtschelleri* Engl.
Asteraceae	*Senecio rhammatophyllus* Mattf.
Asteraceae	*Senecio schultzii* Wedd.
Asteraceae	*Senecio schweinfurthii* O. Hoffm.
Asteraceae	*Senecio subsessilis* Oliv. & Hiern
Asteraceae	*Senecio telekii* (Schweinf.) O.Hoffm.
Asteraceae	*Senecio transmarinus* S. Moore
Asteraceae	*Senecio transmarinus* S. Moore var. *major*

Asteraceae	*Senecio transmarinus* S. Moore var. *sycephyllus*
Asteraceae	*Senecio unionis* Sch.Bip. ex A.Rich.
Asteraceae	*Sonchus melanolepis* Fresen.
Asteraceae	*Stoebe kilimandscharica* O.Hoffm.
Asteraceae	*Ursinia nana* DC
Asteraceae	Crepis dianthoseris N.Kilian, Enke, Sileshi & Gemeinholzer
Athyriaceae	*Cystopteris fragilis* (L.) Bernh.
Athyriaceae	*Polystichum magnificum* F.Ballard
Athyriaceae	*Polystichum setiferum* (Forssk.) Moore ex Woynar
Boraginaceae	*Myosotis keniensis* T.C.E.Fr.
Boraginaceae	*Myosotis vestergrenii* Stroh
Brassicaceae	*Arabidopsis thaliana* (L.) Heynh.
Brassicaceae	*Arabis alpina* L.
Brassicaceae	*Barbarea intermedia* Boreau
Brassicaceae	*Cardamine hirsuta* L.
Brassicaceae	*Cardamine obliqua* A.Rich.
Brassicaceae	*Erophila verna* (L.) Chevall.
Brassicaceae	*Subularia monticola Schweinf.*
Callitrichaceae	*Callitriche oreophila* Schotsman
Callitrichaceae	*Callitriche vulcanicola* Schotsman
Campanulaceae	*Campanula edulis* Forssk.
Caryophylaceae	*Cerastium afromontanum* T.C.E.Fr. & Weim
Caryophylaceae	*Cerastium octandrum* Hochst. ex A.Rich.
Caryophylaceae	*Dianthus longiglumis* Delile
Caryophylaceae	*Herniaria abyssinica* Chaudhri
Caryophylaceae	*Lychnis abyssinica* (Hochst.) Lidén
Caryophylaceae	*Lychnis rotundifolia* (Oliv.) M.Popp
Caryophylaceae	*Minuartia filifolia* (Forssk.) Mattf.
Caryophylaceae	*Paronychia bryoides* Hochst. ex A.Rich.
Caryophylaceae	*Sagina abyssinica* [Hochst ex] A. Rich.
Caryophylaceae	*Sagina afroalpina* Hedberg
Caryophylaceae	*Silene burchellii* Otth ex DC. var *burchellii*
Caryophylaceae	*Silene flammulifolia* Steud. ex A. Rich.
Caryophylaceae	*Silene macrosolen* Steud. ex A.Rich.
Caryophylaceae	*Stellaria media* (L.) Vill.
Colchicaceae	*Merendera schimperiana* Hochst.
Commelinaceae	*Cyanotis polyrrhiza* Hochst. ex Hassk.
Commelinaceae	*Cyanotis barbata* D.Don
Crassulaceae	*Crassula granvikii* Mildbr.
Crassulaceae	*Crassula schimperi* Fisch. & C.A.Mey.
Crassulaceae	*Rosularia semiensis* (J. Gay ex A. Richard) H. Ohba
Crassulaceae	*Sedum crassularia* Raym.-Hamet

