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Research article

Impact of *Pteridium aquilinum* on vegetation in Nyungwe Forest, Rwanda

J.M.V. Senyanzobe [a,*], Josephine M. Mulei [b], Elias Bizuru [a], Concorde Nsengimuremyi [c]

[a] *University of Rwanda, Rwanda*
[b] *University of Eldoret, Kenya*
[c] *College of Kitabi, Rwanda*

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ABSTRACT

Pteridium aquilinum acts as an important ecological filters in dominated communities. A study to investigate the effects of its dominance in the vegetation of Nyungwe was conducted. Sampling was done in Mubuga and Uwajerome mountains. A total of 53 alternate plots measuring 10 m × 10 m were sampled along a transect at regular interval of 10 m. In each plot, the species were identified and the cover abundance measured subjectively. Plant strategies, succession, biological forms, distribution and conservation status of each species were also determined. Data on species composition and cover abundance were analyzed using MVSP software and Shannon -Weiner index was used to determine diversity of communities. Descriptive statistics were used to assess the characteristics of the species.

A total of 141 species belonging to 100 genera and 54 families and distributed in four plant communities were identified. *Pteridium aquilinum, Macaranga kilimandischarica, Lycopodium clavatum and Microglossa parvifolia* were dominant in communities I, II and III, with average cover of 31%, 6% and 4% respectively. The primary forest was dominated by *Pavetta rwandensis* and *Allophyllus chaunostachys* in community IV, with 21% and 10% coverage respectively. Shannon- Weiner and evenness indices were 1.538, 2.925, 3.251 and 2.940 and 0.436, 0.716, 0.791 and 0.768 in communities I, II, III and IV respectively. Species richness were 34, 36, 61 and 46 in communities I, II, III and IV respectively.

Ruderal, chamaephytes, secondary, Africa tropical and least concerns plant species predominated in *Pteridium* vegetation areas with 76% 48%, 69%, 43% and 90% of total species respectively. Competitive, phanerophytes, primary, Afromontane and least concerns plant species dominated in non-dominated area with 54%, 52%, 58%, 40% and 88% of total species respectively.

Pteridium aquilinum restricted the growth of trees as exhibited by the presence of few phanerophytes and enhanced the growth of ruderal species, both of which are indicators of disturbed forest. The tree species observed in *P. aquilinum* cut-areas was *Macaranga kilimandischarica*.

1. Introduction

Fires, deforestations, human clearing, cattle grazing, agricultural activities etc. are ecological disturbances that fundamentally affect an ecosystem (Cochrane and Schulze, 1999; Cochrane, 2001, Silva Matos et al., 2003).

In the case of fire, a portion of the nutrients previously held in plant biomass is returned to the soil as biomass burns (Pringle, 1979) and vegetation with the potential for rapid growth takes advantage of the lack of competition and quickly fill the gaps created by fire. Ferns species have been reported as having the ability to dominate such nutrients-deficit soils (Akomolade & Rahmad, 2018). Every fire occurred in the forest, kills trees either by burning or because the resulting heat and a few days after that fire, *Pteridium* species is sprouting vigorously on both burnt and heat-killed areas, while it is absent in the intact primary forest (Hartig and Beck, 2003).

After deforestation by fires, *Pteridium* species fast colonizes and dominates the vegetation for long time periods (Silva Gallegos et al., 2014). In addition, these species inhibit the establishment of other associated plants (Pakeman and Marrs, 1992; Calvert, 1998; Silva Matos et al., 2003).

Grass species like *Panicum maximum* and *Pteridium* species are widely known to colonize rapidly such burned areas developing large accumulation of litter (Watt, 1940; Humphrey and Swaine, 1997) and the growth

* Corresponding author.
E-mail addresses: nzobe2020@gmail.com, nzobe2000@yahoo.fr (J.M.V. Senyanzobe).

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of *Pteridium* rhizome system is always promoted by fire (Hartig; Beck, 2003). In tropical habitats, the widespread use of fire always favors an ever-increasing spread of bracken ferns (Gliessman, 1978).

