**African Journal of Climate Change and Resource Sustainability**
ajccrs.eanso.org
**Volume 3, Issue 1, 2024**
**Print ISSN: 790-962X | Online ISSN: 790-9638**
Title DOI: https://doi.org/10.37284/2790-9638

EAST AFRICAN
NATURE &
SCIENCE
ORGANIZATION

*Original Article*

# Vulnerability of the Pteridoflora Towards Climate Change in the West Albertine Rift: Case of the Mountain's Stages of the Kahuzi-Biega National Park in the Democratic Republic of the Congo

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**Article DOI: https://doi.org/10.37284/ajccrs.3.1.1916**

**Date Published:**

*10 May 2024*

**Keywords**:

*Vulnerability of Lycophytes and Ferns, Forest Structures, Bio-Indicators, Climate Changes.*

## ABSTRACT

The present article aims at analysing the floristic composition of Lycophytes and Ferns to test the disturbances on the vegetation structure occurring in the mountains zones of the Kahuzi-Biega National Park (KBNP), further, to prove/underline the main threat and the vulnerability which actually is impacting the biodiversity in the mountains of the Western Albertine Rift due to climate changes and resulting in habitat loss as well as result of anthropogenic activities. The KBNP is located at the crossroad of the phytogeography regions of the Guinea-Congolese and Afromontane between 650 to 3326 m of altitude. During 10 years, we conducted comparison studies in the habitats (disturbed and undisturbed) encountered on the vegetation that scales between 1250 à 3300 m of altitude in 30 plots, 15 transects on a one kilometre. The results obtained reveal a variation in the flora composition within the three stages. The difference in the height, the diametric distribution (trees and shrubs) as well as the presence of Pteridophytes between undisturbed and disturbed habitats is highly significant within the 10 years' observations. In stable and mature parcels, Pteridophytes constitute a very rich, diversified and stable population. Permanent threat manifested through the fragility of the habitats and is further translated by a modification of the floristic composition of the canopy, and sometimes trough the taming of the undergrowth in disturbed parcels. The mountainous part of the KBNP might probably constitute a climatic refuge for Pteridophytes in the Albertine Rift considering their diversity. Furthermore, considering these adaptations, the diversity and the specificity of the biotopes occupied, as well as the bioecological services recognized to Lycophytes and Ferns, they are the real markers for bioindicators of the delicatessen towards climate changes observed in the western rift Albertine. However, anthropogenic effects and sometimes, natural hazards resulting in this protected area, may also constitute a source of vulnerability for Pteridophytes.

**APA CITATION**

Mokoso, J. D. D. M., Marie, F. C., Habimana, H. N., Sefu, J. A., Zabo, I. A., Botelanyele, F. K. & Roger, K. L. (2024). Vulnerability of the Pteridoflora Towards Climate Change in the West Albertine Rift: Case of the Mountain's Stages of the Kahuzi-Biega National Park in the Democratic Republic of the Congo *African Journal of Climate Change and Resource Sustainability*, *3*(1), 116-149. https://doi.org/10.37284/ajccrs.3.1.1916.

**CHICAGO CITATION**

Mokoso, Jean De Dieu Mangambu, Fundiko Cakupewa Marie, Honorine Ntahobavuka Habimana, Josué Aruna Sefu, Idrissa Assumani Zabo, Francine Kirongozi Botelanyele and Katusi Lomalisa Roger. 2024. "Vulnerability of the Pteridoflora Towards Climate Change in the West Albertine Rift: Case of the Mountain's Stages of the Kahuzi-Biega National Park in the Democratic Republic of the Congo". *African Journal of Climate Change and Resource Sustainability* 3 (1), 116-149. https://doi.org/10.37284/ajccrs.3.1.1916

**HARVARD CITATION**

Mokoso, J. D. D. M., Marie, F. C., Habimana, H. N., Sefu, J. A., Zabo, I. A., Botelanyele, F. K. & Roger, K. L. (2024) "Vulnerability of the Pteridoflora Towards Climate Change in the West Albertine Rift: Case of the Mountain's Stages of the Kahuzi-Biega National Park in the Democratic Republic of the Congo", *African Journal of Climate Change and Resource Sustainability*, 3(1), pp. 116-149. doi: 10.37284/ajccrs.3.1.1916.

**IEEE CITATION**

J. D. D. M. Mokoso, F. C. Marie, H. N. Habimana, J. A. Sefu, I. A. Zabo, F. K. Botelanyele & K. L. Roger. "Vulnerability of the Pteridoflora Towards Climate Change in the West Albertine Rift: Case of the Mountain's Stages of the Kahuzi-Biega National Park in the Democratic Republic of the Congo", AJCCRS, vol. 3, no. 1, pp. 116-149, May. 2024.

**MLA CITATION**

Mokoso, Jean De Dieu Mangambu, Fundiko Cakupewa Marie, Honorine Ntahobavuka Habimana, Josué Aruna Sefu, Idrissa Assumani Zabo, Francine Kirongozi Botelanyele & Katusi Lomalisa Roger. "Vulnerability of the Pteridoflora Towards Climate Change in the West Albertine Rift: Case of the Mountain's Stages of the Kahuzi-Biega National Park in the Democratic Republic of the Congo". *African Journal of Climate Change and Resource Sustainability*, Vol. 3, no. 1, May. 2023, pp. 116-149, doi:10.37284/ajccrs.3.1.1916.

## INTRODUCTION

The main threat to the mountain biodiversity in the Albertine Rift is the habitat loss as result of the high population density, imputable to human activities, and climate changes (Mansourian et al., 2009; Leadley et al., 2010; IUCN & UNEP 2015; Komla et al., 2020; Mangambu et al., 2021). It is therefore crucial to better apprehend the ecological niche of species and to evaluate their vulnerability to climate changes and to anthropogenic disturbances in order to undertake adequate decisions for their conservation considering the Lycophytes and Ferns as bioindicators.

One of the taxonomic groups the less documented is the one of the Lycophytes and Ferns (Pteridophyte Phylogeny Group I, 2016). These plant species constitute however a major taxonomic group with more than 12000 species identified (Pteridophyte Phylogeny Group I, 2016), with their potential and multiple uses (Thomas 1999; Bergeron & Pellerin, 2014). Species named Pte lycophytes and ferns ridophytes are the vascular cryptograms that are very sensible to variations of the atmospheric humidity rate (Paciencia & Prado, 2005; Mace et al., 2011; Pteridophyte Phylogeny Group I, 2016), the sunshining and the soil composition/nature (Mace et al., 2010). Therefore, their floristic composition change (Singh et al., 2012) compared to other plant species (Orchids, Bryophytes and Lichens) which are very fragile in exposure to changes and forest modifications (Zapfack et al., 1996; Stevart et al., 2006).

But, when the primary characters of the forest are pronounced, the necessary imbalances appear better established to maintain species in the groups of cryptogamic vascular plants (Mangambu, 2016). To satisfy their huge water needs, based on their adaptation features, these species utilize ambient humidity benefiting from the forest shade generated by the canopy cover (Biedinger & Fischer, 1996; Christie & Arnesto, 2003; Fischer & Lindenmayer, 2008). They can thereby be considered as indicators of primary habitats, of the richness and of the specific poverty in combination with the rate of forest degradation (Paciencia & Prado, 2005; Heink al., 2010).

The Lycophytes and Ferns are further used to evaluate the environmental state and called therefore bio-indicators (Wright, 2005). Biological indicators or bio-indicators are groups of species or species categories for which the life strongly depends on the habitat structure (Heink & Kowarik, 2010; Mace et al., 2011). Several authors (Wright, 2005; Aydin & Kazak, 2010; Mace et al., 2011; Komla et al., 2020) have demonstrated that the value, the diversity, and the adaptation features of bio-indicators on the forest structure, can be considered as ecological factors allowing further understanding of the maintenance of the stability in the forest ecosystem (Fischer & Lindenmayer 2008; Picton-Phillipps & Seimon, 2009).

As for the majority of the African tropical forests, the KBNP forest (*Figure 1*) has undergone multiple disturbances in the last decennia as result of human penetration exercising illegal activities such as firebrand, the poaching, and the training of armed militia, linked to the repetitive war conflicts in the region. All these activities have resulted in the decrease of the canopy cover (Mubalama & Bashige, 2006; Mubalama 2010; Masumbuko et al., 2012 a&b).

Furthermore, its crucial to mention the combination with the quick expanding liana *Sericostachys scandens* that is also threatening tree components in the mountain stage (Liengola, 2008; Masumbuko et al., 2012 a&b et 2013). Pressures that are more and more exercised on the park appeared to become extreme during the 90s, *leading to the recognition* of the Park as World Heritage in Extinction/Peril by the UNESCO anno 1997(Mubalama & Bashige, 2006; Mangambu et al., 2010).

In the present study, the following questions are addressed: (*i) into what extend does the species richness among local Lycophytes and Ferns species changes according to the vegetation type? (ii) What is the impact of climate change on the ecological niches of Lycophytes and Ferns in the mountain stages of the Kahuzi-Biega National Park?*

The general goal of the study is to conduct a diagnostic analysis of the state of this forest considering Lycophytes and Ferns as biological indicators. The study will limit and include the vegetation structure on the diametric distribution and the canopy cover of trees and shrubs, that somehow, constitute the backbone of the forest, and so to test the state of the KBNP mountain forest using Lycophytes and Ferns.

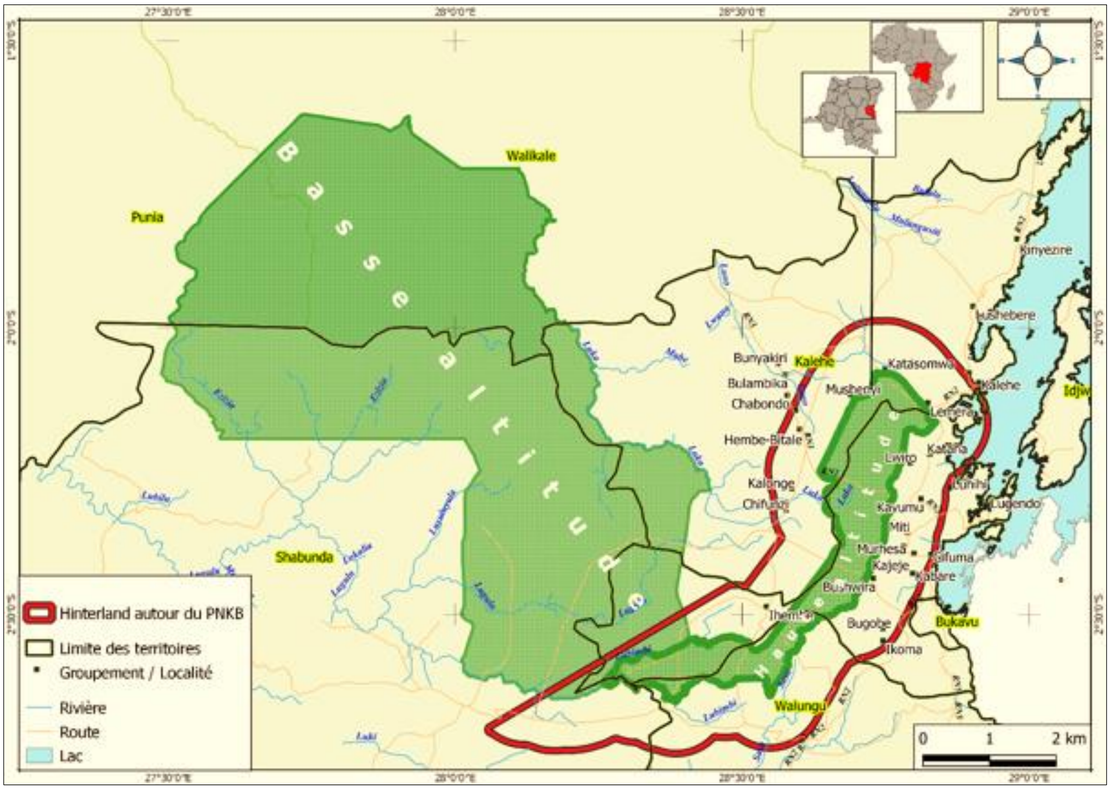
## METHODOLOGY

The Kahuzi-Biega National Park (KBNP) is located in the southern part of the Kivu-Ruwenzori chain. The KBNP, with a surface of 6000 km$^2$ (Figure 1), was created in 1970 to protect Gorillas of Graueri (*Gorilla beringei graueri)* and their habitat (Mangambu, 2016). The park includes two main summits that are former extinct Vulcans, the Kahuzi with 3326 m altitude and the Biega with 2790 m altitude. The KBNP is situated in the South-Kivu zone, in the southern part of the mountains chain of Kivu-Ruwenzori, of the axis NNE-SSW, along the western side of the Albertine rift and is located between two centres of endemism: the Guinean-Congolese and the afro-montane. (Mangambu, 2013).

Based on their physiognomic features, and their floristic composition, depending on the altitude, the KBNP forests constitute planetary stages (678-1250 m), sub-mountainous (1250-1700 m), mountainous (1700-2600 m) and afro-subalpine (2600-3326 m) (Mangambu et al., 2013). In its whole, the region benefits from the mountain climate (of type Cf of the Köppen classification), with abundant rains varying between 1750-2000 mm per year (Yamagiwa et al., 2005).