Crassulaceae	*Sedum meyeri-johannis* Engl.
Crassulaceae	*Sedum mooneyi* M.G.Gilbert
Crassulaceae	*Umbilicus botryoides* Hochst. ex A.Rich.
Crassulaceae	*Aeonium leucoblepharum* Webb ex A. Richard
Cyperaceae	*Carex monostachya* A.Rich.
Cyperaceae	*Carex runssoroensis* var. *aberdarensis* K.Schum.
Cyperaceae	*Carex simensis* A.Rich.
Cyperaceae	*Carex conferta* A.Rich.
Cyperaceae	*Carpha eminii* (K.Schum.) C.B.Clarke.
Cyperaceae	*Carex bequaerttii* De Wild.
Cyperaceae	*Cyperus elegantulus* Steud.
Cyperaceae	*Cyperus plateilema* (Steud.) Kuk.
Cyperaceae	*Isolepis costata* Hochst. ex A.Rich.
Cyperaceae	*Isolepis fluitans* (L.) R.Br. var. *fluitans*, var. *major*
Cyperaceae	*Isolepis setacea* L.) R.Br.
Dipsacaceae	*Dipsacus pinnatifidus* A.Rich.
Dipsacaceae	*Scabiosa columbaria* L
Ericaceae	*Erica arborea* L.
Ericaceae	*Erica johnstonii* (Schweinf. ex Engl.) Dorr
Ericaceae	*Erica tenuipilosa* (Engl.) R.E. Fries ssp. *spicata*
Ericaceae	*Erica trimera* (Engl.) R.E. Fries ssp. *keniensis*
Eriocaulaceae	*Eriocaulon schimperi* Körn. ex Ruhland.
Fabaceae	*Argyrolobium schimperianum* Hochst.
Fabaceae	*Trifolium acaule* A. Rich.
Fabaceae	*Trifolium calocephalum* Fresen.
Fabaceae	*Trifolium cryptopodium* A.Rich.
Fabaceae	*Trifolium elgonense* Gillett
Fabaceae	*Trifolium multinerve* A.Rich.
Fabaceae	*Trifolium rueppellianum* Fresen.
Fabaceae	*Trifolium simense* Fresen.
Gentianaceae	*Swertia abyssinica* Hochst.
Gentianaceae	*Swertia crassiuscula* Gilg. ssp. *crassiuscula*-var. cras & leuc;ssp. *robusta*
Gentianaceae	*Swertia engleri* var. *engleri* (ssp. Engleri,ssp. woodii)
Gentianaceae	*Swertia kilimandscharica* Engl.
Gentianaceae	*Swertia pumila* Hochst. ex Hook.f.
Gentianaceae	*Swertia subnivalis* T.C.E. Fr.
Gentianaceae	*Swertia uniflora* Mildbr.
Gentianaceae	*Swertia volkensii* Gilg. var. baleensis,var *volkensii*
Gentianaceae	*Geranium arabicum* Forssk.
Gentianaceae	*Geranium* sp.nov.=Miehe 3002
Hypericaceae	*Hypericum peplidifolium* A.Rich.
Hypericaceae	*Hypericum revolutum* Vahl