Pteridium species, the most dominant species worldwide (Taylor, 1990; Marrs and Watt, 2006) establishes itself on disturbed areas by fires, deforestations and agricultural activities (Page, 1986; Schneider, 2006; Silva and Silva, 2006; and Miatto et al., 2011). The main strategies for the increase of this bracken fern are: the high resistance to diseases and pests (Cooper-Driver, 1990; Den Ouden, 2000), vegetative reproduction (Page, 1986), high density of the frond canopy and tolerance to abroad range of climatic, edaphic conditions and the presence of allopathic chemicals (Gliessman and Muller, 1976), the resistance of the rhizome to fire and adverse weather conditions allowing the colony to spread vegetatively (Fletcher and Kirkwood, 1979). Its rhizomes run deeply into the soil and is the main factor responsible for colony expansion. Its spores are dispersed all through the year and once the individuals are established, deep rhizomes allow their local persistence (Schneider, 2004).

Due to its clonal growth, longevity and persistence, *P. aquilinum* builds a dense understorey canopy of fronds that dominates the forest floor for decades and centuries (Page, 1986; Schneider, 2004). The impacts of bracken fern dominance are many and most of them are known as negative effects:(i) dense bracken competes for water and nutrients and reduces the growth of the canopy trees (Richardson, 1993; Den Ouden, 2000), (ii) the long term failure of tree regeneration results to the disappearance of tree canopy in bracken vegetation (Den Ouden, 2000; Brandt; Black, 2001), such treeless situation occurred in Mexico (Schneider, 2004), Italy (Vos & Stortelder, 1992), Great Britain (Taylor, 1990), Dutch forest ecosystems (Den Ouden, 2000), (iv) *Pteridium aquilinum* reduces biodiversity as it tends to replace species in existing habitats and there is evidence that decrease in species richness over time is due to its competitive exclusion (Pakeman et al., 2000; Lameire et al., 2000), (v) bracken fern contributes to forest fires due to the large amount of leaflet litters they produce (Adie et al., 2011) and (vi) it affects forest seed banks after invasion success thereby preventing restoration of the environment (Ghorbani et al., 2006; Silva and Silva, 2006; Miatto et al., 2011; Akomolade and Rahmad, 2018).

Nyungwe Forest in Rwanda has also experienced destructive fires in dry EI nino years of 1997 and 1998 and vegetation in the affected areas dried out as most of the species are not adapted to wildfires disturbance. Majority of the species have slow growth rate. As a result, the forest canopy was opened up in various areas totaling approximately 12% of the total forest area. Light tolerant species such as *P. aquilinum* rapidly colonized the burned areas in the forest floor and had negatively impacted seedlings and saplings leading to lack of forest regeneration (Masozera and Mulindahabi, 2007).

The aim of this study was to assess the impacts of *Pteridium aquilinum* dominance on the vegetation of Nyungwe forest. The species composition and ecological characteristics of species were assessed in paired sites, with and without *Pteridium* dominance. The aim was also to evaluate the species diversity in *Pteridium*-dominated sites and intact primary forest. We aimed to answer the following questions: (i) Are there differences in species composition between *Pteridium*-dominated site and *Pteridium*-free area site? has species diversity of Nyungwe forest reduced in areas dominated by *Pteridium*? (iii) has vegetation structure changed in areas dominated by *Pteridium*?

2. Materials and methods

2.1. Description of study area

We carried out the study in Nyungwe Forest which is situated in Western Rwanda between latitude 2˚15–2˚55 S, and longitude 29◦00–29◦30 E, and at an altitude between 1600 m and 2950 m above sea level and about 1000 square kilometers in size. Nyungwe forest experiences a cool, humid climate that is highly influenced by its topography and proximity to Lake Kivu. It receives mean annual rainfall of approximately 1800 mm and an average minimum and maximum temperature of 10.9 °C in April and 19.6 °C in August respectively. Nyungwe is the largest protected area in Rwanda and is the most biologically important montane rainforest in Central Africa (Bizuru et al., 2014).