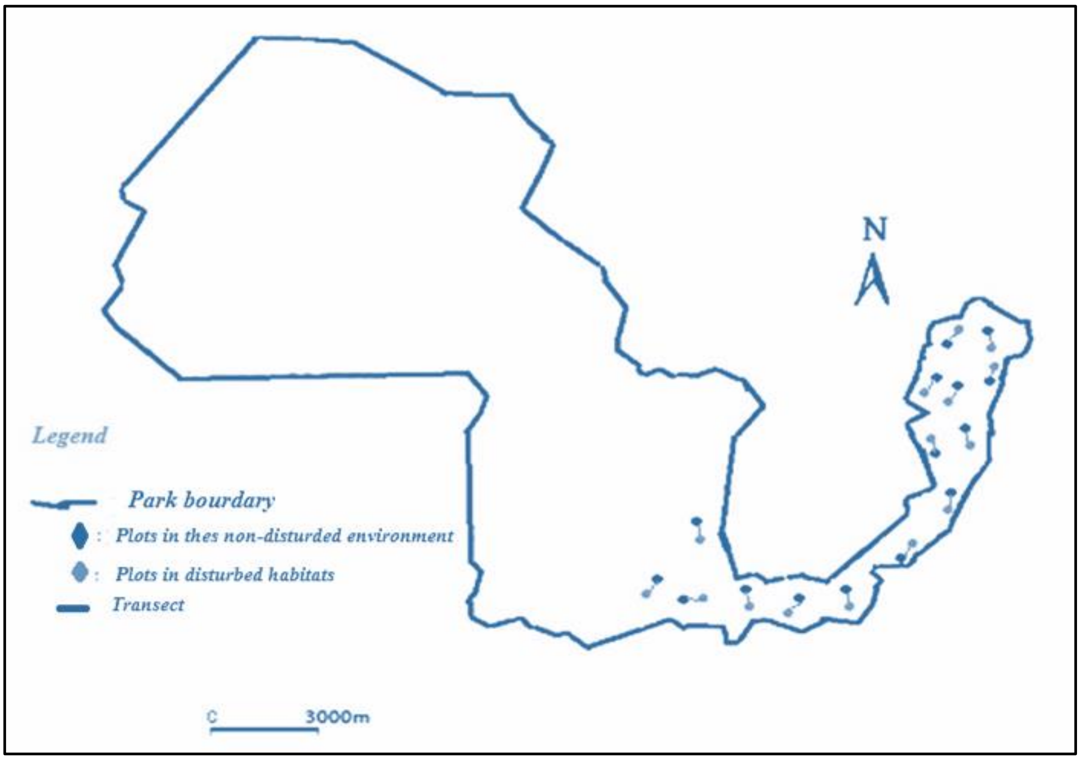
The atmospheric humidity is constantly higher in parallel to the variation of the cloudy cover. The duration of the dry season never goes beyond two months (Fischer, 1996). The temperature varies with altitude, the atmospheric humidity, is constantly higher and the soil superficial and acid (Yamagiwa et al., 2005).

**Figure 1: Map of the high-altitude part of the Kahuzi-Biega National Park**



**Source:** Mukunda et al. 2022 and the localization of the KBNP on the DRC Map. The red cader indicates the investigated zone in the present study.

**Figure 2: Plots localisation in the study area**



## Data Collection

Targeting two types of habitats, stable and disturbed, data were collected in 30 plots (Figure 2) installed on tree vegetation levels (submontane, montane and afro-subalpine) during ten years observations and two inventories each year according to the two seasons (dry and rain) from 2010 à 2022 (minus two years during the COVID-19 period).

Stable environments are those evolving without any natural or artificial disturbance, and which have sometimes reached their climax stage (SE.). These are forests with a closed canopy.

Disturbed environments (DE.) are those where human and natural activities are clearly visible; the canopy is open and the cover is low (Mangambu, 2016; Phillips et al., 2017; Burindwa et al., 2023). Trees and shrubs with *dbh* (diameter at breast height) ≥10 cm, ≥30 cm and ≥50 cm were inventoried in the same plots as the Lycophytes and Ferns, based on circumference measurements taken 130 cm above the ground.

In order to avoid the edge effect during data collection, we considered the size of 25 m x 25 m for the survey; with a total of 16 surveys in one plot. The inventory was carried out only on four surveys that met the conditions mentioned above (stability or disturbance). For each survey, we reported the abundance-dominance of Lycophytes and Ferns (Braun-Blanquet, 1931) in each stratum and of arborescent and shrubby plants using the Dufrêne (2003) scale shown in *Table 1* below).

Species observed outside the strict limits of the survey but still within the same station were incorporated into the floristic list of the survey but were presented in the final table with an abundance of 0 and a coefficient of 0.5 to enable the analyses to be carried out (van der Maarel, 1979). The other floristic characteristics recorded were canopy height, *dbh* and the percentage cover of the tree and shrub strata (percentage estimated for all the species in the survey).

**Table 1: Correspondence of the abundance-dominance scales of a species in the survey located in the plot.**

| Braun-Blanquet (1947) | Average recovery (%) | Dufrêne (2003) | Average recovery (%) | van der Maarel (1979) | Average recovery (%) |
|---|---|---|---|---|---|
| - | - | - | - | 0,5 | 0,5 |
| r | 0,1 | 1 | 0,1 | 1 | 1 |
| + | 0,5 | 2 | 0,2 | 2 | 2 |
| 1 | 3 | 3 | 2,5 | 3 | 3,5 |
| - | - |  | - | 4 | 7,5 |
| 2 | 15 | 5 | 15 | 5 | 12,5 |
| - | - |  | - | 6 | 20 |
| 3 | 37,5 | 7 | 37,5 | 7 | 37,5 |
| 4 | 62 ,5 | 8 | 62 ,5 | 8 | 62 ,5 |
| 5 | 87,5 | 9 | 87,5 | 9 | 85 |

## Species Identification

The identifications of the species collected in the field were verified at the National Botanic Garden of Belgium (BR) and Wageningen University (WAG) and by systems based on the phylogenetic approach, taking into account data from molecular systematic botany. (Pteridophyte Phylogeny Group I, 2016; Angiosperm Phylogeny Group IV, 2016).

## Data analysis

The adaptation of the Pteridoflora within the plant communities where the plots were established was analysed, first by studying the species richness (SW), which is the total number of species observed.

The main factors influencing the distribution of Pteridophyte species (SE. and DE.) in the space between the two types of environments were highlighted in all the surveys by means of a DCA

(Detrended Correspondence Analysis, Bouxin, 2008), which makes it possible to order them by taking into account the specific abundances and floristic richness of Lycophytes and Ferns according to the cover criteria using the CANOCO programme, version 4.5 (ter Braak & Šmilauer 2002).

A comparison of the mean abundances was carried out using Student's t-test with R software version 2.9.2 for the comparison of quantitative floristic traits of presence-abundance between the two types of observation environments on the three levels surveyed

$$t = \frac{\overline{\mathbf{X}}_1 - \overline{\mathbf{X}}_2}{\sqrt{\frac{S_p^2}{n_1} + \frac{S_p^2}{n_2}}} \quad (1.1)$$

With $\overline{X}1$ and $\overline{X}2$ : the arithmetic averages of the two series. $S_p^2$ Joint variance of the two series: $n1$ and $n2$ are the number of data points in the two series. If p < 0.005, the two means are different and the t hypothesis is accepted, but if p > 0.005, the hypothesis is null and is rejected.

Linear regression was applied using the STATISTICA programme to account for the degree of dependence of Pteridophyte richness on cover. The results are significant if P < 0.001 (Larmarange, 2004; Nicolas, 2005).

## RESULTS

### Floristic Richness and Composition of Pteridoflora

### *Horizontal and Vertical Distribution of Lycophytes and Ferns*

In the KBNP, Lycophytes and Ferns are distributed along two gradients: one horizontal (terrestrial plants) and the other related to stratification (epiphytes). In the plots delimited according to the two types of observation environment, we inventoried 205 species of Lycophytes and Ferns over 10 years in 30 plots of one hectare each and 15 transects, two of which linked two plots. The overall results from three stages show that the majority of species are terrestrial, sciaphytic (104 species, i.e. 50.73%), rooted in the soil or attached to rocks in the undergrowth and/or in the hydrophytic environment.

Other species (49; i.e. 23.9%) are most often observed on the lower half of trunks (strata I and II, including hemi-epiphytes) or growing on the basal part of the branches of the phorophyte (strata III, IV and V of the Johansson R classification) and, more often than not, with a mode of growth and development specific to strict epiphytes (i.e. 34 species, representing a rate of 16.58%).

There are also 10 terrestrial hygrophilous species (4.48%), i.e. from damp and sometimes temporarily flooded terrestrial sites. The majority of these species live in shallows or on the slopes of marshes or rivers, and sometimes on their banks.

Four aquatic species (*Azolla nilotica, A. pinnata, Marsilea minuta* and *Salvinia molesta*) or 1.95% have been recorded. Four other species are hydrophilic or wetland plants, or live partially or totally immersed in water but not aquatic (*Marattia fraxinea, Coniogramme africana, Diplazium proliferum* and *Diplazium zanzibaricum*), also represented by 1.95%.

### *Acclimatization to Environmental Conditions Over the Last Five Years*

It has been observed that the apparent instability of the climate in the West Albertine Rift region is determined by a complex balance of energy exchanges between these elements (conduction, convection and thermal radiation). These observations illustrate a complex system with several interdependent variables on the adaptation of Lycophytes and Ferns in the KBNP. For example, temperature and precipitation influence each other by modifying atmospheric circulation, relative humidity and evapotranspiration. It should be noted that only a few environmental variables were taken into account, namely altitude, temperature, substrate and slope.

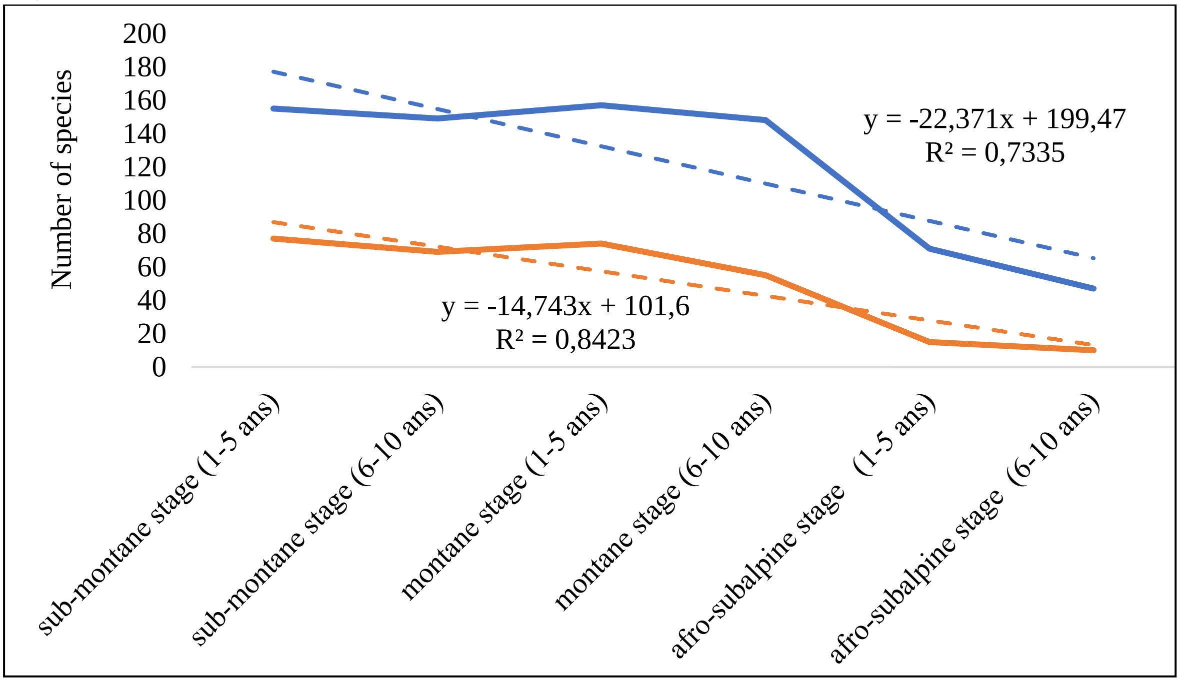
It has further been established that there are other environmental factors such as climate, soil and geology, and human impact, which have a strong influence on the distribution of ferns and Lycophytes. It has also been noted that the cutting of wood and bamboo, mining, bush fires, the granting of concessions to individuals in the park, the installation of armed groups and the return of the Pygmies are unbalancing the functioning of this ecosystem by increasing the temperature and creating several gaps and clearings.

These changes in climatic niches as a result of acclimatization and anthropogenic effects affect certain taxa of Lycophytes and Ferns (table in appendix and figure 3), the number of which has fallen by 212 individuals, and certain species such as *Asplenium bugoiense*, *Asplenium abyssinicum*, *Asplenium burundense*, *Pityrogramma humbertii*, *Asplenium abyssinicum*, *Asplenium bugoiense* and *Asplenium lambinonii* have become rare. Other species have completely disappeared (*Huperzia bampsiana*, *Huperzia dacrydioides*, *Huperzia gnidioides*, *Equisetum ramosissimum*, *Ophioglossum costatum*) in the last five and seven years, depending on the new environmental conditions caused by climate change. This trend prevailed both in the 0-5 years (R2 = 0.73; P < 0.001) and the last five years with a high rate of climate change (R2 = 0.84; P < 0.001).

Fourteen species (6.34%) *Cyathea camerooniana*, *Cyathea deckenii*, *Cyathea dregei*, *Cyathea manniana*, *Histiopteris incisa*, *Hypolepis sparsisora*, *Dryopteris antarctica*, *Dryopteris lewalleana*, *Dryopteris manniana*, *Tectaria gemmifera*, *Triplophyllum varians*, *Osmunda regalis* (terrestrial) and *Asplenium smedsii* (hemi-epiphytic), which often live in humid biotopes, are placed in habitats that emerge from the water during the rainy period and become hydrophytes.

Seven other species (i.e. 3.41%) *Asplenium lambinonii*, *Asplenium loxoscapoïdes*, *Asplenium macrophlebium*, *Asplenium monanthes*, *Nephrolepis undulata* and (sometimes hydrophytic) terrestrial wetland plants), are currently found as hemi-epiphytes in certain altitudes from 2000 to 2230 m.

**Figure 3: Adaptation of Lycophytes and Ferns over 10 years of observation**



In addition, a quarter of the species inventoried over 10 years (53 species or 25.85%) have sometimes changed their adaptive mode, as follows:

Thirteen species (6.34%) are usually terrestrial (*Arthropteris monocarpa, Pteris vittata, Adiantum poiretii, Adiantum reniforme, Cheilanthes schimperi, Pellaea pectiniformis,* *Doryopteris concolor, Asplenium gemiferum, Asplenium elliottii, Asplenium friesiorum, Asplenium kivuensis, Christella gueinziana* and *Arthropteris orientalis*), the majority of which cling to or hide in the shade of tree crowns and become occasional epiphytes.

