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Study of the Congolese distribution of the Lycophytes and Ferns from the mountain areas of Kahuzi-Biega National Park (Eastern DR Congo, Albertine Rift): A contribution to the conservation from this Park

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Abstract

Phytogeographic theories complement classic biodiversity data with spatial information and constitute a potential tool for conservation biology. The studies presented in this paper analyse diversity patterns of Lycophytes and Ferns in the mountains of Kahuzi-Biega National Park (KBNP) which is located in other regional endemic centers of the DRC according to White (as stated in his book the vegetation of Africa). We conducted a phytogeographical analysis of this massif from the mountain areas of Kahuzi-Biega and evaluated its floristic, the Lycophytes and Ferns affinities with other regional endemic centers of DRC. The analysis is based the specimens and a detailed consultation of the bibliography on Phytogeographical of Lycophytes and Ferns in the DRC. The Data projection in different regional centers of endemism along the lines of White shows that the majority of species are liaison species between regional centers and endemism areas of the DRC. The sub-montana zone of the KBPN is considered to be a transitional area between the Kahuzi mountain range and other regional centers of endemism. In its part of conservation, I show how these species are threatened by human activities exercised in this Park. These characteristic species of mountains should be retained in order to better use as indicator species of mountains forest degradation. Hence, some strategies of conservation are proposed.

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Introduction

Forest fragmentation is one of the most important conservation issues of recent times. Knowledge on distribution of biodiversity is crucial for its further exploration, use, and conservation. Biodiversity conservation is one of the major concerns in biogeography and ecology (Geir *et al*., 2008). Species richness is distributed non-uniformly across the biosphere (Moran and Smith, 2001) and nature conservation is often based on the concept of biodiversity hotspots (Ndayishimiye *et al*., 2012). The relevance of this in the context of politics and conservation is demonstrated by the large research programmes of several international environmental NGOs (Koffi *et al.,* 2008a). For this reason, some authors such as (Koffi *et al*., 2008b; Ndayishimiye *et al*., 2010; Noiha *et al*., 2011 ; Mangambu *et al*., 2014), conducted biogeographically studies on a group of the plants indicated on the scale of one or more African biogeographical regions. These studies can be improved across sectors or Phytogeographical regional centers of endemism (Ortega-Huerta and Peterson, 2004).

The present work is based on Lycophytes and Ferns repartition in the Kahuzi-Biega National Park (KBNP) located at the intersect of Guinea-Congolian and African mountain Centers of endemism in the eastern part of the Democratic Republic of the Congo (DRC).For central Africa, defined here as the region covered jointly by the DRC, Burundi and Rwanda, several phytogeographic theories have been proposed based on plant physiognomic arguments and bioclimatic data, and relying on the concept of endemism (Koffi *et al*., 2008aandb; Ndayishimiye *et al*., 2010; Ndayishimiye *et al*., 2012). Ecologists are interested in areas of endemism because of their importance in conservation: narrowly endemic species are by definition rare and therefore potentially threatened (Sosef, 1996; Allouche *et al*., 2006). In addition, this study frames among those carried out by botanists for the use of predictive models to estimate the potential distribution of plant species (Geir *et al*., 2008; Ndayishimiye *et al*., 2009; Aldasoro *et al*., 2009) and the location of endangered plants (Sosef, 1996; Ortega-Huerta *et al*., 2003; Mangambu, 2017). Also to assess the impact of climate change on species repartition (Ortega-Huerta *et al*., 2003; Thuiller *et al*., 2005). Specifically, it provides a better understanding on how the plants species are distributed in different area and the mechanisms governing their distribution in order to preserve the natural heritage (Mangambu, 2013 and 2016).

In this work, we use the phytogeographical floristic model proposed by White (1986, Fig. 1) heritage which divides Africa and Madagascar in 20 regional entities among which, 5 are located in the DRC. If it could be shown that individual species could be used as indicators of this phytogeographic model, their use in conservation biology could be suggested. This search for functional relationships between species richness and the occurrence of indicator species is a common practice in conservation biology (Noiha *et al*., 2011).

Therefore, there is still a need to conduct phytogeographical and distribution studies on Lycophytes and Ferns. The present study aims to fill the gap and upgrade the Analysis of the Congolese distribution of mountainous Lycophytes and Ferns of Kahuzi-Biega National Park in the eastern part of DRC and hence, some strategies of conservation are proposed.

Materials and methods

Study area

This Park was created in 1970 to protect the eastern lowland Grauer's Gorilla (*Gorilla beringei graueri*) and their habitats and is part of UNESCO world heritage since 1980 (Mangambu *et al*., 2017). It is located in the southern part of the chain mountains Kivu-Ruwenzori axis NNE-SSW along to the west (Fig. 1), the Albertan Rift (Mangambu, 2013) and is characterized by primary rainforest and includes two extinct volcanoes namely, Kahuzi and Biega on which, live one of the last populations of mountain gorillas over around 2000 m of altitude (Fischer, 1996).