Floristically, Nyungwe was regarded as the richest forest remaining in Rwanda with more than 240 plant species included dominant species like *Syzygium parvifolium*, *Macaranga kilimandischarica*, *Hagenia abyssinica*, *Carapa grandiflora*, *Newtonia buchananii*, *Neoboutonia macrocalyx Prunus africana*, *Symphonia globulifera*, *Cyathea manniana*, *Polyscias fulva*, *Parinaria excelsa*, *Podocarpus latifolius*, *Erica johnstonii*, *Entandophragma excelsium* and *Maesa lanceolata* (Plumptre et al., 2002). Fires occurred in Nyungwe during dry EI nino years of 1997 and 1998 allowed the forest canopy to open up in various areas and light tolerant species such *Pteridium aquilinum* var *centrali-africanum* a native of Central Africa (Thomson et al., 2005), quickly colonized the burnt areas especially in its central east part. For this reason, fire was considered as a major threat to conservation of plant biodiversity (Masozera and Mulindahabi, 2007).

Specifically, the study was carried out in that affected part and two sites were selected namely Mubuga and Uwajerome mountains (Figure 1). Mubuga site was chosen because of the great natural regeneration of bracken fern after fires, both in its highland and lowland. Uwajerome site, 50 m away to the East of Mubuga, has both secondary and primary forests. The secondary forest is due to the natural regeneration after bracken fern clearing by Wildlife Conservation Society (WSC, 2013) and the primary forest being exempt of 1997–1998 fires was taken as control site.

2.2. Methods

2.2.1. Vegetation sampling

The vegetation sampling was done systematically according Brawn--Blanquet (1932). Plant species were inventoried in plots of 10 m × 10 m which were regularly and alternatively spaced at interval of 10 m. Geographic coordinates of each plot were recorded using a GPS Garmin 12xl (Figure 2).

A total of 53 plots were sampled with 41 plots in fern bracken vegetation and 12 plots in primary forest. In the field, the sampling in fern bracken vegetation was done in the following sites: Mubuga highland (18 plots), Mubuga lowland (13 plots) and Uwajerome secondary forest after the mechanical removal of the fern occurred after fire (10 plots). The succession of the later was started with *Macaranga kilimandischarica* but also the presence of bracken fern was still significant. Uwajerome primary forest (12 plots) was sampled as control site. Because of the heterogeneity in terms of vegetation in the highland of Mubuga site, the area was stratified into 3 subzones: top, middle and lower zone (Figure 2).

2.2.2. Vegetation data recording

In each plot the following data were recorded:

(i) Cover-abundance values.

This was based on an analysis of vegetation plots using Braun-Blanquet'coefficents which use presence/absence and cover-abundance scores. Each species in the plots was identified and cover class recorded (Table 1). Cover-abundance values of each species observed in the field were recorded.

(ii) Mapping data.

GPS data were recorded by using a GPS Garmin 12xl. Areas sampled were mapped according to obtained geographic coordinates for each sampling plot (Figure 2).

(iii) Plant ecological strategies.

In the field, ecological strategies to community species were assessed according three primary ecological strategies proposed by Grime (1977):

(i) competitive strategy (**C**) which allocates species with low disturbance and stress,

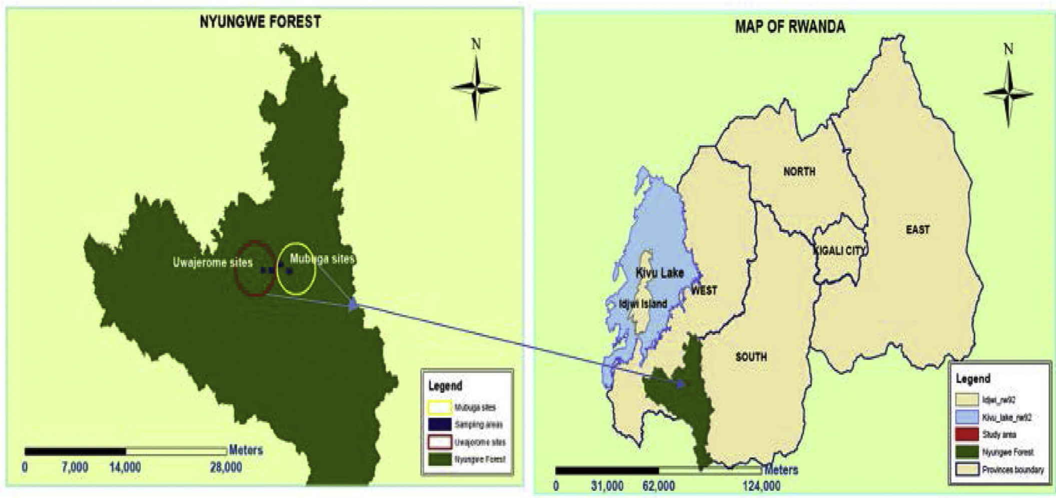

Figure 1. Location of Mubuga and Uwajerome Mountains in Nyungwe forest.