Two species (i.e. 0.97%), *Ophioglossum costatum* and *Ophioglossum vulgatum*, known as terrestrial species, have become accidental or occasional epiphytes on the roots or pallets of large trees as a result of the increasing number of clearings in the park and the disturbance of their natural habitats. Two other species (i.e. 0.97%), *Adiantum capillus-veneris* and *Microsorum scolopendria* are observed as semi-strict or preferential epiphytes and or preferential or temporary epiphytes.

We also note that *Microgramma mauritiana*, an epiphyte of shady environments, some individuals are born on the ground. *Lepisorus excavatus* and *Lepisorus lobrechiana*, two species (i.e. 0.97%) known as hemi-epiphytic in certain parts of the KBNP, are becoming strictly epiphytes according to the increase in seeding on levels III, IV and V of the Johansson (1974) distribution of epiphytes along a phorophyte individual. In has been observed that tree species (1, 46 %) *Crepidomanes mannii*, *Oleandra distenta* and *Vandenboschia radicans* identified as epiphytic stricts, were observed in certain sites of the park as hemi-epiphytic.

Same observation for other species (1,46 %) *Abrodictyum rigidum, Abrodictyum guineense, Pyrrosia lanceolata* and *Pyrrosia schimperiana* (1,95 %) recognized as hemi-epiphytes, they hang on above the 3 m all the way to the first offshoots, stratum occupied by epiphytic. It is thought these groups of species start to adapt to climate change taking place in the KBNP, to cling to the trunk and change their way of life. Seven species (3,41 %) *Asplenium bugoiense, Asplenium ceii, Elaphoglossum hybridum, Melpomene flabelliformis, Zygophlebia villosissima* (hemi-epiphytic), *Diplazium proliferum* and *Diplazium zanzibaricum* are adapted to terrestrial life with long dry seasons.

## Structural Features of the Vegetation

### *Structural Characteristics of Trees During 10 Years of Observation*

*At the submontane level**:** within the disturbed habitats of such* a stage, the majority of trees and shrubs have a *dbh* ≥10 cm and ≥30 cm, low canopy cover with a few feet of trees in a diametric class ≥50 cm (table 2). In stable environments, there was a dominance of big trees with a considerable recovery, (*Table 2*) and all diameter classes are well represented (*Figure 4*) with a remarkable presence of ferns and their allies in the undergrowth. The analysis of Student calculated is significant between the diversity observed in the canopy and the closed canopy. (*p-value* = 0,00514).

*At the montane level:* one notes the effects of the disturbance, the majority of trees and shrubs exhibit a *dbh* ≥10 cm or ≥30 cm and an open canopy (*Table 4*). Note also the remarkable presence of clearings due to the liana *Sericostachys scandens* and anthropogenic effects within the last three years. Furthermore, a vegetation deterioration was observed in the stage as result of a pygmies return. Their return is also due to their conflicts in the management of natural resources.

We also noted the presence of sclerophyll formations resulting from the felling of the primitive forest mantle leading to an upper stratum of 6-10 m high, above an herbaceous stratum where species such *Pteridium aquilinum, Asplenium friesiorum* and *Melinis minutiflora* (Angiosperms) are located.

Yet, stable environments of the medium horizons and higher on hydromorphic soil are dominated by large *dbh* species, *dbh* ≥30 cm or ≥50 cm (*Figure 4*). The undergrowth is rich in hemi-epiphytic, generally the Lycophytes, Ferns, and several other epiphytes. Results from the analysis of the student test is significant between the diversity of the Lycophytes and Ferns observed within the two canopies (open and closed), (with a p-value = 0, 0084).

**Table 2: Characteristic species of the sub-montane stage in relation with diameter classes.**

| | **Diametric classes and tree characteristics** | | |
|---|---|---|---|
| | **≥10 cm** | **≥30 cm** | **≥50 cm** |
| **DE** | *Rytiginia spp., Vernonia spp., Kotschya africana Rubus spp., Mikania spp. and Microglossa spp.* | *Albizia adianthifolia, Dombeya rotundifolia, Macaranga schweinfurthii, Markhamia lutea* and *Spathodea campanulata* | *Polyscias fulva* |
| **SE** | *Memecylon walikalense* and *several Rubiaceae.* | *Garcinia spp., Lebrunia bushaie, Newtonia buchanani, Carapa grandiflora, Chrysophyllum rwandense, Pentadesma lebrunii, Ocotea spp* and *Parinari curatellifolia* | *Carapa grandiflora et Pentadesma lebrunii, Strombosia scheffleri* and *Symphonia globulifera* |

*Legends : DE= (Disturbed Environments) and SE (Stable Environments)*

Yet, stable environments of the medium horizons and higher on hydromorphic soil are dominated by large *dbh* species, *dbh* ≥30 cm or ≥50 cm (*Figure 4*). The undergrowth is rich in hemi-epiphytic, generally the Lycophytes, Ferns, and several other epiphytes. Results from the analysis of the student test is significant between the diversity of the Lycophytes and Ferns observed within the two canopies (open and closed), (with a p-value = 0, 0084).

**Table 3: Characteristic species of the montane stage in relation with diameter classes.**

| | **Diametric classes and tree characteristics** | | |
|---|---|---|---|
| | **≥10 cm** | **≥30 cm** | **≥50 cm** |
| **DE** | *Hypericum lanceolatum* et *Vernonia spp.,* | *Macaranga neomildbreadiana, Croton spp., Dombeya goetzenii, Hagenia abyssinica, Sapium ellepticum, Maesa lenceolata, Agauria salicifolia* et *Myrica salicifolia* | *Polyscias fulva et Agauria salicifolia* |
| **SE** | *Cyathea spp. Alchornea hirtella, Rapanea melanophloeos, Xymalos monospora, Nuxia floribunda Castalia spp., Oxyanthus ssp* and *Pauridiantha paucinervis* | *Bersama abyssinica, Carapa grandiflora, Chrysophyllum gorungosamum, Ekebergia rueppeliana, Entandophragma spp., Ficalhoa laurifolia, Parinaria exelsa, Podocarpus spp., Strombosia scheffleri, Symphonia globulifera and Syzygium spp.,* | *Carapa grandiflora, Chrysophyllum gorungosamum, Entandophragma spp., Ficalhoa laurifolia, Podocarpus spp., Strombosia scheffleri and Symphonia globulifera* |

*At the afro-subalpine level*: characteristic species of the stratum sub-shrubs of disturbed environments are almost absent, however, some feet of shrubs and sub-shrubs are remarkable with a *dbh* ≥10 cm (*Figure 4* and *Table 5*). Whereas in stable environments several individuals can be observed with a *dbh* ≥10 cm. Furthermore, a sporadic presence of the *Podocarpus* spp., *Syzygium* spp as well as the liana *Schefflera* with *dbh* ≥30 cm and/or sometimes with a *dbh* ≥ 50 cm can be mentioned (Figure 4). Results of the analysis of the student *t* test measured is significant between the diversity of the observed Lycophytes and Ferns within the two canopies (open and closed), *p-value* = 0, 0067).

We further surveyed the species richness and the mean average vegetation recovery at the arborescent and shrub strata as well as for the Lycophytes and Ferns.

**Table 4: Characteristic species of the afro-subalpine stage in relation with diametric classes.**

| | **Diametric classes and tree characteristics** | | |
|---|---|---|---|
| | **≥10 cm** | **≥30 cm** | **≥50 cm** |
| **DE** | *Hypericum revolutum*, *Lobelia gibberoa* and *Vaccinium stanleyi*, | *Erica spp.*, *Galiniera coffeoides* and *Syzygium* | |
| **SE** | *Erica ssp.*, *Galiniera coffeoides* and *Rytigynia bridsonii* | *Erica arborea*, *Podocarpus spp.*, *Syzygium spp. Schefflera spp.* | *Podocarpus falcatus*, *Syzygium spp.* |

### *Average Floristic Characteristics*

*Average floristic characteristics from 1-5 years:* Global results obtained show that the Lycophytes and Ferns are more represented and diversified within stable habitats. (73,21 % of the total flora) than within disturbed environments (22,79 %), including in the afro-subalpine stage where the diametric distribution of trees and shrubs, the floristic richness, and the recovery are weaker (*Table 5*) during the first five years of observations and field survey.

**Table 5: Average Floristic characteristics of disturbed and stable environments during the first 5 years.**

| **Floristic character** | **Sub-montane stage** | | **Montane stage** | | **Afro-subalpine stage** | |
|---|---|---|---|---|---|---|
| | **SE.** | **DE.** | **SE.** | **DE.** | **SE.** | **DE.** |
| Pteridophytes richness | 155 | 77 | 157 | 74 | 71 | 15 |
| Trees Richness | 33 | 15 | 36 | 13 | 11 | 0 |
| Shrubs Richness | 59 | 16 | 62 | 21 | 5 | 8 |
| Average recovery (%) | 72±53,6 | 15,8±9,3 | 78,2 ±50,4 | 12±7,1 | 8±6.6 | 0,9±1,9 |
| Canopy average high (m) | 33,5±20,5 | 16,5±8,5 | 29,5±14,5 | 10,5±7,5 | 9,3±4,5 | 0 |
| Average recovery of Pteridophytes (%) | 11,19 | 2,21 | 2,8 | 1,15 | 0 | 0 |

*Legends : DE= (Disturbed Environments) and SE (Stable Environments)*

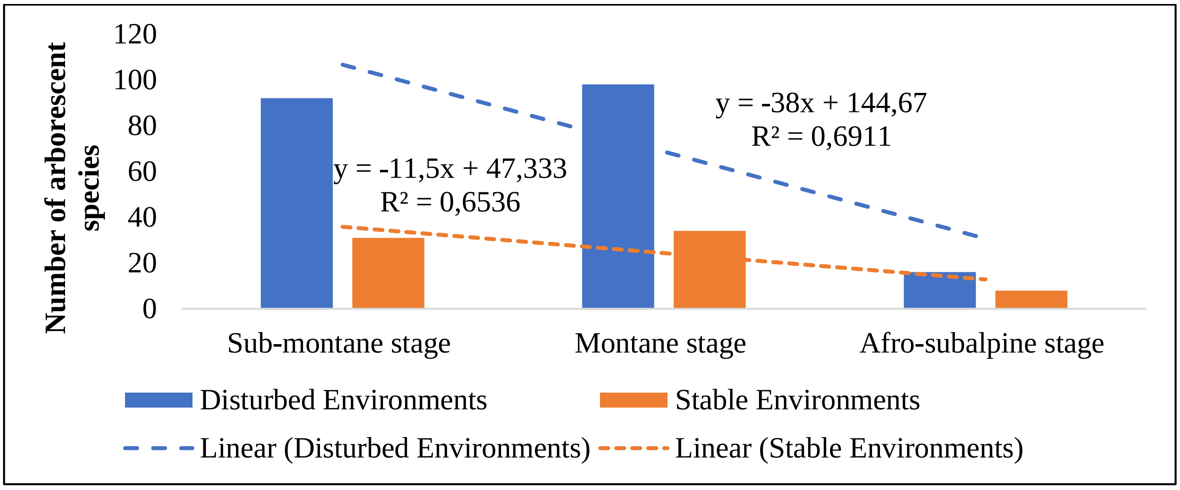
Tree abundance, the diametric distribution of trees and shrubs, (figure 4) and the site cover influence the Pteridophyte abundance including in the afro-subalpine stage where the plant recovery and the diameter class of trees and shrubs are weak, yet presenting a considerable rate of Lycophytes and Ferns.

Within all the disturbed plots, the recovery and the presence of Pteridophytes are weaker than in undisturbed environments. In the afro-subalpine stage, the diametric distribution is not well represented, there is a very weak recovery, and the Pteridological richness is relatively less by the considerable decreasing of trees.

A comparison performed with a *t*-Test shows that in all the stages, the average high of the arborescent stratum in stable habitats is significantly higher than that of the similar stratum in disturbed environments (p-value = 0,008 with significant regression values in stable environments « $R^2$ = 0,69 » and in disturbed habitats « $R^2$ = 0,65», *Figure 4*). This could be explained by the fact that disturbed environments are species poor (Trees, shrubs and Pteridophytes), the canopy is open, the *dbh* of trees and shrubs decreasing, whereas the non-disturbed habitats are more diversified, and all the diameter classes are well represented in a closed canopy.

Article DOI: https://doi.org/10.37284/ajccrs.3.1.1898

**Figure 4: Diametric distribution of trees and shrubs in disturbed and undisturbed habitats in from 1-5 years.**



*Average Floristic characteristics of the 6-10 years:* According to the results in the table 6, it can be noted that the Ferns and Lycophytes diversity in general are more less high in disturbed environments and more diversified within stable habitats despite the changes occurring during the past five years of survey.

Furthermore, within the Afro-subalpine stage Ferns and Lycophytes are particularly vulnerable due to the weak canopy. With a substratum particularly difficult, adapting these species within such changes, we are witnessing the extinction of such rare species occurring at the afro-subalpine stage. It is well stated that the climate change will also contribute to the elevation of the cloud layer in this stage, what may cause several impacts on the environmental conditions that are favourable for their survival/maintenance.