Hypericaceae	*Hypericum afromontanum* Bulloc
Iridaceae	*Dierama cupuliflorum* Klatt
Iridaceae	*Hesperantha petitiana* (A.Rich.) Baker
Iridaceae	*Limosella major* Diels
Iridaceae	*Romulea fischeri* Pax
Juncaceae	*Luzula abyssinica* Parl.
Juncaceae	*Luzula johnstonii* Parl.
Lamiaceae	*Salvia nilotica* Jacq.
Lamiaceae	*Satureja abyssinica* (Benth.) Briq.
Lamiaceae	*Satureja imbricata* Briq.
Lamiaceae	*Satureja kilimandschari* (Gurke) Ryding
Lamiaceae	*Satureja pseudosimensis* Brenan
Lamiaceae	*Satureja punctata* (Benth.) Briq.ssp. *punctata*
Lamiaceae	*Satureja simensis* Briq.
Lamiaceae	*Satureja uhligii* (Gurke) Ryding var. *obtusifolium*
Lamiaceae	T*hymus serrulatus* Hochst. ex Delile
Lamiaceae	*Thymus schimperi* Ronniger
Lobeliaceae	*Lobelia aberdarica* R.E.Fr. & T.C.E.Fr.
Lobeliaceae	*Lobelia bequaertii* De Wild.
Lobeliaceae	*Lobelia deckenii* (Ascher) Hemsl. ssp. *deckenii*, ssp. *burttii*
Lobeliaceae	*Lobelia telekii* ssp. *elgonensis*, *gregororiana*
Lobeliaceae	*Lobelia lindblomii* Mildbr.
Lobeliaceae	*Lobelia rhynchopetalum*
Lobeliaceae	*Lobelia stuhlmannii* Stuhlmann
Lobeliaceae	*Lobelia telekii* Schweinf.
Lobeliaceae	*Lobelia wollastonii* Bak f.
Lycopodiaceae	*Huperzia saururus* (Lam.) Trevis.
Malvaceae	*Malva verticillata* L.
Onagraceae	*Epilobium stereophyllum* Fresen. var. *stereophyllum*
Orchidaceae	*Disa stairsii* Kraenzl.
Oxalidaceae	*Oxalis corniculata* L
Oxalidaceae	*Oxalis obliquifolia* A.Rich.
Plantaginaceae	*Plantago afra* L. var. *stricta*
Poaceae	*Agrostis quinqueseta* (Steud.) Hochst
Poaceae	*Agrostis schimperiana* Steud.
Poaceae	*Agrostis sclerophylla* C.E.Hubb.
Poaceae	*Agrostis trachyphylla* Pilg.
Poaceae	*Agrostis volkensii* Stapf
Poaceae	*Aira caryophyllea* L.
Poaceae	*Alopecurus baptarrhenius* S.M.Phillips
Poaceae	*Andropogon amethystinus* Steud.
Poaceae	*Andropogon lima* (Hack.) Stapf

Poaceae	*Anthoxanthum nivale* K.Schum.
Poaceae	*Bromus leptoclados* Nees
Poaceae	*Colpodium chionogeiton* (Pilg.) Tzvelev
Poaceae	*Colpodium hedbergii* (Melderis) Tzvelev
Poaceae	*Deschampsia angusta* Stapf & C.E.Hubb.
Poaceae	*Deschampsia caespitosa* (L.) P.Beauv.
Poaceae	*Deschampsia flexuosa* var. *afromontana* (L.) Trin.
Poaceae	*Festuca abyssinica* Hochst. ex A.Rich.
Poaceae	*Festuca macrophylla* E.B.Alexeev
Poaceae	*Festuca pilgeri* St. Yves
Poaceae	*Festuca richardii* E.B.Alexeev
Poaceae	*Festuca simensis* A.Rich.
Poaceae	*Helictotrichon elongatum* (A.Rich.) C.E.Hubb.
Poaceae	*Helictotrichon* cf *umbrosum* (Steud.) C.E.Hubb.
Poaceae	*Koeleria capensis* (Steud.) Nees
Poaceae	*Pennisetum humile Hochst. ex A.Rich.*
Poaceae	*Pentaschistis borussica* (K. Schum.) Pilg.
Poaceae	*Pentaschistis pictigluma* (Steud.) Pilg. var *gracilis*
Poaceae	*Pentaschistis pictigluma* (Steud.) Pilg. var. *minor*
Poaceae	*Pentaschistis pictigluma* (Steud.) Pilg. var. *pictigluma*
Poaceae	*Pentaschistis trisetoides* Pilg.
Poaceae	*Poa annua* L.
Poaceae	*Poa leptoclada* A.Rich.
Poaceae	*Poa schimperiana* Hochst. ex A.Rich.
Poaceae	*Polypogon schimperianus* (Hochst. ex Steud.) Cope)
Poaceae	*Rytidosperma grandiflorum* (Hochst. ex A.Rich.) S.M.Phillips
Poaceae	*Rytidosperma subulata* (A.Rich.) T.A.Cope
Poaceae	*Vulpia bromoides* (L.) Gray
Poaceae	*Agrostis gracilifolia* C.E.Hubb ssp. *gracilifolia* S.M. Philips
Polygalaceae	*Polygala steudneri* Chodat
Polygonaceae	*Rumex nepalensis* Spreng.
Primulaceae	*Anagallis serpens* ssp. *meyeri-johannis* (Engl.) P.Taylor
Pteridaceae	*Anogramma leptophylla* (L.) Link
Ranunculaceae	*Delphinium macrocentrum* Oliv.
Ranunculaceae	*Delphinium wellbyi* Hemsl.
Ranunculaceae	*Ranunculus distrias* Steud. ex A.Rich.
Ranunculaceae	*Ranunculus oligocarpus* Speg.
Ranunculaceae	*Ranunculus oreophytus* Del.
Ranunculaceae	*Ranunculus stagnalis* Hochst. ex A.Rich.
Ranunculaceae	*Ranunculus trichophyllus* Chaix
Ranunculaceae	*Ranunculus volkensii* Engl.
Rosaceae	*Alchemilla abyssinica*Fresen.