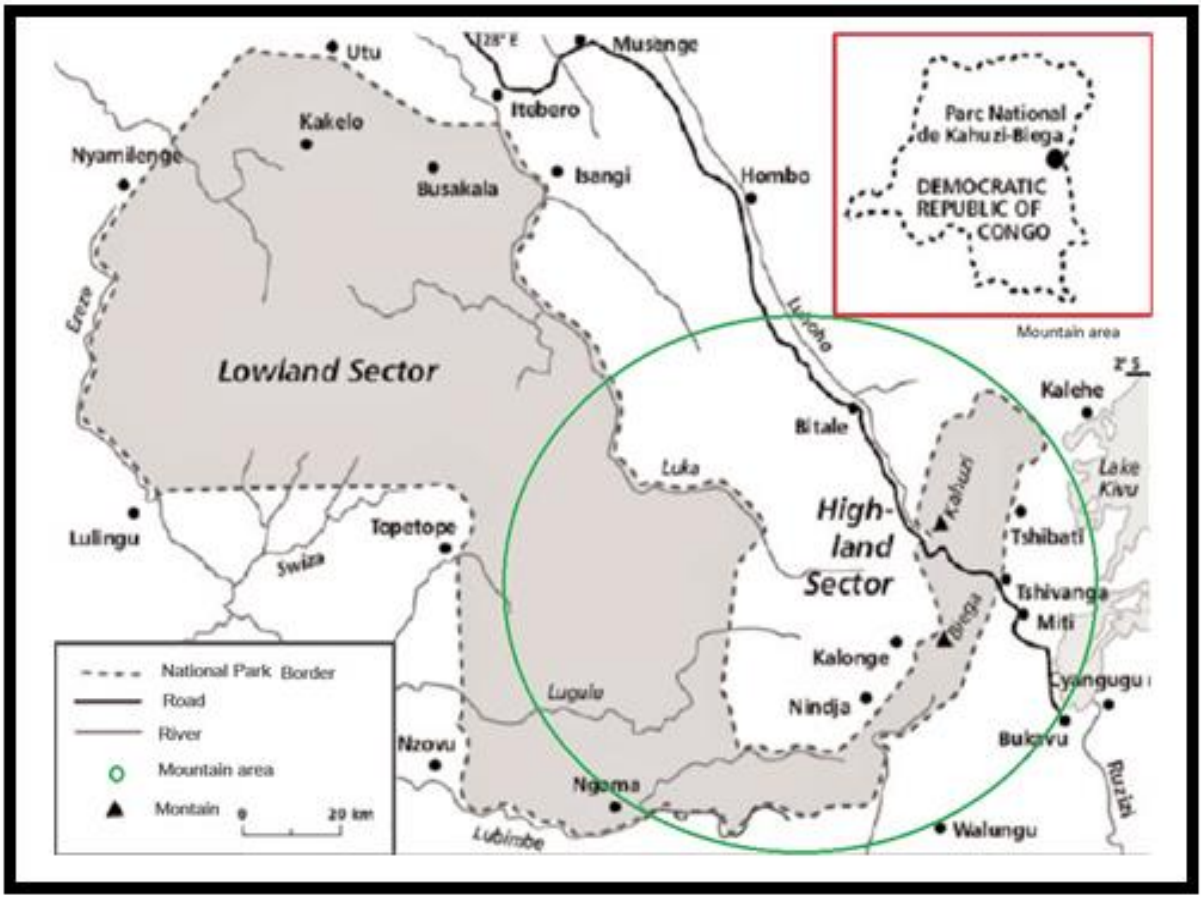

Fig. 1. Map of Kahuzi-Biega National Park, « Part encircled "2/6, ± 2400 km 'study area». Source (Mangambu *et al.*, 2010).

This Park covers 6000 km² of area and includes two main peaks which are extinct volcanoes, namely Kahuzi (3326 m of altitude) and Biega (2790 m of altitude). According to their physiognomy and floristic composition, depending on the altitude, lowland forests, KBNP is divided into many parts (678-1250 m), submontainous, (1250-1700 m), mountain (1700-2600 m) and Afro-alpine (2600-3326 m). Overall, the area has a mountain climates (Cf of type Köppen), with heavy rainfall, ranging from 1750 to 2000 mm per year (Mangambu *et al.*, 2013a). Climate at Mount Kahuzi is characterised by night frosts, an expression of Afro-alpine type with 'summer every day and winter every night' (Fischer, 1996).

The humidity is constantly high parallel to the change in cloud cover. The length of the dry season does not exceed two months.

The temperature varies with altitude and the soil is shallow and acid (Mangambu *et al.*, 2013b).

Specimens examined, Chorologic units and phytogeographical classification

A total of 9819 (5987 from KBNP and 3832 others DRC) specimens collected in PNKB were examined and localized. These herbaria data come from investigations in the field between 2004 to 2017, and the historical material found in the DRC in herbaria: Epulu (UPU), Lwiro (LWI), Mulungu (MLGU) and Yangambi (YBI). Double of these specimens are in Belgium at the Botanical Garden of Belgium (BR). Some others are in some academic institutions and the University of Wageningen (WAG). Geographic coordinates of all specimens were included in the database.

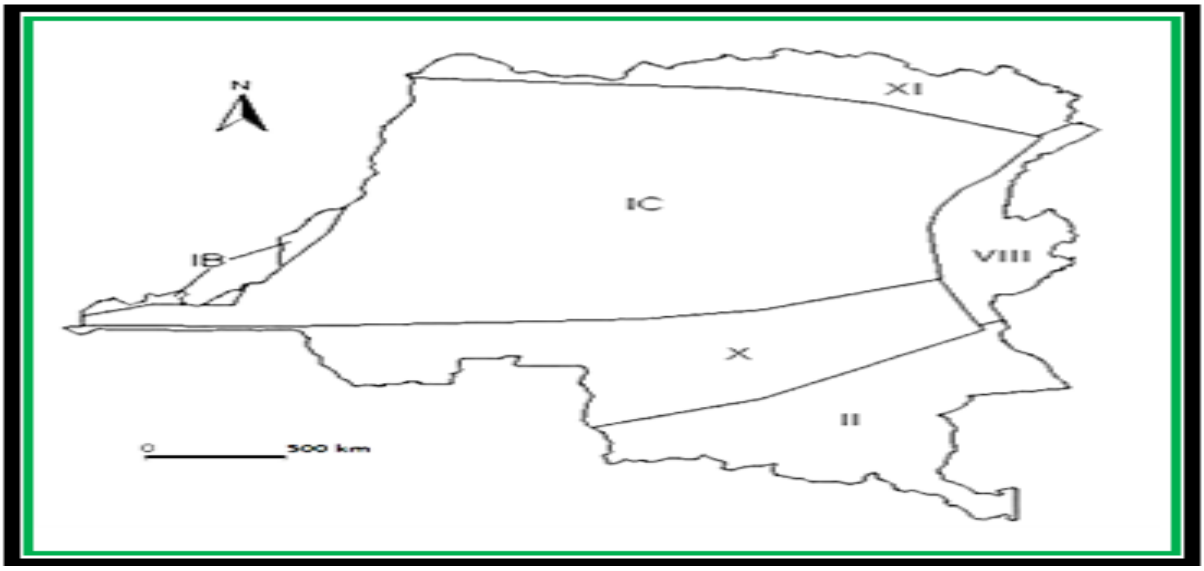

Fig. 2. Entities Phytogeographical of White (1986) covering the DRC.