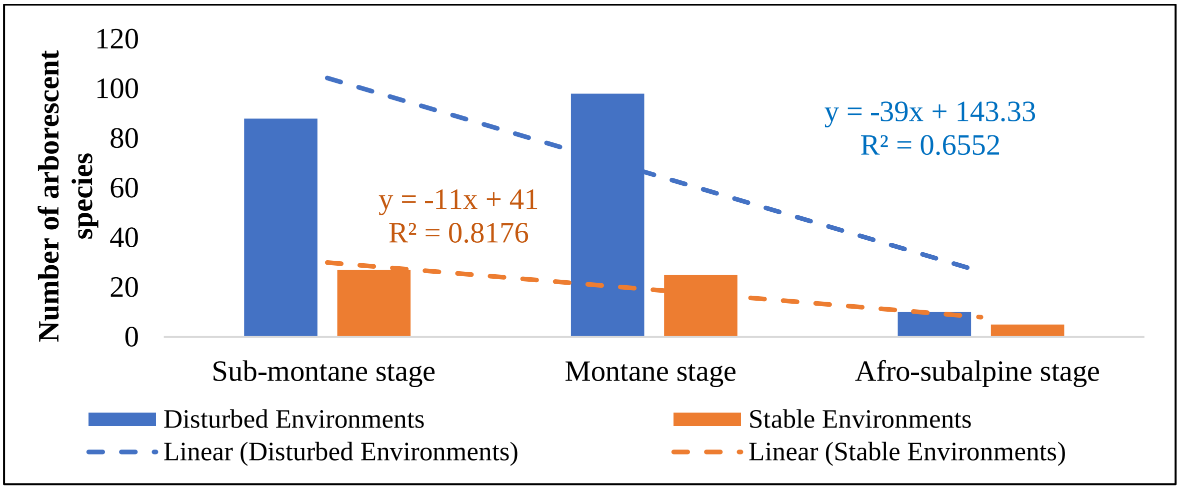
**Table 6: Average floristic characteristics of disturbed and stable environments during the 6-10 years**

| Floristic character | Sub-montane stage | | Montane stage | | Afro-subalpine stage | |
|---|---|---|---|---|---|---|
| | **SE.** | **DE.** | **SE.** | **DE.** | **SE.** | **DE.** |
| Pteridophytes richness | 149 | 69 | 148 | 55 | 47 | 10 |
| Tree Richness | 29 | 12 | 36 | 9 | 5 | 0 |
| Shrubs Richness | 59 | 13 | 62 | 16 | 5 | 5 |
| Average recovery (%) | 69±49,6 | 12,8±8,3 | 68,2 ±50,4 | 9±6,1 | 8±16.6 | 0,9±1,9 |
| Canopy average high (m) | 33,5±16,5 | 10,5±8,5 | 22,5±13,5 | 8,3±6,5 | 8,3±5,5 | 0 |
| Average cover of Lycophytes and Ferns (%) | 0,1 | 1,85% | 2,5 | 1,5 | 0 | 0 |

A comparison made by the *t*-Test shows that in all the stages, the average high of the arborescent stratum in stable habitats is significantly higher than that of the similar stratum in disturbed environments (p-value = 0,006 (p-value = 0,008 with significant regression values in stable environments « R² = 0,65 » and in disturbed habitats « R² = 0,81», *Figure 5*.

This could be motivated by the fact that disturbed environments are species poor (Trees, shrubs and Pteridophytes), the canopy is open, the *dbh* of trees and shrubs decreasing, whereas the non-disturbed habitats are more diversified, and all the diameter classes are well represented, and the canopy is closed.

**Figure 5: Diametric distribution of trees and shrubs in disturbed and undisturbed habitats from 6-10 years.**

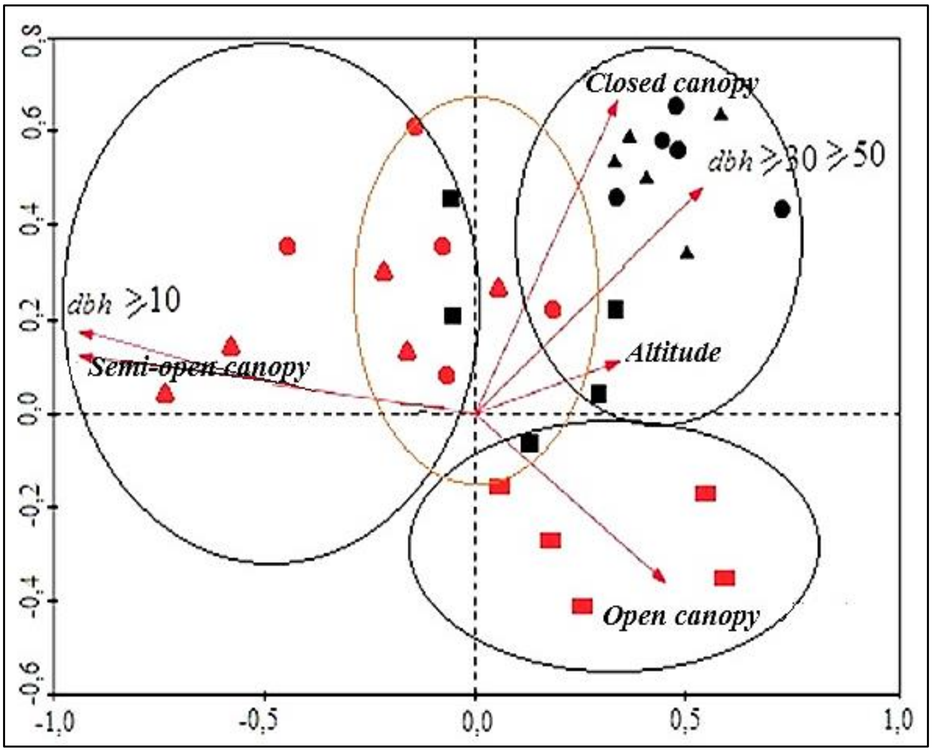


## Multivariate Feature of the Plots in Relation to the Lycophytes and Ferns Richness

### *Lycophytes and Ferns Richness During the First 5 Years*

The analysis of the floristic composition of the plots in disturbed environments (DE) and stable (SE), all strata considered, allowed to individualizing 30 plots (*Figure 6*). Globally, in the plots of the non-disturbed habitats, the floristic compositions are almost the same within the two stages (submontane et montane), with a t-Test of Student, p-value = 0.0072). The same observations were also performed in the two first stages within the plots of disturbed environments (test *t* of Student, p-value = 0,0064).

**Figure 6: Multivariate analysis of the habitats according to the floristic composition of Pteridoflora and trees in the 30 plots**



*(15 in DE and 15 and SE, but in single stage, 4 [DE] et 4 [SE]) for the first 5 years' survey, Structural parameters analysed according to the van der Maarel scale, the recovery percentage of the canopy and the presence or absence of Lycophytes and Ferns in the habitats*

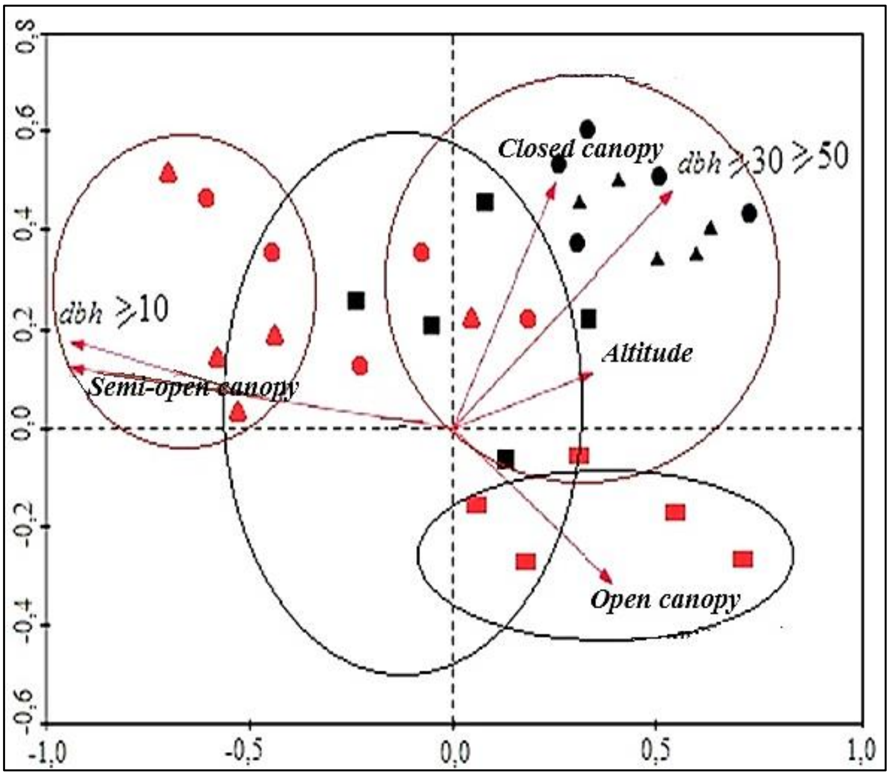
Yet, it was revealed that the results obtained in stable habitats of the afro-subalpine stage are approximate to those performed in disturbed environments of the former stages (*t* test of Student, p-value = 0,0056, *Figure 6*). The results from the recovery and the weak diametric distribution of trees, with a *dbh* ≥50 cm (Table 6) link the two first disturbed habitats through their floristic richness in the Pteridoflora, habitats habitually endowed with a weak rate of phorophyte potential.

However, the result of the multivariate analysis of habitats according to the floristic composition in Pteridophytes in the 30 plots (*Figure 6*), clearly categorizes the plots of disturbed and undisturbed habitats showing a correlation between the Lycophytes and Ferns richness and the diversity and the *dbh* within the arborescent stratum and sub-arborescent stratum.

### Richness of Lycophytes and Ferns During the 6-10 Years

Analysis of the floristic composition of all 30 plots (stables and disturbed habitats) during the past five years of observation (6-10 years, *Figure 7*) shows the following:

**Figure 7: Multi-variate analysis of the habitats according to the floristic composition of Pteridoflora and trees within 24 plots**



*(12 in DE and et 12 in SE. But, in each stage in very single the past (6-10 years) inventory.*

Structural parameters analysed are the species abundance-dominance according to the van der Maarel scale, the recovery percentage of the canopy and the presence or absence of Lycophytes and Ferns in such habitats

Floristic compositions were almost the same in the first two stages (sub-montane and montane, with the t test of Student, p-value = 0.0056, *Figure 7*). Same observations were performed in the two first stages at the level of the plots in disturbed environments. (t test of Student, p-value = 0,0068).

The overview of the results obtained in the stable habitats of the afro-subalpine stage are approximative to those of the disturbed habitats of the two former stages (*t* test of Student, p-value = 0,0059, *Figure 7*).

This is due to a recovery and to the diametric to a low or sometimes almost non-existent cover and diametric distribution of trees *dbh* ≥50 cm (*Table 6*), which brings the first two disturbed environments closer in terms of their floristic richness in pteridoflora and which are usually endowed with a low level of potential phorophytes, and the environments are very open.

Nevertheless, the result of the multi-variate analysis of the environments, according to the floristic composition of the Lycophytes and Ferns in the 30 plots (*Figure 7*) clearly categorizes the plots into disturbed and undisturbed environments, and shows a correlation between the richness of the Lycophytes and Ferns and the diversity and *dbh* in the arborescent and sub-arboreal strata.

## DISCUSSION

### Floristic Richness of Lycophytes and Ferns in Different Forest Types

Changes in land use are the main cause of biodiversity decline (Salovaara et al., 2004). These changes, linked to agricultural and forestry practices and poaching, modify the contours of forests increasing the proportion of clearings and edges in agroforestry landscapes (Kiew & Anthonysamy 1987; Mubalama, 2010). However, these effects on biodiversity are still poorly understood in the KBNP. The work of Masumbuko et al. (2013) is the first step in developing a theory of ecological discontinuities in different systems and at different scales.

These authors highlight the need to compare causal structures and changes, at specific scales and sites, to *build* syntheses on the influence of these particular landscape entities. In this context, the present study contributes to a better understanding of the effects of stability and degradation on plant biodiversity, by studying the distribution patterns of Lycophytes and Ferns, in response to the diversity of these discontinuities in the structure of woody plants**.**

The overall results obtained show that Lycophytes and Ferns are more represented and diversified in stable environments (73.21 % of the total flora) than in disturbed environments (22.79 %), including in the Afro-Subalpine zone where the diametric distribution of trees and shrubs, Pteridophyte richness and the cover are lower. This results from the interaction of various ecological factors that act simultaneously on floristic differences, in particular the degree of anthropization of the forests, a key factor in the region, and the disruption of the vegetation structure as a result of the pronounced action of certain invasive plants (Kiew & Anthonysamy 1987; Gentry, 1992; Grytnes & Beaman, 2006; Masumbuko, 2011; Komla et al., 2020).

As a result, the floristic richness of Lycophytes and Ferns strongly varies according to changes in abiotic environmental conditions, which explains why some Pteridophyte species are considered as bio-indicators (Kiew &Anthonysamy, 1987).

Our study shows that, although some species found in disturbed areas cannot tolerate stronger sunlight, the common feature of Lycophytes and Ferns of the rift in wetland habitat vegetation receiving more than 1250 mm of annual rainfall (Mangambu et al., 2013) in their protected areas as refuges for Lycophytes and Ferns in the context of climate change.

## Water Deficit: The Main Constraint on the Presence of Pteridoflora

Our study shows that the extent to which disturbed environments is the main constraint to the presence of Lycophytes and Ferns in the western Albertine Rift in the mountain stages of the Kahuzi-Biega National Park. Jones et al (2013) also drew similar conclusions considering the niche of Lycophytes and Ferns in the Caribbean in habitats that have undergone either natural or anthropogenic modifications and in front of dry conditions. For these authors, the duration of dry environments is the main factor constraining the distribution of vascular plants in this region of the globe.

Other studies have also highlighted the major role of water availability for Lycophytes and Ferns (Hawkins et al., 2003; Kreft & Jetz, 2007; Kreft et al., 2010) and for biodiversity as a whole, especially in tropical and warm temperate zones (Hernandez et al., 2006). We noted that seven species *Asplenium lambinonii, Asplenium loxoscapoïdes, Asplenium macrophlebium, Asplenium monanthes*, *Nephrolepis undulata* and (sometimes hydrophytic) terrestrial plants of wetlands, have become hemi-epiphytes at certain altitudes of 2000 - 2230 m in search of moisture under the crowns of tall trees.

Also, for example, species that are usually terrestrial, such as *Ophioglossum costatum and Ophioglossum vulgatum*, known as terrestrial species, have become accidental or occasional epiphytes on the roots or pallets of tall trees as a result of the increase in the number of clearings in the park and the disturbance to their natural habitats. Two other species *Adiantum capillus-veneris* and *Microsorum scolopendria* have been observed as semi-strict or preferential epiphytes and or preferential or temporary epiphytes in recent years.

### *Influence of Light*

The effects of light on plants no longer need to be demonstrated (Mangambu et al., 2013). They affect the biology of species and individuals, including morphological development, physiological and reproductive functions (Puig, 2001). In addition, light requirements influence habitat parameters, particularly humidity and temperature. As with spermatophytes, the light requirement of Lycophytes and Ferns is highly variable, depending on the species (Sonké et al., 2001). It influences the distribution of taxa, particularly the positioning of epiphytes on hosts. Depending on exposure to sunlight, they can be classified as: hemi-heliophilous; hemi-sciaphilous; strict heliophilous.