Rosaceae	*Alchemilla argyrophylla* ssp. *argyrophylla* Oliv.
Rosaceae	*Alchemilla haumannii* Engl.
Rosaceae	*Alchemilla johnstonii* Oliv.
Rosaceae	*Alchemilla microbetula* T.C.E. Fries
Rosaceae	*Alchemilla pedata* A. Rich.
Rosaceae	*Alchemilla subnivalis* Baker f.
Rosaceae	*Alchemilla stuhlmannii* Engl.
Rosaceae	*Alchemilla triphylla* Rothm.
Rosaceae	*Anemone thomsonii* Oliv. var. *thomsonii*
Rosaceae	*Aphanes bachitii* (Hauman & Balle) Rotm.
Rosaceae	*Alchemilla argyrophylla* Oliv. ssp. *argyrophylloides* (Baker f.) Rothm
Rosaceae	*Alchemilla argyrophylla Oliv.* ssp. *argyrophylla* Oliv.
Rubiaceae	*Galium acrophyum*Hochst. ex Chiov.
Rubiaceae	*Galium ruwenzoriense* (Cortesi) Chiov.
Rubiaceae	*Galium simense* Fresen.
Rubiaceae	*Galium ossirwaense* K.Krause var. glabrum
Rubiaceae	*Galium thunbergianum* Eckl. & Zeyh.
Saxifragaceae	*Saxifraga hederifolia* Hochst. ex A.Rich.
Scrophulariaceae	*Bartsia longiflora* ssp. *longiflora* Hochst. ex Benth.
Scrophulariaceae	*Hebenstretia angolensis* Rolfe
Scrophulariaceae	*Lithospermum afromontanum* Weim
Scrophulariaceae	*Rhabdotosperma scrophulariifolia* (Hochst.) Hartl
Scrophulariaceae	*Verbascum sedgwickianum* (Schimp.) Hub.
Scrophulariaceae	*Veronica anagallis-aquatica* L.
Scrophulariaceae	*Veronica arvensis* L.
Scrophulariaceae	*Veronica glandulosa* Hochst ex. Benth.
Scrophulariaceae	*Veronica gunae* Schweinf. ex Engl.
Scrophulariaceae	*Bartsia decurva* Hochst. ex Benth.
Urticaceae	*Parietaria debilis* G.Forst.
Valerianaceae	*Valerianella microcarpa* Loisel. var *microcarpa*
Violaceae	*Viola eminii* (Engl.) R.E.Fr.

Appendix 10: Plates of Some typical Afroalpine species from Eastern Africa….