Legend. (I) Guineo-Congolian regional center of endemism (IB: Lower Guinea sub-center, IC sub-center Congolese), (II) Zambezian regional center of endemism (VIII) Afromountain archipelago-like regional center of endemism, (X) the Guineo-Congolian/Zambezian regional transition zone and (XI) Congolian/Sudanian regional transition zone concern central Africa.

They are based on the distribution showing places specimens were collected. The chorological units derive from works of (Pauwels, 1968; Pichi-Sermolli, 1983 and 1885; Lejoly *et al.*, 1988; Fischer, 1996; Lubini, 1997 and 2001; Aldasoro *et al.*, 2004, Plumptre *et al.*, 2008) and 14 booklets of Lycophytes and Ferns in Central Africa (DRC, Rwanda and Burundi). They were used to produce the distribution centers for the taxa used in the study. Different types of areas distribution are based on the classification of White (1986). We distinguish the following categories (Fig. 2).

Table 1. (A and B). The to the number of taxa and the richest families in genera.

A. The richest families

Richest families	Number taxa	Percentage (%)
Pteridaceae	37	20.67
Aspleniaceae	30	16.75
Polypodiaceae	16	8.93
Dryopteridaceae	14	7.82
Thelypteridaceae	12	6.7
Total	109	60,87

b. The generic diversity

richest families	Number generic	Percentage (%)
Polypodiaceae	11	16.42
Pteridaceae	9	13.43
Thelypteridaceae	8	11.94
Dennstaedtiaceae	4	5.97
Hymenophyllaceae	4	5.97
Total	36	

Results and discussion

The floristic composition

The floristic composition of mountainous Lycophytes and Ferns identified in the KBNP is 179 taxa (176 species and infra specific taxa which include 4 subspecies and 2 varieties). It is reported here that in the enclosed table we have inventoried 179 different taxa grouped into 28 families, and 67 genera. The families are the most diverse to the number of taxa and the richest families in genera are reported in table 1 (A and B) that cover more than 60 % of the inventoried flora diversity in total.

Congolese distribution of mountains lycophytes and ferns in KBNP

The Phytogeographical analyzes are reported in Table 2 and shows the spectrum of distribution according to phytochoria of WHITE (1986) that covers the DRC.

Table 2. Phytogeographical spectrum of Congolese distribution of Lycophytes and Ferns of KBNP mountainous forest ecosystem following the model of White (1986).

Congolese distribution	Numbertaxa	Percentage (%)
Species distributed in all centers and regional endemism areas	15	8.38
Related species	110	61.46
Afromontana species	54	30.16
Total	179	100

In view of the results, most species are liaison species between areas centers or endemism with a proportion of 110 taxa (61.46%), followed by afro-mountains with 54 taxa (30.16 %) Lycophytes and Ferns which are in the 5 centers and regional endemic areas represent only 8.38%. They are represented by taxa (61.46) of the total floristic species and are distributed as follow: A rate of 14.52 % of liaison species is present between the Zambezian and Afro-mountainous endemism of regional centers. Among them 3.33% are Zambezian species that grow in the Albertine Rift Mountains.

Species distributed in all centers and regional endemism areas

Species distributed in all centers and regional endemism areas of the DRC represent 15 taxa (or 8.37%) of the Pteridological flora identified in the KBNP Mountains. The Species *Davallia chaerophylloides, Lygodium microphyllum, Microgramma lycopodioides, Nephrolepis biserrata, Selaginella molliceps* and *S. myosurus* have a large distribution in the Guinea-Congolain and Zambezian regional centers of endemism.

Fig. 3. The endemic species from the mountain areas of Kahuzi-Biega National Park (*Asplenium kivuensis* to the right and *Lycopodium carolinum*, to the left).

They are sporadically represented in all stages of KBNP Mountains. By contrast, other species (*Arthropteris orientalis, Asplenium aethiopicum* subsp. *aethiopicum, Christella dentata, Lycopodiella cernua, Nephrolepis undulata, Oleandra distenta, Pteridium aquilinum* subsp. *aquilinum*, *P. aquilinum* subsp. *centrali-africanum*and *Selaginella versocolor*) are almost equally distributed in the centers.

Fig. 4. Three endemic species from Kivu-Ruwenzori mountain system (*Lepisorus robbrechtianum*to the right, *Loxogramme ntahobavukiana*in the center and *Sticherus inflexus*to the left).

Species distributed in the African mountain regional center of endemism

Afromontana species represent 54 taxa (30.16 %) of flora in Lycophytes and Ferns found in KBNP Mountains. Among these species, *Asplenium kivuensis* and *Lycopodium carolinum* are endemic KBNP (Fig. 3).

Species known in other mountain systems of the DRC are (52taxa or 29.01%): *Adiantum incisum, A. reniforme, Amauropelta bergiana* var. *bergiana, Asplenium abyssinicum, A. actiniopteroides, A. bugoiense, A. ceii, A. loxoscaphoides, A. monanthes, A. preussii, A. smedsii, Athyrium scandicinum, Ctenopteris villosissima, Cyathea camerooniana* var. *ugandensis, Cyathea milbraedii, Blotiella hieronymii, B. stipitata, Dryopteris manniana, Elaphoglossum barteri, E. deckenii, E. hybridum, E. kivuense, E. lastii, Elaphoglossum rwandense, Isoetes welwitschii, Huperzia bampsiana, H. dacrydioides, H. saururus, Lepisorus robbrechtianum* (Fig. 4), *Loxogramme ntahobavukiana* (Fig. 4), *Lycopodiella affinis, Metathelypteris vandervekenii, Odontosoria africana, Pellaea angulosa, Pityrogramma humbertii* var. *elongata, P. rupicola, Pteris repens, Pyrrosia schimperiana, Sphaerostephanos arbuscula* subsp. *africanus, Hymenophyllum triangulare, Melpomene flabelliformis, Pityrogramma argentea, Pleopeltis lanceolata, Pteris auquieri, P. kivuensis, P. tripartita, Sticherus inflexus* (Fig. 4), *Thelypteris confluens, Triplophyllum varians, Vandenboschia radicans, Vittaria volkensii* and *Vittaria reckmansii.*