This is confirmed by the changes taking place in the KBNP, where *Abrodictyum rigidum*, *Abrodictyum guineense*, *Pyrrosia lanceolata* and *Pyrrosia schimperiana*, recognized as hemi-epiphytes, have been observed for the last six years in the mountainous zone of the KBNP as true epiphytes. They cling below 3 m to the first branches, a stratum occupied by true epiphytes. We can confirm the hypothesis that these species groups are beginning to adapt to the climatic changes taking place in the KBNP by clinging to the trunk and changing their way of life.

### *Vegetation Disturbance as a Threat to the Survival of Lycophytes and Ferns*

Climate change is a major threat to global biodiversity in the 21st century (Mansourian et al., 2009; Leadley et al., 2010&2014; Heubes et al., 2013). Our results show that climate change has devastating effects on the potential climatic niche of all other groups. In fact, it is this tolerance of Pteridophyte land plants to warmer temperatures that allows it to be the only one able to expand its niche in the future, insofar as climate change is broadly comparable to the global warming observed in the western Albertine Rift in the mountain stages of the Kahuzi-Biega National Park in the DRC.

The work of Hansen et al. (2010) has shown that species extinction is a function of global warming. Indeed, on the scale of the mountain forest of the KBNP with several clearings, the area combining the climatic conditions necessary for the simultaneous presence of the taxa studied will become smaller than its initial size. In this study, we noted that certain species that are usually terrestrial (*Arthropteris monocarpa, Pteris vittata, Adiantum poiretii, Adiantum reniforme, Cheilanthes schimperi, Pellaea pectiniformis, Doryopteris concolor, Asplenium gemiferum, Asplenium elliottii, Asplenium friesiorum, Asplenium kivuensis, Christella gueinziana and Arthropteris orientalis*) how to hang on the crowns and hide in the shade of the trees, becoming occasional epiphytes as the heat escapes to the ground.

In addition, it is expected that there will be huge losses if mountain vegetation continues to be disturbed, and these drastic restrictions on the potential climatic niches of these taxa will inevitably have devastating consequences for their species richness. Certain species such as *Asplenium bugoiense, Asplenium ceii, Elaphoglossum hybridum, Melpomene flabelliformis, Zygophlebia villosissima* (hemi-epiphytes), *Diplazium proliferum* and *Diplazium zanzibaricum* are adapted to terrestrial life by long periods of the dry season in the last three years of field observations.

The links between habitat loss and species diversity have also been demonstrated for all components of the biodiversity, as noted by Brooks et al (2002), Thomas et al (2004) and Araújo & Guisan (2006) in their work. Thus, within the climatic niche of a taxon, its effective presence in a habitat is subordinate to the specific micro-ecological conditions (soil, vegetation, presence of watercourses, etc.) governing its effective niche.

## Ecological Behaviour of Lycophytes and Ferns in Response to Changes in Vegetation Structure

### *Adaptation of Terrestrial Lycophytes and Ferns*

The high species richness of trees is strongly linked to the high complexity of tropical rainforests (Pausas and Sáez, 2000; Niemi et al., 2004). It is both the cause and consequence of this complexity, through several interactions between the tree population and all the other components of the ecosystem (soil, fungi, flora, fauna, microorganisms and atmosphere (Pausas et al., 2003; Duveiller et al., 2008).

In our inventory plots, we noticed that the changes in microclimate and suitable habitat caused by the opening up of the canopy enabled certain species of Lycophytes and Ferns, considered invasive, to occupy large areas forming edges.

This is the case, for example, with the species *Asplenium friesiorum, Nephrolepis undulata, Odontosoria africana* and *Pteridium aquilinum*, which do not allow other plant species to develop. According to Mangambu et al. (2018), the majority of these light species are already present in the primary forest, where they are still rare or simply located at natural openings. They can also form large stands in the undergrowth, sometimes halting vegetation dynamics for a long period.

In terrestrial environments, *Hypolepis sparsisora*, *Pteridium aquilinum*, *Gleichenia elongata* and *Microsorum scolopendria* (in their terrestrial state) are the most common and the largest in terms of numbers of individuals. They are bio-indicators of acid soils, where the pH of the soil increases through the clay-humus complex, by its large underground biomass. The leaf type distinguishes three groups within terrestrial Lycophytes and Ferns. The macrophylls of *Pteridium aquilinum* require a great deal of sunlight, while the leptophyll and microphyll taxa, which colonise shady areas, are sciaphytic.

According to Habiyaremye (1997), Fontaine and Lavergne (2010) and Mangambu 2013, *Pteridium aquilinum* and *Pseudocyclosorus pulcher* secrete toxic substances, with bulky rhizomes that reduce biodiversity and do not favour floristic dynamism. However, species of the *Cyathea* genus are involved in the reconstitution of rainforests on dry land. Mangambu et al. (2010) also accepted the hypothesis based on their research in the mountain zone of the KBNP.

### *Adaptation of epiphytic Lycophytes and Ferns*

Epiphytes play an obvious bioecological role in the KBNP forest ecosystem. In addition to this interest, their value is enhanced by the great diversity of their morphological and physiological adaptations. These adaptations are intimately linked to the ecological niche and are necessary living conditions inherent in the species' biological strategy (Sonké et al., 2001; Burindwa et al., 2023).

Epiphytes colonise biotopes with a water deficit. To this end, they develop resistance structures to the poor living conditions they face, which are essential to their development (White and Abernethy, 1996; Sonké et al., 2001; Birindwa et al., 2023). These adaptations include the reduction in the number of leaves, the flattening of *Microgramma mauritiana* stems, external and internal water reserves, specific histological structures and location in relation to the sun.

The habitat influences leaf development and these bio-morphological adaptations are such that the majority of epiphytes have microphylls (*Platycerium elephantotis, Platycerium stemaria, Pyrrosia lanceolata, Pyrrosia schimperiana, Microsorum scolopendria, Pleopeltis macrocarpa, Davallia chaerophylloides*). This character is inseparable from the water supply to which they are subject, but in the past five years, they have become rare due to canopies that have become open and the fall of certain trees. Epiphytes generally grow in very shady environments, with high humidity levels. As these conditions are only met in habitats that are less exposed to incident solar radiation, the discontinuity of the plant cover is a factor that limits the harmonious growth of epiphytes, whose development requires a specific microclimate.

### *Hydrophytic and Hygrophytic Taxa*

The aquatic ferns (*Azolla nilotica, A. pinnata, Marsilea minuta* and *Salvinia molesta*) recorded have a well-known morphological form that characterizes specimens in this group. Four other species are hydrophilic (*Marattia fraxinea, Coniogramme africana, Diplazium proliferum* and *Diplazium zanzibaricum*), with nyctinimeric movements and organs of propagation buried in the soil (Judd et al., 2002). *Azolla pinnata, Azolla nilotica* and *Salvinia molesta* are free-living hydrophytes with floats that keep them at the surface of the water (Tardieu Blot, 1964; Mangambu, 2016). These three species have small leptophyll-like leaves and were observed for 10 years in the same biotopes. In fact, the reduction in leaf area is an adaptation to the high hygrometry of the environment and justifies their high light requirements.

## Terrestrial Taxa

### *Fragile Habitats and Taxa Survival*

The primary and secondary forests of the montane zone are biotopes where ferns proliferate. In fact, most of the species recorded are found on the banks of watercourses and the others are hemi-epiphytes. Like all the ecosystems of the Albertine Rift that are now close to urban areas, this floor is subject to human activities of varying scale and intensity (Mangambu, 2016).

As a result, they are in a state of degradation that is considered critical to their survival if no measures are taken to promote their sustainable management. Cause and effect, the disappearance of the tree flora would inevitably doom all the epiphytes and with them several other dryland species.

Strict epiphytes such as *Asplenium africanum, Asplenium megalura, Huperzia afromontana, Asplenium stuhmanni, Asplenium theciferum, Asplenium varabile, Elaphoglossum acrostichoides, Elaphoglossum aubertii, Elaphoglossum barteri, Elaphoglossum deckenii, Huperzia bampsiana* and *Huperzia dacrydioides* are found in this habitat are fragile because their ecological requirements are intimately dependent on the existence of the forest**.**

## Critical Analysis of the Concept of Bio-Indication of the Lycophytes and Ferns of the KBNP

The use of bio-indication aims to provide conclusions about environmental conditions based on vegetation characteristics but does not take into account the full complexity of the systems studied. The approaches and results obtained are limited by the lack of knowledge about the behaviour of Lycophytes and Ferns in relation to the conditions of the vegetation structure and the general ecology of the species studied. It should be noted that only a few environmental variables were taken into account, namely altitude, tree and shrub diameter class and canopy cover.

Lycophytes and Ferns are generally plants that, in their own way, provide bio-indications about the habitat. This information is edaphic and climatic in nature (Birindwa et al., 2023). We know that epiphytes (*Davallia chaerophylloides, Nephrolepis biserrata, Nephrolepis undulata, Oleandra distenta, Platycerium sp. Microgramma sp, Microsorium sp*.) are moisture-demanding (Massens Da Musa, 1993; Mangambu, 2016). By virtue of their morpho-physiological behavior (defoliation, wilting, revival), these species are good and reliable bioindicators of the hygrometric level of the ecological niche and the seasonal rhythm. The presence of terrestrial species also provides information on the physico-chemical nature of the soil, including its fertility (Komla et al., 2020).

The results obtained reveal that there is little information on the diversity, the abundance and adaptation of Pteridophytes under conditions of disturbance or canopy opening. Normally, to confirm this bio-indication hypothesis, other environmental factors such as climate could be taken into account (Niemi et al, 2005; Banaticla & Buot, 2005) and the influence of soil and geology (Kluge et al., 2006). But the general structure of trees has a strong influence on the distribution of Lycophytes and Ferns on trees (Delnatte 2010; Heink & Kowarik, 2010; Mace et al., 2011; Noiha et al., 2011).

However & Gradstein (2008) and Heink & Kowarik (2010) explain that whatever the number of environmental factors used, disturbance of the natural habitat has negative effects on the floristic richness of Pteridophytes and other groups such as orchids and Bryophytes (Hemp, 2001 & 2002; Dale & Beyeler, 2001; Stevart, 2003; Niemi & McDonald, 2004; Komla et al., 2020). Studies carried out in the forests of the Philippines, Bolivia, Costa Rica, Colombia, Peru and French Guiana have confirmed the use of Lycophytes and Ferns as one of the main biological indicators in tropical forests (Mace & Baillie, 2007; Delnatte, 2010).

Other studies concluded that the composition patterns of Pteridophyte species are strongly correlated with those of tree species at different spatial scales (Tuomisto et al., 1995; Ruokolainen et al., 1997; Paciencia & Prado, 2005). In the Philippines for example, the distribution of Lycophytes and Ferns is dependent on the floristic composition and structure of the woody vegetation along the slope (Banaticla & Buot, 2005). In Costa Rica, the distribution of Lycophytes and Ferns shows a peak in diversity at mid-altitudes, strongly correlated with climatic variables such as humidity and temperature (Dale & Beyeler, 2001; Kluge et al., 2006).

Lycophytes and Ferns have also been used to classify the vegetation in Peru. Four forest types have been identified between flooded forests and terra firma forests (Salovaara et al., 2004). Using Pteridophytes on a phytosociological basis, environments have been further described on the Atachi-Bacca Mountains and these studies have confirmed Pteridophytes as biodiversity indicators of this ecosystem (Christie & Arnesto, 2003). In addition, Delettre & Butet (2005) have revealed that the relative proportion of Lycophytes and Ferns, like that of Monocotyledons, increases proportionally with the hostile nature of the environment (drought and hydromorphy).

### West Albertine Rift: an Endangered Refuge and a Forced Reduction in Lycophytes and Ferns

During the last ice age, certain regions, including the Kahuzi Mountains, played a major role in the conservation of Pteridophytes in sub-Saharan Africa, from which these plants recolonized the surrounding regions as climatic conditions improved (Mangambu, 2013). Like most of these regions known as biodiversity "refuges", Mont's

Article DOI: https://doi.org/10.37284/ajccrs.3.1.1898

Kahuzi and Biega may not be able to continue to play this role due to climate change (Mangambu et al., 2013).

In addition, climate change could exacerbate other threats to biodiversity, including changes in land use, habitat fragmentation and the over-exploitation of natural resources (Alkemade et al., 2009; Mansourian et al., 2009; Leadley et al., 2010; Heubes et al., 2010).

Our results reveal that mountain vegetation is a favourable region for the current presence, above all, for the preservation of the climatic niche of all Pteridophyte groups, whatever the climatic scenario considered. Having already played this role of refuge in the past (Mangambu, 2013), the Mont's Togo will then constitute a refuge of major importance for the Pteridophytes of the region and neighbouring regions disturbed by high population density and other anthropogenic effects (Komla et al., 2020). Yet this part of the country is cruelly lacking in protected areas.

We therefore confirm the hypothesis of Maizi et al. (2010), according to which species considered as bio-indicators provide quantitative and qualitative information that allow to characterize the environment or one of the main components of the floristic structure (Dukes and Mooney, 1999; Drossart 2009), specific diversity, forest architecture and habitat (Johansson 1974 & 1975; Gentry, 1992; Pausas &Austin, 2001; Grytnes & Beaman, 2006).

## CONCLUSION

The present study attempted to answer questions about the vulnerability of Lycophytes and Ferns. Although they generally share the same niches, Pteridophytes have ecological characteristics that give them different degrees of vulnerability to climate change in the Kahuzi-Biega National Park, which has long played a crucial role in international conservation strategies despite its status as an endangered site since 1997. This study provides original results concerning the dynamics of Pteridophyte populations in an ecosystem destabilized by illegal activities and climate change.

In stable plots, i.e. in the stable and mature ecosystem of the KBNP, Pteridophytes constitute a very rich, diverse and stable population. In disturbed patches, there is permanent stress, resulting in a change in the floristic composition of the canopy and sometimes the taming of the undergrowth. Sciaphilous and less tolerant species disappear, while the environment is enriched by invasive species.