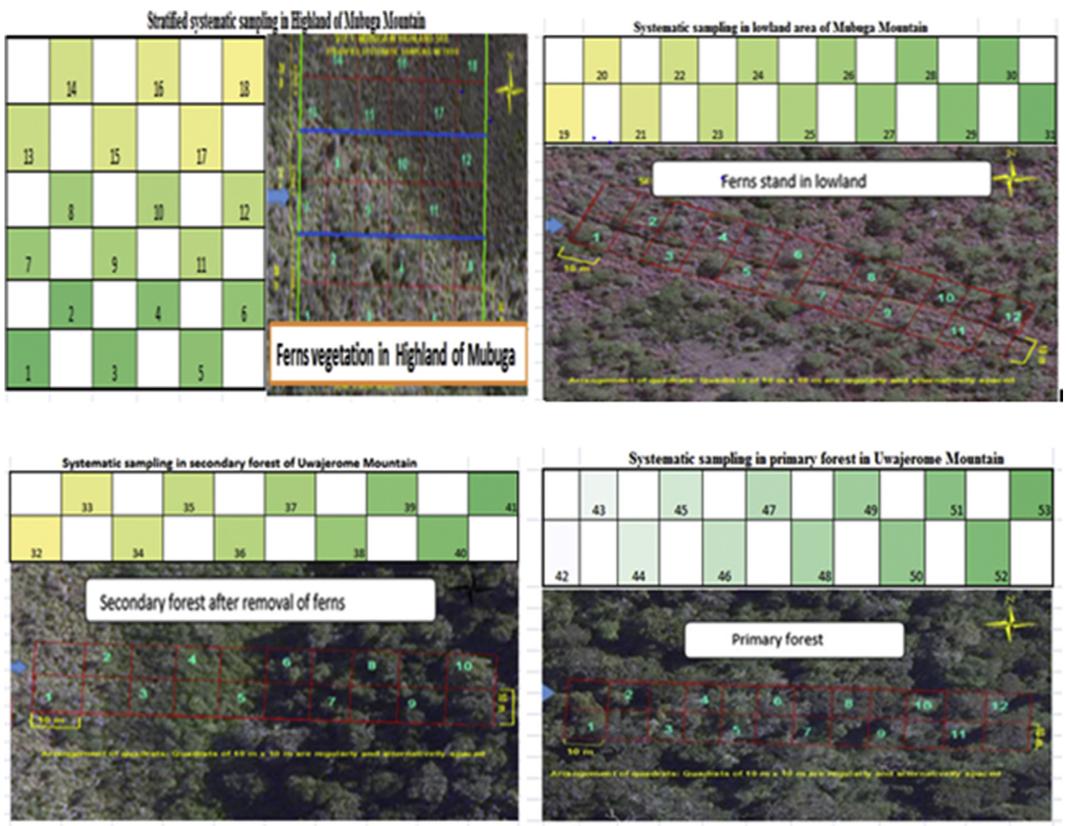

Figure 2. Areas sampled in four sites.

Table 1. Braun-Blanquet'coefficients used.

Classes	Range of cover	Mean cover percent values
5	75–100	87.5
4	50–75	62.5
3	25–50	37.5
2	5–25	15
1	1–5	2.5
+	<1	0.5

(ii) stress-tolerant strategy (**S**) which allocates species with low disturbance and high stress,
(iii) and ruderal strategy (**R**) with species adapted to low stress and high disturbance habitats.

(iv) Plant succession.

The succession of each plant species in the communities where assessed according Gibson et al. (1983) where the following were observed:

(a) primary species (**Pf**) were species which started from a point with no biological material present,
(b) secondary species (**Sf**) were species after disturbance of fire,
(c) pioneer species (**Pn**) were plant species that dominate a community in early stage.