Species linking different centers and zones of endemism

They are represented by 110 taxa (61.79%) of the total floral and are distributed as follow:

A rote of 14.52 (26 species) of liaison species is represented between the regional centers of Zambezian endemism center and Afromontain. Among them 5.02 % are Zambezian species that climb up Albertina Rift mountain. These species include: *Adiantum poiretii, Blotiella crenata, Dryopteris*

antarctica, D. kilemensis, D. inaequalis, Drynaria volkensii, Diplazium zanzibaricum, Elaphoglossum acrostichoides et *E. aubertii*. However 9.49 % of species: *Asplenium gemmiferum, A. megalura, A. praemorsum, A. protensum, A. Stuhlmannii, A. linckii, Cheilanthes farinosa, Christella gueintziana, D. lewalleana, Blechnum tabulare, Huperzia gnidioides, Marsilea minuta, Pellaea pectiniformis, Pteris catoptera, P. cretica, P. intricata* and *Polystichum transvaalense*, are rare mountain plants in the Zambezian regional center.

The Congolese sub-center, Zambezian endemism center and Afromontainre present 13.96 % (25 taxa) of forest wealth found in the mountain areas of KBNP. They are namely: *Asplenium friesiorum* subsp *friesiorum, A. mannii, A. theciferum, Antrophyum mannianum, Arthropteris monocarpa, Azolla nilotica, Azolla nilotica, Equisetum ramosissimum, Hymenophyllum capillare, H. hirsutum, Blotiella glabra, Coniogramme africana, Cyathea dregei, Diplazium proliferum, Drynaria laurentii, Equisetum ramosissimum, Hymenophyllum capillare, Hypolepis sparsisora, Osmunda regalis, Pteris friesii, P. pteridioides, Pellaea doniana, P. viridis, Pleopeltis macrocarpa,* and*Tectaria gemmifera.*

These species are mostly in the Zambezian and Afro-montain on regional centers. But between the two Guineo-Congolian regional center of endemism and those of Zambezian and Afromountain, only four of taxa (*Blotiella currorii, Amauropelta oppositiformis, Asplenium aethiopicum* subsp *tripinnatum* and *Platycerium elephantotis*) are distributed. These species are often present in the sub- mountain floor of the PNKB mountain range.

A 20 taxa (11.17%) is present between the lower Guinea sub center, the Zambezian endemism centers and Afromontain, and transition area of the Guinea-Congolian/Zambezia Transition zone Among which, 5.02% of taxa (*Adiantum capillus-veneris, Azolla pinnata, Equisetum ramosissimum* subsp. *ramosissimum*, *Lepisorus excavatus, Phymatosorus scolopendria, Pneumatopteris unita, Pteris vittata, P. linearis* and *Thelypteris striata*) are almost distributed equally to all three centers and transition areas: Guinea-congolian/Zambezian.

Four species (*Asplenium elliottii, A. rutifolium, Cyathea manniana* and *Didymochlaena truncatula*) are distributed in the regional Africa mountain center, while *Loxogramma abyssinica, Lygodium smithianum* and *Trichomanes rigidum* are Guinea-Zambezian species occurring sporadically in our study area. But *Loxogramma abyssinica, Lygodium smithianum, Psilotum nudum* and *Trichomanes rigidum* are Afro-tropical species occurring sporadically in our study area and regularly in the submontain floors.

Between Congolese sub-centers and African mountain, we found a total of 15 taxa (8.37 %). But 5.58 % of species (*Asplenium hypomelas, A. sandersonii, Lomariopsis congoensis, Lomariopsis congoensis, L. hederacea, Microsorum punctatum, Pseudocyclosorus pulcher, Selaginella auquieri, S. kivuensis, Sticherus flagellaris* and *Vittaria guineensis* var. *orientalis*) are distributed in the Guinea-Congolian sub-center and rise gradually in the sub-mountain KBNP. The majority of species are only found in the submountain KBNP. Only 2.22% of species (*Asplenium africanum, Gleichenia elongata, Pseudocyclosorus camerounensis* and *Salvinia nymphellula*) are distributed between the Guinea-Congolian and Afromountain regions.

Species link between the Zambezian endemism zone and the Afromountain as well as the Guinea-congolian/Sudanian regional transition zone represent only 7 species (3.91 %) of the total flora of Lycophytes and Ferns in KBNP. Among them, 2.23 % (*Actiniopteris semiflabellata, A. dimorpha, Asplenium erectum* and *Lycopodium clavatum*) are Zambezian and mountain. They are isolated in the transition region Guinea-congolian/Sudanian. Note also that 1.67 % (*Adiantum patens, Doryopteris concolor* and *Pellaea dura*) are Zambezian species but also occur sporadically in the Afromontana and

Guinea-Congolian/Sudanian transition area. 3.37 % taxa (*Asplenium macrophlebium, A. variabile* var. *paucijugum, Crepidomanes mannii, Hymenophyllum kuhnii, Histiopteris incisa*and *Pteridium aquilinum* subsp. *centrali-africanum*) is distributed in all areas Guinea-Congolian, the regional area of transition and Guinea-congolian/Zambezian. It's found in the sub-mountain of Afromountain endemism center.1.67 % of species of Lycophytes and Ferns is found in all centers, regional areas of the DRC except in the lower Guinea-sub center. These are: *Pityrogramma calomelanos, Cyclosorus interruptus* and *Dicranopteris linearis*. The species *Marattia fraxinea* is also found almost everywhere except in the Guinea-Congolian/Sudanian transition. The species *Cheilanthes similis* is found everywhere except in the Guinea-Congolian center.