The results confirm the value of Pteridophytes as biological indicators of the KBNP mountains, and also highlight the major role played by the dominant trees, both in terms of the structure and diversity of the tree strata. This pivotal compartment reflects the level of diversity of the tree strata. It can therefore be used as a valid indicator when drawing up management plans for KBNP. However, the main threat currently facing KBNP in the study area is habitat loss, due to human activities and climate change.

It was crucial to gain a better understanding of the ecological niche of the species and to assess their vulnerability to climate change and human disturbance in order to make appropriate decisions for their conservation.

In addition, better prospecting in the study area in general will allow to confirm and sometimes increase the data and results, and to recommend appropriate conservation strategies on the further projection of the niche of the taxa studied. It would also be interesting to study the dynamics of certain species of Lycophytes and Ferns that are threatened by the local population or that representing large groupings in the KBNP.

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## APPENDIX

### Appendix 1: Floristic richness of Pteridophytes in different levels of the Kahuzi-Biega National Park over 10 years

| | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** | | | | | | | **6-10 years** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **SMS** | | **MS** | | **ASS** | | **Nbr** | **SMS** | | **MS** | | **ASS** | | **Nbr** |
| | | | | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| **LYCOPODIACEAE (LYCOPHYTES)** | | | | | | | | | | | | | | | | | |
| 1 | *Huperzia afromontana* Pic.Serm | SE | | 0 | 0 | + | + | 0 | 0 | 2 | 0 | + | + | 0 | 0 | 0 | 2 |
| 2 | *Huperzia bampsiana* Pic.Serm | SE | | 0 | 0 | + | + | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | *Huperzia dacrydioides* (Baker) Pic.Serm. | SE | | 0 | 0 | + | + | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | *Huperzia gnidioides* (L.f.) Trevis. | H-Ep | | 0 | 0 | 0 | + | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | *Huperzia saururus* (Lam.) Trevis | TR | | 0 | 0 | 0 | 0 | + | 0 | 3 | 0 | 0 | 0 | 0 | + | + | 3 |
| 6 | *Lycopodiella affinis* (Bory) Pic.Serm | TR | | 0 | + | + | + | + | 0 | 10 | 0 | + | + | + | + | 0 | 10 |
| 7 | *Lycopodiella caroliniana* (L.) Pic.Serm | TR | | 0 | 0 | 0 | 0 | + | + | 10 | 0 | 0 | 0 | 0 | + | + | 10 |
| 8 | *Lycopodiella cernua* (L.) Pic.Serm | TR | | + | + | + | + | + | 0 | 10 | + | + | + | + | + | 0 | 10 |
| 9 | *Lycopodium clavatum* L. | | | 0 | 0 | + | + | + | 0 | 10 | 0 | 0 | + | + | + | 0 | 10 |
| **ISOETACEAE (LYCOPHYTE)** | | | | | | | | | | | | | | | | | |
| 10 | *Isoetes welwitschii* A. Braun | TR | | + | 0 | + | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| **SELAGINELLACEAE(LYCOPHYTES)** | | | | | | | | | | | | | | | | | |
| 11 | *Selaginella auquieri* Bizzarri | TR | | + | 0 | + | 0 | 0 | 0 | 4 | + | 0 | + | 0 | 0 | 0 | 3 |
| 12 | *Selaginella dregei* (C.Presl) Hieron | TR | | + | 0 | + | 0 | 0 | 0 | 4 | + | 0 | + | 0 | 0 | 0 | 3 |
| 13 | *Selaginella kivuensis* Bizzarri | TR | | + | + | + | 0 | 0 | 0 | 7 | + | + | + | 0 | 0 | 0 | 7 |
| 14 | *Selaginella kraussiana* (Kunze) A.Braun | TR | | + | + | 0 | + | 0 | 0 | 8 | + | + | 0 | + | 0 | 0 | 8 |
| 15 | *Selaginella lewalleana* Bizzarri | TR | | + | + | 0 | 0 | 0 | 0 | 7 | + | + | 0 | 0 | 0 | 0 | 6 |
| 16 | *Selaginella molliceps* Spring | TR | | + | 0 | 0 | 0 | 0 | 0 | 6 | + | 0 | 0 | 0 | 0 | 0 | 6 |
| 17 | *Selaginella myosurus* (Sw.) Alston | TR | | + | 0 | 0 | 0 | 0 | 0 | 9 | + | 0 | 0 | 0 | 0 | 0 | 9 |
| 18 | *Selaginella soyauxii* Hieron | TR | | + | 0 | 0 | 0 | 0 | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 7 |

| | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** | | | | | | | **6-10 years** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **SMS** | | **MS** | | **ASS** | | **Nbr** | **SMS** | | **MS** | | **ASS** | | **Nbr** |
| | | | | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| 19 | *Selaginella versicolor* Spring | TR | | + | 0 | 0 | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 10 |
| 20 | *Selaginella vogelii* Spring | TR | | + | + | 0 | 0 | 0 | 0 | 10 | + | + | 0 | 0 | 0 | 0 | 10 |
| | Lycophytes | | | 12 | 5 | 8 | 4 | 5 | 1 | 131 | 10 | 7 | 7 | 4 | 5 | 1 | 119 |
| | **EQUISETACEAE(FERN)** | | | | | | | | | | | | | | | | |
| 21 | *Equisetum ramosissimum* Desf. | TR | | + | 0 | + | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **PSILOTACEAE(FERN)** | | | | | | | | | | | | | | | | |
| 22 | *Psilotum nudum* (L.) P.Beauv | H-Ep | | + | 0 | + | 0 | 0 | 0 | 7 | + | 0 | 0 | 0 | 0 | 0 | 2 |
| | OPHIOGLOSSACEAE(FERNS) | | | | | | | | | | | | | | | | |
| 23 | *Ophioglossum costatum* R.Br. | TR | A-OE | + | 0 | + | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | *Ophioglossum vulgatum* L. | TR | A-OE | + | 0 | + | 0 | 0 | 0 | 3 | + | 0 | 0 | 0 | 0 | 0 | 1 |
| | **MARATTIACEAE(FERN)** | | | | | | | | | | | | | | | | |
| 25 | *Marattia fraxinea* Sm | HYDR | | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 7 |
| | **OSMUNDACEAE(FERN)** | | | | | | | | | | | | | | | | |
| 26 | *Osmunda regalis* L | TR | HY | + | + | 0 | + | + | 0 | 8 | + | + | 0 | + | + | 0 | 8 |
| | **HYMENOPHYLLACEAE(FERNS)** | | | | | | | | | | | | | | | | |
| 27 | *Abrodictyum rigidum* (Sw.) Ebih. & Dub. | H-Ep | SSHE | 0 | + | 0 | 0 | + | 0 | 6 | 0 | + | 0 | 0 | + | 0 | 5 |
| 28 | *Abrodictyum cupressoides* (Desv.) Ebih. & Dub. | H-Ep | | + | + | + | 0 | 0 | 0 | 4 | + | 0 | + | 0 | 0 | 0 | 2 |
| 29 | *Abrodictyum guineense* (Afzel. ex Sw.) J.P.Roux | H-Ep | SSHE | + | 0 | 0 | 0 | 0 | 0 | 3 | + | 0 | 0 | 0 | 0 | 0 | 3 |
| 30 | *Crepidomanes chevalieri* (H.Christ) Ebih. & Dub. | H-Ep | | + | 0 | + | 0 | 0 | 0 | 3 | + | 0 | 0 | 0 | 0 | 0 | 2 |
| 31 | *Crepidomanes frappieri* (Cordem.) J.P.Roux | H-Ep | | + | 0 | 0 | 0 | 0 | 0 | 3 | + | 0 | 0 | 0 | 0 | 0 | 3 |
| 32 | *Crepidomanes mannii* (Hook.) J.P. Roux | SE | H-Ep | + | 0 | + | 0 | 0 | 0 | 7 | + | 0 | + | 0 | 0 | 0 | 7 |
| 33 | *Crepidomanes melanotrichum* (Schltdl.) J.P.Roux | H-Ep | | + | 0 | + | 0 | + | 0 | 4 | + | 0 | + | 0 | + | 0 | 4 |
| 34 | *Crepidomanes mettenii* (C.Chr.) Ebih. & Dub. | H-Ep | | + | + | + | 0 | 0 | 0 | 3 | + | 0 | + | 0 | 0 | 0 | 2 |
| 35 | *Hymenophyllum capillare* Desv. | H-Ep | | 0 | 0 | + | 0 | 0 | 0 | 5 | 0 | 0 | + | 0 | 0 | 0 | 4 |
| 36 | *Hymenophyllum hirsutum* (L.) Sw. | H-Ep | | + | 0 | 0 | 0 | + | 0 | 6 | + | 0 | 0 | 0 | + | 0 | 4 |

|  | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** |  |  |  |  |  |  | **6-10 years** |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | **SMS** |  | **MS** |  | **ASS** |  | **Nbr** | **SMS** |  | **MS** |  | **ASS** |  | **Nbr** |
|  |  |  |  | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| 37 | *Hymenophyllum kuhnii* C.Chr. | H-Ep |  | 0 | 0 | + | 0 | 0 | 0 | 3 | 0 | 0 | + | 0 | 0 | 0 | 3 |
| 38 | *Hymenophyllum splendidum* Bosch | H-Ep |  | + | 0 | + | 0 | 0 | 0 | 6 | + | 0 | + | 0 | 0 | 0 | 6 |
| 39 | *Hymenophyllum triangulare* Baker | H-Ep |  | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 9 |
| 40 | *Polyphlebium borbonicum* (Bosch) Ebih. & Dub. | H-Ep |  | + | + | + | 0 | 0 | 0 | 8 | + | + | + | 0 | 0 | 0 | 6 |
| 41 | *Trichomanes crispiforme* Alston | H-Ep |  | + | + | + | 0 | + | 0 | 6 | + | + | + | 0 | + | 0 | 6 |
| 42 | *Vandenboschia radicans* (Sw.) Copel. | SE | H-Ep | + | 0 | + | 0 | 0 | 0 | 3 | + | 0 | + | 0 | 0 | 0 | 3 |
|  | **GLEICHENIACEAE(FERNS)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 43 | *Dicranopteris elegantula* Pic.Serm | TR |  | + | + | + | + | 0 | 0 | 10 | + | 0 | + | + | 0 | 0 | 9 |
| 44 | *Dicranopteris linearis* (Burm.f.) Underw. | TR |  | + | + | + | 0 | 0 | 0 | 8 | + | + | + | 0 | 0 | 0 | 6 |
| 45 | *Gleichenia elongata* Baker | TR |  | + | + | + | 0 | 0 | 0 | 6 | + | + | + | 0 | + | 0 | 6 |
| 46 | *Sticherus flagellaris* (Bory ex Willd.) Chings | TR | A-OE | 0 | 0 | + | 0 | + | 0 | 7 | 0 | 0 | + | 0 | 0 | 0 | 5 |
| 47 | *Sticherus inflexus* Pic.Serm | TR |  | 0 | 0 | + | + | + | 0 | 6 | 0 | + | + | + | 0 | 0 | 3 |
|  | **LYGODIACEAE(FERNS)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 48 | *Lygodium microphyllum* (Cav.) R.Br | TR |  | + | + | 0 | 0 | 0 | 0 | 6 | + | + | 0 | 0 | 0 | 0 | 6 |
| 49 | *Lygodium smithianum* C.Presl ex Kuhn | TR |  | 0 | + | 0 | 0 | 0 | 0 | 3 | 0 | + | 0 | 0 | 0 | 0 | 2 |
|  | **MARSILEACEAE(FERNS)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 50 | *Azolla nilotica* Decne. ex Mett | Aq |  | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | + | 0 | 0 | 0 | 0 | 2 |
| 51 | *Azolla pinnata* R.Br. | Aq |  | + | + | 0 | 0 | 0 | 0 | 8 | + | + | 0 | 0 | 0 | 0 | 6 |
| 52 | *Marsilea minuta* L. var. minuta | Aq |  | + | + | 0 | 0 | 0 | 0 | 3 | + | + | 0 | 0 | 0 | 0 | 6 |
| 53 | *Salvinia molesta* D.S.Mitch | Aq |  | 0 | + | 0 | 0 | 0 | 0 | 3 | 0 | + | 0 | 0 | 0 | 0 | 1 |
|  | **CYATHEACEAE(FERNS)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 54 | *Cyathea camerooniana* (Hook.) R.M.Tryon | TR | TR-hy | + | 0 | + | 0 | 0 | 0 | 10 | + | + | + | 0 | 0 | 0 | 6 |
| 55 | *Cyathea deckenii* (Kuhn) R.M.Tryon | TR | TR-hy | + | 0 | + | 0 | + | 0 | 10 | + | + | + | 0 | + | 0 | 6 |
| 56 | *Cyathea dregei* (Kunze) R.M.Tryon | TR | TR-hy | + | 0 | + | 0 | + | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 3 |
| 57 | *Cyathea manniana* (Hook.) R.M.Tryon | TR | TR-hy | + | + | + | + | 0 | 0 | 10 | + | + | + | + | 0 | 0 | 10 |

| | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** | | | | | | | **6-10 years** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **SMS** | | **MS** | | **ASS** | | **Nbr** | **SMS** | | **MS** | | **ASS** | | **Nbr** |
| | | | | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| | | | | **LINDSAEACEAE(FERN)** | | | | | | | | | | | | | |
| 58 | *Odontosoria africana* F.Ballard | TR | | + | + | + | + | + | 0 | 10 | + | + | + | + | + | 0 | 10 |
| | | | | **PTERIDACEAE(FERNS)** | | | | | | | | | | | | | |
| 59 | *Coniogramme africana* Hieron. | HYDR | | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 10 |
| 60 | *Actiniopteris dimorpha* Pic.Serm. | H-Ep | | + | + | 0 | 0 | + | 0 | 8 | + | + | 0 | 0 | + | 0 | 6 |
| 61 | *Actiniopteris semiflabellata* Pic.Serm | H-Ep | | + | 0 | 0 | 0 | 0 | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 7 |
| 62 | *Pityrogramma argentea* (Willd.) Domin | TR | | 0 | 0 | 0 | 0 | + | + | 10 | 0 | 0 | 0 | 0 | + | 0 | 7 |
| 63 | *Pityrogramma calomelanos* (L.) Link | TR | | + | + | + | + | 0 | 0 | 9 | + | + | + | + | 0 | 0 | 9 |
| 64 | *Pityrogramma humbertii* C.Chr. | TR | | 0 | 0 | 0 | 0 | 0 | + | 6 | 0 | 0 | 0 | 0 | + | 0 | 3 |
| 65 | *Pteris auquieri* Pic.Serm. | TR | | + | 0 | + | + | 0 | 0 | 7 | + | 0 | + | + | 0 | 0 | 5 |
| 66 | *Pteris burtonii* Baker | TR | | + | + | + | 0 | 0 | 0 | 10 | + | + | + | 0 | 0 | 0 | 10 |
| 67 | *Pteris catoptera* Kunze | TR | | + | + | + | + | 0 | 0 | 10 | + | + | + | + | 0 | 0 | 10 |
| 68 | *Pteris cretica* L. | TR | | 0 | 0 | + | + | + | 0 | 10 | 0 | 0 | + | + | + | 0 | 10 |
| 69 | *Pteris dentata* Forssk. | TR | | + | + | + | + | 0 | 0 | 10 | + | + | + | + | + | 0 | 10 |
| 70 | *Pteris friesii* Hieron | TR | | + | 0 | + | + | 0 | 0 | 10 | + | 0 | + | + | + | 0 | 10 |
| 71 | *Pteris hamulosa* (H.Christ) H.Christ | TR | | + | 0 | 0 | 0 | 0 | 0 | 7 | + | 0 | 0 | 0 | 0 | 0 | 7 |
| 72 | *Pteris intricata* C.H.Wright | TR | | + | + | + | 0 | 0 | 0 | 10 | + | + | + | 0 | 0 | 0 | 10 |
| 73 | *Pteris kivuensis* C.Chr | TR | | + | + | 0 | + | + | 0 | 10 | + | + | + | + | + | 0 | 9 |
| 74 | *Pteris linearis* Poir | TR | | + | + | + | + | + | 0 | 10 | + | + | + | + | + | 0 | 6 |
| 75 | *Pteris mildbraedii* Hieron | TR | | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 10 |
| 76 | *Pteris preussii* Hieron | TR | | + | + | + | 0 | 0 | 0 | 10 | + | + | + | 0 | 0 | 0 | 9 |
| 77 | *Pteris repens* C.Chr. | TR | | 0 | + | + | 0 | 0 | 0 | 8 | 0 | + | + | 0 | 0 | 0 | 5 |
| 78 | *Pteris tripartita* Sw. | TR | | + | + | + | 0 | 0 | 0 | 10 | + | + | + | 0 | + | 0 | 6 |
| 79 | *Pteris vittata* L | TR | OE | + | + | + | + | + | 0 | 10 | + | + | + | + | + | 0 | 6 |
| 80 | *Adiantum capillus-veneris* L. | TR | OE | + | + | 0 | 0 | 0 | 0 | 10 | + | + | 0 | 0 | 0 | 0 | 9 |
| 81 | *Adiantum poiretii* Wikstr. | TR | OE | + | 0 | 0 | 0 | 0 | 0 | 7 | + | 0 | 0 | 0 | 0 | 0 | 7 |
| 82 | *Adiantum patens* Willd. | TR | | + | + | + | 0 | 0 | 0 | 8 | + | + | + | 0 | 0 | 0 | 8 |
| 83 | *Adiantum raddianum* C.Presl | TR | | + | 0 | 0 | 0 | 0 | 0 | 3 | + | 0 | 0 | 0 | 0 | 0 | 3 |
| 84 | *Adiantum reniforme* L. | TR | OE | + | + | 0 | 0 | 0 | 0 | 2 | + | + | 0 | 0 | 0 | 0 | 2 |
| 85 | *Adiantum vogelii* Mett. ex Keyserl | TR | | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 10 |

| | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** | | | | | | | **6-10 years** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **SMS** | | **MS** | | **ASS** | | **Nbr** | **SMS** | | **MS** | | **ASS** | | **Nbr** | |
| | | | | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | |
| 86 | *Antrophyum mannianum* Hook. | H-Ep | | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 10 | |
| 87 | *Vittaria reekmansii* Pic.Serm | H-Ep | | + | 0 | + | 0 | 0 | 0 | 7 | + | 0 | + | 0 | 0 | 0 | 7 | |
| 88 | *Vittaria volkensii* Hieron. | H-Ep | | + | 0 | + | + | + | 0 | 6 | + | 0 | + | + | + | 0 | 5 | |
| 89 | *Cheilanthes angustifrondosa* Alston | TR | | + | 0 | + | + | 0 | 0 | 10 | + | 0 | + | + | + | 0 | 10 | |
| 90 | *Cheilanthes bergiana* Schltdl. | TR | | + | 0 | + | + | 0 | 0 | 6 | + | 0 | + | + | + | 0 | 6 | |
| 91 | *Cheilanthes schimperi* Kunze | TR | OE | + | + | + | 0 | 0 | 0 | 7 | + | + | + | 0 | 0 | 0 | 7 | |
| 92 | *Cheilanthes similis* F.Ballard | TR | | + | + | + | 0 | 0 | 0 | 10 | + | + | + | 0 | 0 | 0 | 10 | |
| 93 | *Cheilanthes viridis* (Forssk.) Sw | TR | | + | 0 | + | + | 0 | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 | |
| 94 | *Pellaea calomelanos* (Sw.) Link | TR | | + | + | + | + | 0 | 0 | 10 | + | + | + | + | 0 | 0 | 10 | |
| 95 | *Pellaea doniana* J.Sm. ex Hook | TR | | + | 0 | + | + | 0 | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 | |
| 96 | *Pellaea dura* (Willd.) Hook. | TR | | + | 0 | + | 0 | 0 | 0 | 6 | + | 0 | + | 0 | 0 | 0 | 6 | |
| 97 | *Pellaea longipilosa* Bonap | TR | | + | + | + | 0 | 0 | 0 | 6 | + | + | + | 0 | 0 | 0 | 6 | |
| 98 | *Pellaea pectiniformis* Baker | TR | OE | + | 0 | + | 0 | 0 | 0 | 7 | + | 0 | + | 0 | 0 | 0 | 7 | |
| 99 | *Doryopteris concolor* (Langsd. et Fisch.) Kuhn | TR | OE | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 8 | |
| **DENNSTAEDTIACEAE(FERNS)** | | | | | | | | | | | | | | | | | | |
| 100 | *Blotiella crenata* (Alston) Schelpe | TR | | + | 0 | + | + | 0 | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 | |
| 101 | *Blotiella currorii* (Hook.) R.M.Tryoni | TR | | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | |
| 102 | *Blotiella glabra* (Bory) R.M.Tryon | TR | | + | 0 | + | 0 | + | 0 | 10 | + | 0 | + | 0 | + | 0 | 10 | |
| 103 | *Blotiella hieronymii* (Kümmerle) Pic.Serm | TR | | + | 0 | 0 | 0 | + | 0 | 10 | + | 0 | 0 | 0 | + | 0 | 10 | |
| 104 | *Blotiella natalensis* (Hook.) R.M.Tryon | TR | | + | 0 | + | 0 | 0 | 0 | 8 | + | 0 | + | 0 | 0 | 0 | 8 | |
| 105 | *Blotiella sinuata* (Alston) Pic.Serm | TR | | 0 | 0 | + | 0 | 0 | 0 | 10 | 0 | 0 | + | 0 | 0 | 0 | 10 | |
| 106 | *Blotiella stipitata* (Alston) Faden | TR | | + | 0 | + | + | 0 | 0 | 10 | + | 0 | + | + | + | 0 | 10 | |
| 107 | *Histiopteris incisa* (Thunb.) J.Sm. | TR | TR-hy | + | 0 | + | 0 | 0 | 0 | 8 | + | 0 | + | 0 | 0 | 0 | 8 | |

| | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** | | | | | | | **6-10 years** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **SMS** | | **MS** | | **ASS** | | **Nbr** | **SMS** | | **MS** | | **ASS** | | **Nbr** |
| | | | | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| 108 | *Hypolepis sparsisora* (Schrad.) Kuhn | TR | TR-hy | + | + | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 7 |
| 109 | *Pteridium aquilinum* (L.) Kuhn | TR | | + | + | + | + | + | 0 | 10 | + | + | + | + | + | 0 | 10 |
| | **ASPLENIACEAE(FERNS)** | | | | | | | | | | | | | | | | |
| 110 | *Asplenium africanum* Desv | SE | | + | 0 | 0 | 0 | 0 | 0 | 6 | + | 0 | 0 | 0 | 0 | 0 | 6 |
| 111 | *Asplenium gemiferum* Schrad | TR | OE | + | 0 | + | + | + | 0 | 10 | + | + | + | + | + | 0 | 10 |
| 112 | *Asplenium rutifolium* (P.J.Bergius) Kunze | SE | | 0 | 0 | + | + | 0 | 0 | 7 | 0 | 0 | + | + | + | 0 | 5 |
| 113 | *Asplenium abyssinicum* Fée | TR | | 0 | 0 | + | + | 0 | 0 | 8 | 0 | 0 | + | + | + | 0 | 3 |
| 114 | *Asplenium aethiopicum* (Burn.f) Bech | ES | | + | + | + | + | + | 0 | 10 | + | 0 | + | + | + | 0 | 7 |
| 115 | *Asplenium bugoiense* Hieron. | H-Ep | TR | + | 0 | + | + | 0 | 0 | 8 | + | 0 | + | + | + | 0 | 3 |
| 116 | *Asplenium burundense* Pic.Serm. | ES | | + | 0 | 0 | 0 | 0 | 0 | 3 | + | 0 | 0 | 0 | 0 | 0 | 2 |
| 117 | *Asplenium ceii* Pic.Serm. | H-Ep | TR | + | + | + | + | 0 | 0 | 10 | + | 0 | + | + | + | 0 | 7 |
| 118 | *Asplenium dregeanum* Kunze | ES | | + | + | + | + | 0 | 0 | 10 | + | + | + | + | + | 0 | 10 |
| 119 | *Asplenium elliottii* C.H.Wright | TR | OE | + | + | + | + | + | 0 | 10 | + | + | + | + | + | 0 | 10 |
| 120 | *Asplenium emarginatum* P.Beauv | TR | | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 10 |
| 121 | *Asplenium erectum* Bory ex willd | TR | | + | + | + | + | + | 0 | 10 | + | + | + | + | 0 | 0 | 10 |
| 122 | *Asplenium friesiorum* C.Chr. | TR | OE | + | + | + | + | + | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 |
| 123 | *Asplenium goetzei* Hieron. | SE | | + | 0 | + | + | + | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 |
| 124 | *Asplenium hemitomum* Hieron. | SE | | + | + | + | + | 0 | 0 | 10 | + | + | + | + | 0 | 0 | 10 |
| 125 | *Asplenium holstii* Hieron. | H-Ep | | + | + | + | + | + | 0 | 10 | + | + | + | + | 0 | 0 | 10 |
| 126 | *Asplenium hypomelas* Kuhn | H-Ep | | 0 | 0 | + | 0 | 0 | 0 | 10 | 0 | 0 | + | 0 | 0 | 0 | 10 |
| 127 | *Asplenium Kivuensis* Mangambu | TR | OE | 0 | 0 | + | 0 | 0 | 0 | 4 | 0 | 0 | + | 0 | 0 | 0 | 5 |
| 128 | *Asplenium lambinonii* Pic.Serm. | TR | H-Ep | 0 | 0 | + | 0 | + | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| 129 | *Asplenium linckii* Kuchn | H-Ep | | + | + | + | + | + | 0 | 10 | + | + | + | + | 0 | 0 | 10 |
| 130 | *Asplenium longicauda* Hook. | H-Ep | | + | 0 | + | 0 | 0 | 0 | 7 | + | 0 | + | 0 | 0 | 0 | 6 |
| 131 | *Asplenium loxoscapoïdes* Bak. | TR | H-Ep | 0 | + | + | + | + | 0 | 10 | 0 | + | + | + | 0 | 0 | 7 |

| | *Pteridoflora* | MH | MH | 1- 5 year | | | | | | | 6-10 years | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | SMS | | MS | | ASS | | Nbr | SMS | | MS | | ASS | | Nbr |
| | | | | ST | P | ST | P | ST | P | 10 | ST | P | ST | P | ST | P | 10 |
| 132 | *Asplenium macrophlebium* Baker | TR | H-Ep | + | 0 | + | + | 0 | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 |
| 133 | *Asplenium mannii* Hook. | H-Ep | | + | 0 | + | 0 | + | + | 10 | + | 0 | + | 0 | + | 0 | 8 |
| 134 | *Asplenium megalura* Hieron. | SE | | + | 0 | + | + | 0 | 0 | 8 | + | 0 | + | + | 0 | 0 | 9 |
| 135 | *Asplenium monanthes* L. | TR | H-Ep | 0 | 0 | + | 0 | 0 | 0 | 7 | 0 | 0 | + | 0 | 0 | 0 | 7 |
| 136 | *Asplenium preussii* Hieron. | SE | | + | 0 | + | + | 0 | 0 | 8 | + | + | + | + | 0 | 0 | 8 |
| 137 | *Asplenium protensum* Schrad. | SE | | + | 0 | + | + | + | 0 | 8 | + | 0 | + | + | 0 | 0 | 8 |
| 138 | *Asplenium pseudoauriculatum* Schelep | H-Ep | | + | 0 | + | + | + | 0 | 8 | + | 0 | + | + | 0 | 0 | 7 |
| 139 | *Asplenium reekmansii* Pic.Serm. | H-Ep | | + | 0 | + | 0 | + | 0 | 3 | + | 0 | + | 0 | 0 | 0 | 2 |
| 140 | *Asplenium rutifolium* (P.J. Bergines) Kuntz | H-Ep | | + | 0 | + | + | + | 0 | 7 | + | 0 | + | + | 0 | 0 | 3 |
| 141 | *Asplenium sandersonii* Kook. | H-Ep | | 0 | 0 | + | + | + | 0 | 10 | 0 | + | + | + | + | 0 | 10 |
| 142 | *Asplenium smedsii* Pic.Serm. | H-Ep | TR-hy | 0 | + | + | + | + | 0 | 7 | 0 | 0 | + | + | 0 | 0 | 4 |
| 143 | *Asplenium stuhmanni* Hieron | SE | | 0 | 0 | + | + | 0 | 0 | 5 | 0 | 0 | + | + | 0 | 0 | 5 |
| 144 | *Asplenium theciferum* (Kunth) Mett. | SE | | 0 | + | + | + | + | 0 | 9 | 0 | + | + | + | 0 | 0 | 8 |
| 145 | *Asplenium varabile* Hook | SE | | + | 0 | 0 | 0 | 0 | 0 | 6 | + | 0 | 0 | 0 | 0 | 0 | 5 |
| | **BLECHNACEAE(FERNS)** | | | | | | | | | | | | | | | | |
| 146 | *Blechnum attenuatum* (Sw.) Mett. | H-Ep | | + | 0 | + | 0 | 0 | 0 | 7 | + | 0 | + | 0 | 0 | 0 | 7 |
| 147 | *Blechnum tabulare* (Thunb.) Kuhn | TR | | 0 | 0 | + | + | + | 0 | 9 | 0 | 0 | + | + | 0 | 0 | 8 |
| | **ATHYRIACEAE(FERNS)** | | | | | | | | | | | | | | | | |
| 148 | *Diplazium proliferum* (Lam.) Kaulf | HYDR | TR | + | + | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 7 |
| 149 | *Diplazium zanzibaricum* (Baker) C.Chr | HYDR | TR | + | 0 | + | 0 | 0 | 0 | 6 | + | 0 | + | 0 | 0 | 0 | 6 |
| | **THELYPTERIDACEAE(FERNS)** | | | | | | | | | | | | | | | | |
| 150 | *Amauropelta oppositiformis* (C.Chr.) Holttum | TR-hy | | + | + | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 7 |
| 151 | *Ampelopteris prolifera* (Retz.)Copeland | TR-hy | | + | + | + | + | 0 | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 |
| 152 | *Christella callensii* (Alston) Holttum | TR-hy | | + | + | + | 0 | 0 | + | 10 | + | 0 | + | 0 | 0 | + | 7 |