Plate 1 *Carduus keniensis*
(Saddle hut, Mt. Meru taken on 27/11/08)

Plate 2 *Anemone thomsonii*
(Shira, Mt. Kilimanjaro on 4/11/08)

Plate 3 *Cardamine obliqua*
(Bujuku, Rwenzori on 28/8/08)

Plate 4 *Alchemilla johnstonii*
(Mt Meru, near Crater on 30/11/08)

Plate 5 *Dendrosenecio advinalis* var. *petiolatus*
(Bujuku, Rwenzori on 21/08/08)

Plate 6 *Disa stairsii*
(John Mate hut, Rwenzori on 14/8/08)

Plate 7 *Galium ruwenzoriense*

(Bujuku, Rwenzori taken on 24/8/08)

Plate 8 *Haplocarpha rueppellii*

(Baranko, Mt Kilimanjaro on 8/11/08)

Plate 9 *Gladiolus watsonioides*
(Near Saddle hut Mt Meru on 30/11/08)

Plate 10 *Ranunculus oreophytus*
(Lower Bukurungu, Rwenzori on 17/8/08)

Plate 11 *Helichrysum formosissimum*

(Baranko hut, Mt Kilimanjaro on 8/11/08)

Plate 12 *Hebenestreitia angolensis*

(Near Saddle hut Mt Meru on 30/11/08)

Plate 13 *Galium acrophyum*
(Saddle hut Mt Meru on 30/11/08)

Plate 14 *Helichrysum forskahlii*
(Baranko, Mt Kilimanjaro on 8/11/08)

Plate 15: *Subularia monticola*

(Bujuku, Rwenzori on 28/8/08)

Plate 16: *Huperzia saururus*

(Bujuku, Rwenzori on 20/8/08)

Appendix 11: Botanical illustrations of *Pentaschistis* species

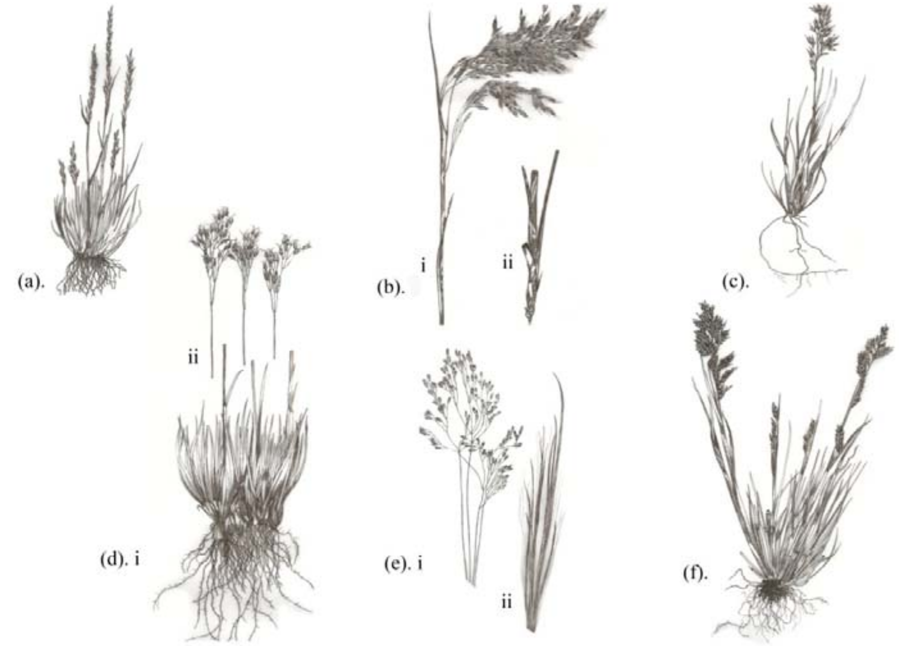

Illustration: 17 (a)– (f): (a) *Pentaschistis pictigluma* var. *minor*– growth habit; (b) *P. chrysurus*– (i) Inflorescences ii) a section of the stem and leaf sheath; (c) *P. trisetoides*– habit; (d) *P. borussica* (i) habit, (ii) inflorescence; (e) *P. natalensis*, (i) inflorescence, (ii) leaf and leaf sheath; (f) *P. gracilis* var. *gracilis*– growth habit (Botanical illustration by Nicholus M.)