A 1.67 % of species (*Asplenium dregeanum, A. hemitomum* and *Blechnum attenuatum*) occurs in the mountainous KBNP and in the Congolese sub- center and the Guineo-Congolian/Zambezian transition area. While, *Huperzia afromontana* is present in the mountains of eastern DRC and in the Guinea-Congolian/Sudanian transition area on Blue Mountain, near the Garamba National Park. The species *Ophioglossum costatum* forms a large disconnect between the lower Guinea sub-center and regional centers of endemism as well as the Zambezian African Mountains. *Asplenium emarginatum* is present in Guinea-Congolian regional centers of endemism and African mountain as well as the Guinea-Congolian/Sudanian transition area.

Implications for conservation of Lycophytes and Fernsfrom the KBNP Mountains

The convention on biological diversity

Since the early 1990s, the threat to global biodiversity has played an increasingly important role in political discussions. The Convention on Biological Diversity, which was one result of the Earth Summit in Rio de Janeiro 1992, obliges the member countries to protect biodiversity and support further research on this topic.

It was also in the 1990s that the international environmental NGOs started large scale priority setting programmes to focus conservation action (Schelpe, 1983; Sechrest *et al.,* 2002). Rainforests are extremely useful and valuable ecosystems (Kujirakwinja *et al.*, 2010). They play a crucial role in the regulation of greenhouse gases, in the great climate balance and represent the largest reservoir of biodiversity on the planet (Sechrest *et al.,* 2002).

In KBNP, various pressures are increasing day after day on natural resources in general and forest in particular because of poverty and the increase in population around the park. Moreover, this KBNP forest is the only forest close to the town of Bukavu for which it plays a key role in regulating the urban climate. This current situation of the KBNP is worrying because its deterioration accelerated these past twenty years and it is exclusively anthropogenic (Masumbuko *et al.*, 2012; Mangambu, 2013). It noted moreover that, following the abandonment of some degraded areas, regeneration can be achieved in few years and that stability is reached. Runge (2007); Kabonyi *et al.* (2011) and Chibembe *et al.* (2014) had already pointed out that after a period of crisis, the forest can naturally and quickly regain lost ground. Under the current climate that is favourable to a forest expansion, a progressive dynamics plants could take place (Masumbuko *et al.*, 2012). Therefore, in order to return to the situation of 1994 (before the multiple civil wars), the full protection of the mountain area is essential.

Pressures create degradations and natural or artificial vegetation

These anthropogenic pressures create degradations and natural or artificial vegetation changes of the KBNP and their consequences affect not only species richness, abundance of species, but also the genetic diversity (Masumbuko *et al.*, 2012), the growth rate of populations, species interactions or dispersal of individuals and their rate of predation (Mangambu, 2013 and 2016) which have a negative effect on the movement of Gorilla Graueri (*Gorilla beringei graueri*), the flagship endangered animal in KBNP.

This is in line with observations made by Liengola (2008) and Masumbuko *et al.* (2013) on the invasion of the vine *Sericostachys scandens*, illegal activities of the population (logging and bamboo, samples of plants, mining and bush fires), the granting of concessions to private individuals in the Park and the installation of armed groups unbalance the functioning of this ecosystem by increasing the temperature with the creation of gaps and clearings.

Human pressure on Ferns and their allies in KBNP is observed for a long time to meet some basic needs; the local population is engaged in the resulting plants for various uses. Mangambu *et al.* (2012) in their studies enthnobotanic survey of Pteridophytes, harvest of extinction risk and conservation strategies in the surroundings of the Kahuzi-Biega National Park. Their results show that 25.2% the Fern and Allies used for the basic needs of the populations, while Shalukoma (2009) show that 12.2% the angiosperms used for the basic needs of the these populations. It shows fern and allies Ferns is threatened more that the Angiosperms. We refer to them as species with wide ecological amplitude. Liaison species between lower Guinea sub- centers, regional centers of endemism, Zambezian and that of afromountain are best represented in this distribution pattern. These characteristic species of mountains should be retained in order to better use as indicator species of mountains forest degradation

Some species found in the KBNP Mountains have reduced distribution areas when compared to others which were collected almost in all areas that are centers of endemism in the DRC. Whatever their distribution in the DRC, the Afromountain species in the region do not exceed this territorial entity. These montane species, that can be considered "indicator ", should be protected in order to use them as indicators of mountains forest degradation (White, 1986; Sechrest *et al.*, 2002; Kujirakwinja *et al.*, 2010). Overall, the results show that the Lycophytes and Ferns are most represented and diversified in stable environments (78 % of the total flora) than in disturbed habitats (22%), including the Afro-alpine floor where the diametric distribution of trees and shrubs, floristic richness and recovery are lower.

The environmental degradation

Following these environmental degradation, we still found that some the species that are only represented by a few specimens. We can cite the case of: *Amauropelta bergiana* var. *bergiana, Blotiella hieronymii, Athyrium scandicinum, Elaphoglossum hybridum, Isoetes welwitschii, Huperzia bampsiana, Metathelypteris vanderverkenii, Sphaerostephanos arbuscula* subsp. *Africanus* and *Hymenophyllum triangulare* became rare. AfterKornas´ and Kazimierz (1993), Hemps (2001 and 2002) and Roux (2009), these species are among the species characteristics of the areas of African Mountains of East Africa. According Hemps (2002), the species restricted to a small geographic region are considered prone to extinction. Par example andemic taxa Ferns from Kivu-Ruwenzori Mountain System (*Cyathea camerooniana* var. *ugandensis Cyathea milbraedii, Elaphoglossum kivuense, Elaphoglossum rwandense, Huperzia bampsiana, Lepisorus robbrechtianus, Loxogramme ntahobavukiana, Odontosoria Africana, Pityrogramma humbertii* var. *elongata , P. rupicola, Pteris auquieri, P. kivuensis, Sticherus inflexus* (Mangambu *et al.,* 2016; Mangambu and Van Diggelen, 2017). This is a key issue in conservation biology, where the vulnerability concept can be a more profound interpretation of phytogeographic observations. A species is considered very vulnerable when it is bound to particular altitudinal limits, when it is associated with undisturbed of primary forests. Therefore, Lycophytes and Ferns species richness varies greatly with changes in abiotic environments, explaining why some species are considered as bio-indicators (Hemps, 2002; Mangambu *et al.*, 2013b).