|  | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** |  |  |  |  |  |  | **6-10 years** |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  | **SMS** |  | **MS** |  | **ASS** |  | **Nbr** | **SMS** |  | **MS** |  | **ASS** |  | **Nbr** |
|  |  |  |  | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| 153 | *Christella dentata* (Forssk.) Brownsey & | TR |  | 0 | 0 | + | 0 | 0 | + | 10 | 0 | 0 | + | 0 | 0 | + | 7 |
| 154 | *Christella friesii* (Brause) Holttum | TR-hy |  | + | 0 | + | 0 | + | + | 10 | + | 0 | + | 0 | 0 | + | 7 |
| 155 | *Christella gueinziana* (Mett.)Holttum | TR | OE | + | + | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 10 |
| 156 | *Cyclosorus striatus* (Schumach.) Ching | TR-hy |  | + | 0 | + | 0 | + | 0 | 8 | + | 0 | + | 0 | 0 | 0 | 7 |
| 157 | *Cyclosorus interruptus* (Willd.) H.Itô | TR |  | + | 0 | + | + | + | 0 | 10 | + | 0 | + | + | 0 | 0 | 7 |
| 158 | *Pneumatopteris afra* (H.Christ) Holttum | TR-hy |  | + | 0 | + | 0 | + | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 7 |
| 159 | *Pneumatopteris unita* (Kunze) Holttum | TR-hy |  | 0 | 0 | + | + | + | 0 | 9 | 0 | 0 | + | + | 0 | 0 | 7 |
| 160 | *Pseudocyclosorus pulcher* (Bory ex Willd.) Holttum | TR-hy |  | 0 | 0 | + | 0 | 0 | 0 | 10 | 0 | 0 | + | 0 | 0 | 0 | 7 |
| 161 | *Thelypteris confluens* (Thunb.) C.V.Morton | TR-hy |  | 0 | + | + | 0 | + | 0 | 6 | 0 | 0 | + | 0 | 0 | 0 | 8 |
| 162 | *Sphaerostephanos arbuscula* (Willd.) Holttum | TR-hy |  | 0 | + | + | 0 | + | 0 | 6 | 0 | 0 | + | 0 | 0 | 0 | 7 |
|  | **DIDYMOCHLAENACEAE(FERN)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 163 | *Didymochlaena truncatula* (Sw.) J.Sm. |  |  | 0 | 0 | + | 0 | 0 | 0 | 10 | 0 | 0 | + | 0 | 0 | 0 | 10 |
|  | **DRYOPTERIDACEAE(FERNS)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 164 | *Elaphoglossum acrostichoides* (Hook. & Grev.) | SE |  | + | 0 | + | + | + | 0 | 10 | + | 0 | + | + | 0 | 0 | 10 |
| 165 | *Elaphoglossum aubertii* (Desv.) T.Moore | SE |  | 0 | 0 | + | + | + | 0 | 8 | 0 | 0 | + | + | 0 | 0 | 7 |
| 166 | *Elaphoglossum barteri* (Baker) C.Chr. | SE |  | 0 | + | + | 0 | + | 0 | 6 | 0 | 0 | + | 0 | 0 | 0 | 8 |
| 167 | *Elaphoglossum deckenii* (Kuhn) C.Chr | SE |  | + | + | + | 0 | 0 | 0 | 6 | + | + | + | 0 | 0 | 0 | 8 |
| 168 | *Elaphoglossum hybridum* (Bory) Brack | H-Ep | TR | 0 | + | + | + | + | + | 10 | 0 | 0 | + | + | 0 | 0 | 8 |
| 169 | *Elaphoglossum kivuense* Schelpe | SE |  | + | 0 | 0 | + | 0 | 0 | 10 | + | 0 | + | + | 0 | 0 | 8 |
| 170 | *Elaphoglossum lancifolium* (Desv.) C.V.Morton | SE |  | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| 171 | *Dryopteris antarctica* (Baker) C.Chr. | TR | TR-hy | + | + | 0 | 0 | + | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 10 |

| | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** | | | | | | | **6-10 years** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **SMS** | | **MS** | | **ASS** | | **Nbr** | **SMS** | | **MS** | | **ASS** | | **Nbr** |
| | | | | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| 172 | *Dryopteris athamantica* (Kunze) Kuntze | TR | | + | 0 | 0 | 0 | 0 | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 10 |
| 173 | *Dryopteris inaequalis* (Schltdl.) Kuntze | TR | | 0 | + | + | 0 | + | 0 | 10 | 0 | 0 | + | 0 | 0 | 0 | 10 |
| 174 | *Dryopteris kilemensis* (Kuhn) Kuntze | TR | | + | + | + | 0 | 0 | 0 | 10 | + | + | + | 0 | 0 | 0 | 10 |
| 175 | *Dryopteris lewalleana* Pic.Serm | TR | TR-hy | + | + | + | + | + | 0 | 10 | + | + | + | + | 0 | 0 | 9 |
| 176 | *Dryopteris manniana* (Hook.) C.Chr. | TR | TR-hy | + | + | + | + | + | 0 | 10 | + | + | + | + | 0 | 0 | 10 |
| 177 | *Polystichum sinense* (H.Christ) H.Christ | TR | | 0 | + | + | + | + | 0 | 10 | 0 | + | + | + | 0 | 0 | 10 |
| 178 | *Polystichum transvaalense* N.C.Anthony | TR | | 0 | 0 | + | 0 | 0 | 0 | 10 | 0 | 0 | + | 0 | 0 | 0 | 10 |
| **NEPHROLEPIDACEAE(FERNS)** | | | | | | | | | | | | | | | | | |
| 179 | *Nephrolepis biserrata* (Sw.) Schott | SE | | + | 0 | 0 | 0 | 0 | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 10 |
| 180 | *Nephrolepis undulata* (Afzel. ex Sw.) J.Sm | TR | H-Ep | + | + | + | + | + | 0 | 10 | + | + | + | + | 0 | 0 | 10 |
| **OLEANDRACRACEAE(FERNS)** | | | | | | | | | | | | | | | | | |
| 181 | *Oleandra distenta* Kunze | SE | H-Ep | + | + | + | 0 | + | + | 10 | + | + | + | + | + | 0 | 9 |
| 182 | *Oleandra welwitschii* (Baker) Pic.Serm | SE | | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | + | 0 | 0 | 0 | 7 |
| DAVALLIACEAE(FERNS) | | | | | | | | | | | | | | | | | |
| 183 | *Davallia chaerophylloides* (Poir.) Steud | SE | | + | 0 | 0 | 0 | 0 | 0 | 7 | + | 0 | 0 | 0 | 0 | 0 | 5 |
| **LOMARIOPSIDACEAE(Ferns)** | | | | | | | | | | | | | | | | | |
| 184 | *Lomariopsis guineensis* (Underw.) Alston | H-Ep | | + | 0 | + | 0 | 0 | 0 | 10 | + | + | 0 | 0 | 0 | 0 | 5 |
| 185 | *Lomariopsis hederacea* Alston | H-Ep | | + | 0 | 0 | 0 | 0 | 0 | 4 | + | + | 0 | 0 | 0 | 0 | 4 |
| **TECTARIACEAE(FERNS)** | | | | | | | | | | | | | | | | | |
| 186 | *Arthropteris monocarpa* (Cordem.) C.Chr | H-Ep | OE | 0 | + | + | + | + | + | 9 | 0 | + | + | + | 0 | + | 7 |
| 187 | *Arthropteris orientalis* (J.F.Gmel.) Posth | TR | OE | + | 0 | 0 | 0 | + | + | 10 | + | + | + | 0 | + | + | 9 |
| 188 | *Tectaria gemmifera* (Fée) Alston | TR | TR-hy | + | + | 0 | + | + | 0 | 10 | + | 0 | + | + | + | 0 | 7 |
| 189 | *Triplophyllum varians* (T.Moore) Holttum | TR | TR-hy | + | 0 | 0 | 0 | 0 | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 10 |
| **POLYPODIACEAE(FERNS)** | | | | | | | | | | | | | | | | | |

| | ***Pteridoflora*** | **MH** | **MH** | **1- 5 year** | | | | | | | **6-10 years** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **SMS** | | **MS** | | **ASS** | | **Nbr** | **SMS** | | **MS** | | **ASS** | | **Nbr** |
| | | | | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** | **ST** | **P** | **ST** | **P** | **ST** | **P** | **10** |
| 190 | *Loxogramme abyssinica* (Baker) M.G.Price | H-Ep | | + | + | + | + | 0 | 0 | 7 | + | + | + | + | 0 | 0 | 7 |
| 191 | *Loxogramme ntahobavukian* Mangambu | H-Ep | | + | 0 | + | 0 | 0 | 0 | 5 | + | 0 | + | 0 | 0 | 0 | 3 |
| 192 | *Platycerium elephantotis* Schweinf. | SE | | + | 0 | + | 0 | 0 | 0 | 9 | + | 0 | + | 0 | 0 | 0 | 9 |
| 193 | *Platycerium stemaria* (P.Beauv.) Desv | SE | | + | 0 | 0 | 0 | 0 | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 8 |
| 194 | *Pyrrosia lanceolata* (l.) farw. farci | H-Ep | SSHE | + | 0 | + | 0 | 0 | 0 | 10 | + | 0 | 0 | 0 | 0 | 0 | 8 |
| 195 | *Pyrrosia schimperiana* (Mett. ex-Kuhn) Alston | H-Ep | SSHE | 0 | 0 | + | 0 | 0 | 0 | 10 | 0 | 0 | + | 0 | 0 | 0 | 10 |
| 196 | *Aglaomorpha laurentii (*H.Ch. ex De Wild. & T.Dur.)Hov. | SE | | + | 0 | + | 0 | 0 | 0 | 9 | + | 0 | + | 0 | 0 | 0 | 9 |
| 197 | *Aglaomorpha volkensii* Hieron | SE | | 0 | 0 | + | 0 | 0 | 0 | 9 | 0 | 0 | + | 0 | 0 | 0 | 10 |
| 198 | *Lepisorus excavatus* (Bory ex Willd.) Ching | H-Ep | SE | + | 0 | + | + | + | + | 9 | + | 0 | + | + | + | + | 7 |
| 199 | *Lepisorus lobrechiana* Mangambu | H-Ep | SE | + | 0 | + | 0 | 0 | 0 | 5 | + | 0 | + | 0 | 0 | 0 | 4 |
| 200 | *Microsorum punctatum* (L.) Copel | H-Ep | | + | + | + | + | + | 0 | 9 | + | + | + | + | 0 | 0 | 7 |
| 201 | *Microsorum scolopendria* (Burm.f.) Copel | TR | PHE | + | 0 | + | + | + | + | 9 | + | 0 | + | + | + | + | 8 |
| 202 | *Pleopeltis macrocarpa* (Bory ex Willd.) Kaulf | SE | | + | 0 | + | 0 | + | 0 | 9 | + | 0 | + | 0 | + | 0 | 5 |
| 203 | *Microgramma mauritiana* (Willd.) Tardieu | SE | TR | + | + | + | 0 | 0 | 0 | 8 | + | + | 0 | 0 | 0 | 0 | 6 |
| 204 | *Melpomene flabelliformis* (Poir.) A.R.Sm. & R.C.Moran | H-Ep | TR | 0 | 0 | + | 0 | + | + | 9 | 0 | 0 | + | 0 | + | + | 7 |
| 205 | *Zygophlebia villosissima* (Hook.) L.E.Bishop | H-Ep | TR | 0 | 0 | + | 0 | + | + | 6 | 0 | 0 | + | + | + | + | 7 |
| | Ferns | | | 143 | 72 | 147 | 70 | 66 | 14 | 1502 | 139 | 62 | 141 | 51 | 42 | 9 | 1310 |
| | Pteridoflora | | | 155 | 77 | 157 | 74 | 71 | 15 | 1633 | 149 | 69 | 148 | 55 | 47 | 10 | 1429 |

*Legend: SMS Sub-montane stage, MS : Montane stage, AAS : Afro-subalpine stage, MH : main habitat, MH modified habitat, TR : terrestrial, H-Ep hemi-epiphytes, SE : Strict epiphyte, HYD : hydrophyte, TR-hy : terrestrial-hydrophyte, OE : Occasional epiphytes, SSHE : semi-strict hemi-epiphytes, Aq : aquatic et AOE accidental or occasional epiphytes*