(v) Biological forms.

Biological forms were measured according Raunkiaer methodology (1934). In the field, different forms were found as follows:

Phanerophytes **(Pha):** were mostly woody plants with perennating buds above the ground surface, fully exposed to the atmosphere and at a height of more than 40 cm.

Chamaephytes **(Cha):** were woody or semi-woody perennials with buds above the ground surface but below 40 cm.

Therophytes **(The):** were annual plants surviving only as seeds in unfavorable season.

Hemicryptophytes **(Hcry):** were perennial herbs perennating tissues at the soil surface, leaf litter or dead plants remains give the buds some protection.

Geophytes **(Ge):** were plants with subterranean organs such as bulbs, rhizomes and tubers from which shoots emerge in the next growing season.

Epiphytes **(Ep):** were plants that harmlessly grow upon other plants.

(vi) Plant phytogeographic distribution.

Community species were classified into their phytogeographic distribution (White, 1978) and (Fischer and Killmann, 2008). Cosmopolitans (**Cos**) were species found over the world, Pantropicals (**Pan**) found in all tropics, Tropicals (**Trop**) were species of the tropic, Afrotropicals (**Af-trp**) were species found in Africa tropics, Afromontane (**AME**) were species of Africa Mountain and Alberine Rift Endemics (**ARE**) were species endemic to Albertine Rift.

(vii) Conservation status.

The status of plant species was assessed in order to establish a list of threatened species following IUCN criteria (IUCN, 2012). Species were assessed in categories of threats:

(a) Critically Endangered species (**CRE**): were plant species with extreme high risk of extinction,
(b) Endangered species (**EN**): were plant species with high risk of extinction,
(c) Vulnerable species (**VU**): were plant species with high risk of endangerment,
(d) Least concern species (**LC**): were plant species with lowest risk, widespread and abundant.

(viii) Plant species identification.

Plant species were identified using taxonomic keys in Combe (1977), Troupin (1971, 1978, 1982, 1983, 1985, 1988), Bleosch (2009), and Fischer and Killmann (2008) and comparison with already identified herbarium held at the National Herbarium of Rwanda, based in Huye District. For the checklist, data from International Plant Names List (**IPN**) were used. The study done by Thomson et al. (2005) was used to identify *Pteridium aquilinum var centrali-africanum* (African fern) from *Pteridium aquilinum var aquilinum* (European fern).

2.2.3. Data analysis

Data on vegetation were analyzed using MVSP (Multivariate Statistical Package) software where variables are plots and samples (cases) are species. Correspondence Analysis of that software was used to delineate communities in all areas sampled and plant diversity of communities was calculated using Shannon- Weiner index which took into account both species and presence/absence values.

3. Results

3.1. Species composition, diversity and communities

During sampling, 141 species belonging to 100 genera and 54 families were recorded in 53 plots. Cover-abundance values of the species were analyzed and delineated four communities dominated by *Pteridium aquilinum* and *Microglossa parvifolia* (16 plots); *Pteridium aquilinum* and *Lycopodium clavatum* (13 plots); *Macaranga kilimandischarica* and *Pteridium aquilinum* (12 plots) and *Pavetta rwandensis* and *Allophylus chaunostachys* (12 plots) respectively (Figure 3). Among the recorded species, *Pteridium aquilinum* was dominant in three communities with average coverage of 31% (Tables 1, 2, and 3) and *Pavetta rwandensis* and *Allophyllus chaunostachys* were dominant in community IV with 21% and 10 % of coverage respectively (Table 4). The species diversity in communities calculated by Shannon-Weiner formula were presented in Table 5. Shannon's indices were between 1.5 and 3.5, values accepted in most ecological studies during data analysis (Mahmuda et al., 2018). Community III whose plots representing samples in secondary forest after removal of ferns was the more diverse with average values of 61 species with diversity and evenness indices of 3.251and 0.791 respectively (Table 2) followed by the community IV of 46 species with diversity and