The current climate change and vegetation cover

We believe that the current climate change and vegetation cover, will make us witness the disappearance of some rare species found in the KBNP. The results obtained by Mangambu *et al.* (2013a) agree that in the African-subalpine KBNP certain groups of plants, such as Lycophytes and Ferns are vulnerable to changes that are taking place in KBNP.

For example, in the afro-alpine stage, there are plants such as *Dendromus kahuziensis* (Moss), *Lycopodium carolinum* (Lycophytes) *Pertusaria kahuziensis* (Ascomycetes) *Pauridiantha kahuziensis* (Rubiaceae) and *Psychotria kahuziensis* (Rubiaceae) and animals as *Angustivestris kahuziensis* (Gastropoda), *Cercopithecus hamlyni kahuziensis* (Primates), *Styposis kahuziensis* (Arthropoda) *Tetrabates kahuziensis* (Arachnida) and *Oreopaederus kahuziensis* (Coleoptera) that are endemic to Mount Kahuzi. These species characteristic of this stage should be preserved in order to be used as indicator species (Mangambu, 2013 and 2016).The same observations are made by Plumptre *et al.* (2003) in the Misotshi-Kabogo area encompassing Mont Marungu chain and Mount Kabobo massif in Eastern DRC. In these summits there was a forest of bamboo around 2007 (Plumptre *et al.*, 2008). This forest does not exist anymore. The Chimp Schweinfurth (*Pan troglodytes schweinfurthii*), an endemic species here that was observed in all levels have become rare and are seen only sporadically in the forest.

Thus some studies (Plumptre *et al*, 2008; Figueiredo *et al.*, 2009) point out that the interaction between various environmental factors that act simultaneously on floristic differences, including the degree of human impact on forests, a key factor in the region and the disturbance of vegetation structure due to a pronounced action of invasive plants (White, 1983 and 1993; Pausas and Austin, 2001; Plumptre *et al.*, 2008).These observations are related to deforestation and fragmentation thus two major potential determinants of biodiversity loss and change of landscape structure including the studied endemic species.

Problems require primarily a political solution

It is obvious that these problems require primarily a political solution. Thus, as part of a forest management of KBNP and to mitigate these ecological disturbances as demonstrated below, we believe that the awareness of the state of Congo, the managers of KBNP and the Congolese Institute for the Conservation of Nature (ICCN) may involve a better distinction between the effects of human disturbance and that of natural disturbances on stand structures at different scales. All the current challenge is to understand how the knowledge of disturbance processes can help practitioners to develop opportunistic and versatile intervention strategies for preserving the ecological integrity of these ecosystems. Development and protection of forests are recognized of general interest.

Conclusion

Knowledge on distribution of biodiversity is crucial for its further exploration, use, and conservation because the biodiversity conservation is one of the major concerns in biogeography and ecology. This study reveals that the Lycophytes and Ferns collected in the mountains of KBNP areas are also distributed in other centers of endemism as proposed by White (as stated in his book the vegetation of Africa). Some species found in the KBNP Mountains have reduced distribution areas when compared to others which were collected almost in all areas that are centers of endemism in the DRC. We refer to them as species with wide ecological amplitude. Liaison species between lower Guinea sub- centers, regional centers of endemism, Zambezian and that of afromountain are best represented in this distribution pattern. These characteristic species of mountains should be retained in order to better use as indicator species of mountains forest degradation. The species represented by a few specimens (less than ten, for example) need further study to assess if they are endangered. This area must be taken into account by decision makers for conservation and we reiterate that this area must:

Preserving the areas with a high concentration of endemic species should decrease the risk of losing this part of KBNP area.

Create several arboretums to be used in the implementation of these plants used by the population.

Strengthen development activities in favour of people living near the KBNP and increase sensitization in order to safeguard natural resources in general and these of KBNP in particular.

Reinvigorate cooperation with other partner countries in the sustainable management of the environment in general and biodiversity in particular.

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Annexe

The floristic composition of mountainous Lycophytes and Ferns identified in the KBNP is regrouped in two Classes (Lycopodiopsida and Polypodiopsida), 28 families, 19 Subfamilies, 67 genera and 179 taxa (176 species and infra specific taxa which include 4 subspecies and 2 varieties). The floristic list was arranged according to the phylogenetic classification of Lycophytes and Ferns (The Pteridophyte Phylogeny Group I, 2016)

CLASS LYCOPODIOPSIDA

I. LYCOPODIACEAE

I. 1. Subfamily: Lycopodielloideae

1. *Lycopodiella affinis* (Bory) Pic.Serm.
2. *Lycopodiella cernua* (L.) Pic. Serm.

I. 2. Subfamily: Lycopodioideae

3. *Lycopodium carolinum* (Lawalrée) Symoens
4. *Lycopodium clavatum* L.

I. 3. Subfamily: Huperzioideae

5. *Huperzia afromontana* Pic.Serm.
6. *Huperzia bampsiana* Pic. Serm.
7. *Huperzia dacrydioides* (Bakerer) Pic.Serm.
8. *Huperzia gnidioides* (L. F.) Trevisan
9. *Huperzia saururus* (Lam.) Trevisan

II. ISOETACEAE

10. *Isoetes welwitschii* A. Braun Ex Kuhn

III. SELAGINELLACEAE

11. Selaginella auquieri Bizzarri
12. *Selaginella kivuensis* Bizzarri
13. *Selaginella kraussiana* (Kunze) A. Braun
14. *Selaginella molliceps* Spring
15. *Selaginella myosurus* (Sw.) Alston
16. *Selaginella versicolor* Spring

CLASS POLYPODIOPSIDA

IV. EQUISETACEAE

17. *Equisetum ramosissimum* Desf. subsp. *ramosissimum*

V. PSILOTACEAE

18. *Psilotum nudum L. Beauv.*

VI. MARATTIACEAE

19. *Marattia fraxinea* Sm.

VII. OSMUNDACEAE

20. *Osmunda regalis* L.

VIII. HYMENOPHYLLACEAE

VIII.1. Subfamily: Trichomanoideae

21. *Trichomanes rigidum* Sw

22. *Crepidomanes mannii* (Hook.) J.P. Roux

23. *Vandenboschia radicans* (Sw.) Copel

VIII.2. Subfamily: Hymenophylloideae

24. *Hymenophyllum capillare* Desv.

25. *Hymenophyllum hirsutum* (L.) Sw.

26. *Hymenophyllum kuhnii* C.Chr.

27. *Hymenophyllum triangulare* Baker

IX. GLEICHENIACEAE

28. *Dicranopteris linearis* Holttum var. Linearis

29. *Gleichenia elongata* Baker

30. *Sticherus flagellaris* (Willd.) Ching

31. *Sticherus inflexus* Pichi -Serm

X. LYGODIACEAE

32. *Lygodium microphyllum* (Cav.) R. Br.

33. *Lygodium smithianum* Presl Ex Kuhn

IX. AZOLLACEAE

34. *Azolla nilotica* Decne. ex Mett.

35. *Azolla pinnata* R.BR. var. africana Desv. Baker.

36. *Salvinia nymphellula* Desv.

XII. MARSILEACEAE

37. *Marsilea minuta* L.

XIII. CYATHEACEAE

38. *Cyathea cameroonіana* (Hook.) R.M. Tryon

 # C. cameroonіana Holttum var. *aethiopica* (Welw. Ex. Hook) Holttum

#C. cameroonіana Holttum var. *Ugandensis* Holttum

39. *Cyathea dregei* Kunze

40. *Cyathea manniana* Hook.

41. *Cyathea milbraedii* (Brause) Domin

XIV. LINDSAEACEAE

42. *Odontosoria Africana* Ballard

XV. PTERIDACEAE

XII.1. Subfamily: Cryptogrammoideae

43. *Coniogramme Africana* Hieron

XII.2. Subfamily: Pteridoideae

44. *Actiniopteris dimorpha* Pic. Serm

45. *Actiniopteris semiflabellata* Pic. Serm

46. *Pityrogramma argentea* Willd.

47. *Pityrogramma calomelanos* L. Link.

48. *Pityrogramma humbertii* C. Chr. var. *elongate* C. Chr.

49. *Pityrogramma rupicola* Pic. Serm

50. *Pteris auquieri* Pic. Serm.

51. *Pteris burtonii* Baker.

52. *Pteris catoptera* Kunze

53. *Pteris cretica* L.

54. *Pteris dentate* forsk.

55. *Pteris friesii* Hieron.

56. *Pteris intricate* C.H. Wright.

57. *Pteris kivuensis* C. Chr.

58. *Pteris linearis* Poir.

59. *Pteris pteridioides* (Hook.) Ballard

60. Pteris repens (C.CHR.) ALSTON

61. Pteris tripartita SW.

62. Pteris vittata L.

XII.3. Subfamily: vittaroideae

63. *Adiantum capillus-veneris* L.

64. *Adiantum incisum*forsk.

65. *Adiantum patens* Willd. subsp. *oatesii* (Baker.) Schelpe

66. *Adiantum poiretii* Wikstr.

67. *Adiantum reniforme* L.

68. *Antrophyum mannianum* Hook.

69. *Vittaria guineensis* Desv. var. *orientalis* Hieron
70. *Vittaria reeckmansii* Pic. Serm.
71. *Vittaria volkensii* Hieron.

XII. 4. Subfamily: Cheilanthoideae
72. *Cheilanthes farinose* (Forssk.) Kaulf.
73. *Cheilanthes similis* F. Ballard
74. *Doryopteris concolor* (Langsd. Et Fisch.) Kuhn.
75. *Pellaea angulosa* (Willd.) Baker
76. *Pellaea doniana* Hook.
77. *Pellaea dura* Hook. var. schweinfurthii (Hieron.) Verdc.
78. *Pellaea longipilosa* Bonap.
79. *Pellaea pectiniformis* Baker. Et Hook.
80. *Pellaea viridis* (Kunze) Verdc. var. Canonica

XVI. DENNSTAEDTIACEAE
81. *Blotiella crenata* Alston et Schelpe
82. *Blotiella currorii* (Hook.) A.F. Tryon
83. *Blotiella glabra* (Bory) A. F. Tryon
84. *Blotiella hieronymi* (Kümmerle) Pic. Serm.
85. *Blotiella stipitata* (Alston) Faden
86. *Histiopteris incise* (Thunb.) J. Sm.
87. *Hypolepis sparsisora* (Schrad.) Kuhn
88. *Pteridium aquilinum* (L.) Kuhn
**Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum*
**Pteridium aquilinum* (L.) Kuhn subsp. *centrali-africanum* Hieron. Ex R. E. Fries