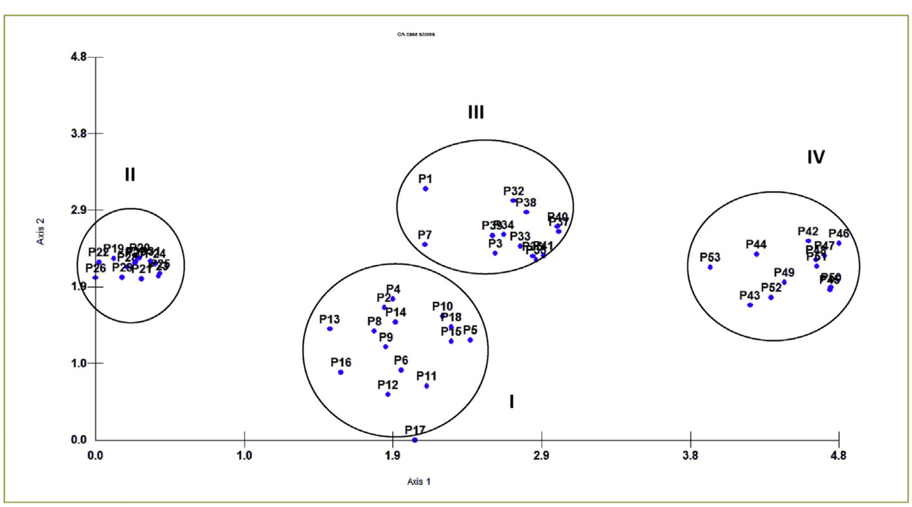

Figure 3. Individualization of communities. I: Community dominated by *Pteridium aquilinum* and *Microglossa parvifolia*. II: Community dominated by *Pteridium aquilinum* and *Lycopodium clavatum*. III: Community dominated by *Macaranga kilimandischarica* and *Pteridium aquilinum*. IV: Community dominated by *Pavetta rwandensis* and *Allophylus chaunostachys*.

Table 2. Species diversity in communities.

Community	Shannon-Weiner index		
	Diversity	Evenness	Number of species
I	1.54	0.44	34
II	2.93	0.73	36
III	3.25	0.79	61
IV	2.94	0.77	46

Table 3. Percentage of floristic data in community I.

Ecological strategies		%	Biological forms		%	Plant succession		%	Plant distribution		%	Conservation status		%
R	37	71	Pha	20	38	Pf	12	23	Cos	1	2	Lc	44	84
C	15	29	Cha	18	36	Sf	35	67	Pan	4	8	VU	2	4
			The	1	2	Pn	3	6	Trop	1	2	EN	6	12
			Ge	4	8	Epf	2	4	Af-trp	24	46	CRE	0	0
			Hcry	5	10				AME	16	30			
			Ep	3	6				ARE	6	12			
Tot. of species	**52**	**100**		**52**	**100**		**52**	**100**		**52**	**100**		**52**	**100**

Table 4. Percentage of floristic data in community II.

Ecological strategies		%	Biological forms		%	Plant succession		%	Plant distribution		%	Conservation status		%
R	37	88	Pha	7	17	Pf	2	5	Cos	2	5	Lc	40	96
C	5	12	Cha	22	53	Sf	36	85	Pan	4	10	VU	0	0
			The	1	2	Pn	2	5	Trop	3	7	EN	1	2
			Ge	2	5	Epf	2	5	Af-trp	20	48	CRE	1	2
			Hcry	9	21				AME	7	16			
			Ep	1	2				ARE	6	14			
Tot. of species	**42**			**42**	**100**		**42**	**100**		**42**	**100**		**42**	**100**

Table 5. Percentage of floristic data in community III.

Ecological strategies		%	Biological forms		%	Plant succession		%	Plant distribution		%	Conservation status		%
R	61	73	Pha	30	35	Pf	6	7	Cos	2	2	Lc	76	91
C	23	27	Cha	45	55	Sf	73	87	Pan	7	8	VU	2	2
			The	1	1	Pn	5	6	Trop	2	2	EN	6	7
			Ge	2	2	Epf	0	0	Af-trp	30	35	CRE	0	0
			Hcry	4	5				AME	30	35			
			Ep	2	2				ARE	15	18			
Tot. of species	**84**	**100**		**84**	**100**		**84**	**100**		**84**	**100**		**84**	**100**

evenness indices of 2.940 and 0.768 respectively (Table 2). The lowest richness was observed in communities of ferns vegetation after fires represented by communities I&II of 34 and 36 species, diversity indices of 1.538 and 2.923 and evenness of 0.436 and 0.716 respectively (Figures 4, 5, and 6).