XVII. ASPLENIACEAE
89. Asplenium abyssinicum Fée.
90. *Asplenium actiniopteroides* Peter.
91. *Asplenium aethiopicum* (Burm.F.) Bech
 # Asplenium aethiopicum (Burm.F.) Bech subsp *aethiopicum*
#A.aethiopicum (Burm.F.) Bech subsp. *tripinnatum* (Baker) A.F. Braithw.
92. *Asplenium africanum* Desv.
93. *Asplenium bugoiense* Hieron
94. *Asplenium ceii* Pic. Serm.
95 Asplenium Dregeanum Kunze
96. *Asplenium elliottii* C.H.Wright
97. *Asplenium emarginatum* P. Beauv.
98. *Asplenium erectum*Bory Ex Willd. var. *usambarense* (Hieron) Schelpe
99. *Asplenium friesiorum* C.Chr.
100. *Asplenium gemmiferum* Schrad.
101. *Asplenium hypomelas* Kuhn
102. *Asplenium hemitomum* Hieron
103. *Asplenium linckii* Kuhn
104. *Asplenium kivuensis* Mangambu
105. *Asplenium macrophlebium* Baker
106. *Asplenium mannii* Hook.
107. *Asplenium megalura* Hieron
108. *Asplenium monanthes* L.
109. *Asplenium protensum* Schrad.
110. *Asplenium sandersonii* Hook.
111. *Asplenium smedsi*i Pic. Serm.
112. *Asplenium stuhlmannii* Hieron
113. *Asplenium loxoscaphoides* Baker
114. *Asplenium preussii* Hieron
115. *Asplenium rutifolium* (Bergius) Kunze
116. *Asplenium theciferum* (Kunth) Mett
117. *Asplenium variabile*Hook var. *paucijugum* (Ballard) Alston

XVIII. BLECHNACEAE
XV.1. Subfamily: Blechnoideae
118. *Blechnum attenuatum* Sw. Mell.
119. *Blechnum tabulare* (Thunb.) Kuhn

XIX. ATHYRIACEAE
120. *Athyrium Scandicinum* (Willd.) Presl.
121. *Diplazium proliferum* (Lam.) Kaulf.
122. *Diplazium zanzibaricum* (Baker.) C. Chr.

XX. THELYPTERIDACEAE
XVII.1. Subfamily: Thelypteridoideae
123. *Amauropelta bergiana* (Schltdl.) Holttum var. *Bergiana*
124. *Amauropelta oppositiformis* (C. Chr) Holttum
125. *Christella dentata* (Forssk.) Brownsey Et Jermy
126. *Christella gueinziana* (Mett.) Holttum
127. *Cyclosorus interruptus* (Willd.) H. Ito
128. *Metathelypteris vandervekenii* Pic. Serm.
129. *Pneumatopteris unita* (Kunze) Holttum
130. *Pseudocyclosorus camerounensis* Holttum

131. *Pseudocyclosorus pulcher* (Willd.) Holttum
132. *Sphaerostephanos arbuscul a*(Willd.) Holtten subsp. africanus Holttum
133. *Thelypteris confluens* (Thunb.) Morton
134. *Thelypteris striat a*(Schumach.) Schelpe

XXI. DIDYMOCHLAENACEAE
135. *Didymochlaena truncatula* (Sw.) J.Sm.

XXII. DRYOPTERIDACEAE
XIX.1. Subfamily: Elaphoglossoideae
136. *Elaphoglossum acrostichoides* (Hook. Et Grev.) Schelpe
137. *Elaphoglossum aubertii* (Desv.) T. Moore
138. *Elaphoglossum barteri* (Baker.) C.Chr
139. *Elaphoglossum conforme* (Sw.) Schott
140. *Elaphoglossum deckenii* (Kuhn) C.Chr
141. *Elaphoglossum hybridum* (Bory) Brack.
142. *Elaphoglossum kivuense* Schelpe
143. *Elaphoglossum lastii* (Bak.) C. Chr.
144. *Elaphoglossum rwandense* Pichi-Sem.
XIX.2. Subfamily: Dryopteridoideae
145. *Dryopteris Antarctica* (Baker) C.Chr.
146. *Dryopteris inaequalis* (Schltdl.) Kuntze
147. *Dryopteris kilemensis* (Hook) Kuntze
148. *Dryopteris lewalleana* Pic.Serm.
149. *Dryopteris manniana* (Hook.) C.Chr.
150. *Polystichum transvaalense* N.C.Anthony

XXIII. NEPHROLEPIDACEAE
151. *Nephrolepis biserrata* (Sw.) Schott.
152. *Nephrolepis undulate* Afz. ex Sw. J. Sm.

XIV. LOMARIOPSIDACEAE
153. *Lomariopsis congoensis* Holttum
154. *Lomariopsis hederacea* Alston

XXV. TECTARIACEAE
155. *Arthropteris monocarpa* (Cordem.) C. Chr.
156. *Arthropteris orientalis* (J.F.Gmel.) Posth.
157. *Tectaria gemmifera* (Fée) Alston
158. *Triplophyllum varians* (T.Moore) Holttum

XXVI. OLEANDRACEAE
159. *Oleandra distenta*Kunze

XXVII. DAVALLIACEAE
160. *Davallia chaerophylloides*(Poir.) Steud.

XXVIII. POLYPODIACEAE
XXVIII.1. Subfamily: Loxogrammoideae
161. *Loxogramme abyssinica*(Baker) M.G. Price
162. *Loxogramme ntahobavukiana*Mangambu & Van Diggelen

XXVIII.2. Subfamily: Platycerioideae
163. *Platycerium elephantotis* Schweinf.
164. *Platycerium stemaria* (Beauv.) Desv.
XXVIII.3. Subfamily: Drynarioideae
165. *Drynaria laurentii*(Christ) Hieron
166. *Drynaria volkensii* Hieron
167. *Pyrrosia schimperiana* (Kuhn) Alston

XXVIII.4. Subfamily: Microsoroideae
168. Lepisorus excavatus (Willd.) Ching
169. *Lepisorus robbrechtianum*Mangambu & Van Diggelen
170. *Microsorum punctatum* (L.) Copel.
171. *Phymatosorus scolopendria* (Burm.F.) Pic.Serm.

XXVIII.5. Subfamily: Microgrammoideae
172. *Microgramma lycopodioides* (L.) Copel.
173. *Pleopeltis lanceolata* Kaulf.
174. *Pleopeltis macrocarpa* (Bory Ex Willd.) Kaulf.

XXVIII.6. Subfamily: Grammitidoideae
175. *Zygophlebia villosissima* (Hook.) L.E.Bishop.
176. *Melpomene flabelliformis* (Poir.) A.R.Sm. & R.C.Moran.