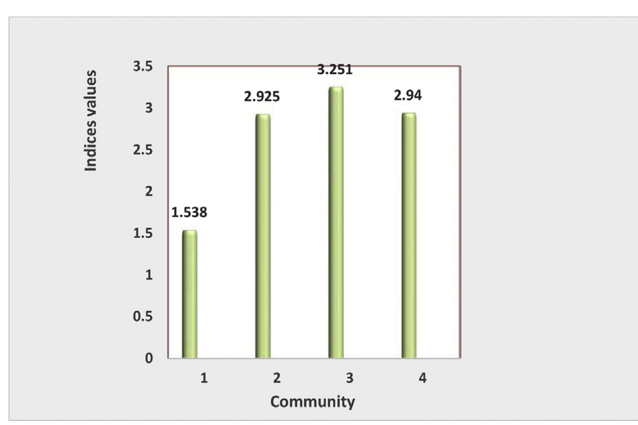

Figure 4. Shannon index in communities.

3.2. Species characteristics

Species characteristics such as ecological strategies, biological forms, plant succession, and plant distribution and conservation status in the four communities were determined and each community was shown the percentage of species recorded as vegetation characteristics (Tables 3, 4, 5, and 6).

4. Discussion

The species in plots varied considerably between the sites of sampling areas. The vegetation was dominated by one species of fern (*Pteridium*

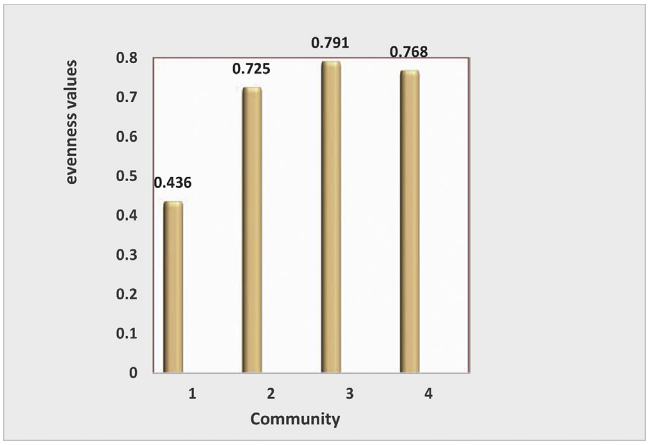

Figure 5. Species evenness in communities.

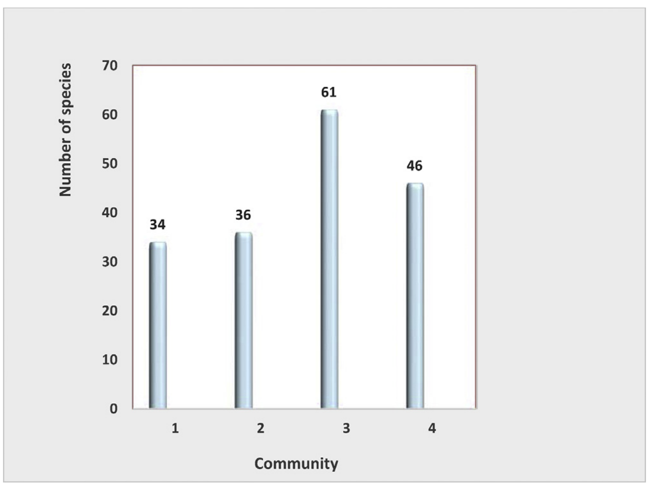

Figure 6. Species richness in communities.

aquilinum) in plots characterized as burned zones with a coverage of 61.8% and 17.4 respectively in highland and lowland areas of Mubuga site (Tables 1 and 2).

In the Uwajerome primary forest which was taken as control site, *Pteridium aquilinum* was rarely represented with 0.1% of the coverage (Table 4). However, in the Uwajerome secondary forest where the bracken fern was removed mechanically, *Macaranga kilimandischarica* was the most dominant species with coverage of 16.3% as compared to 13.4 % of *P.* aquilinum (Table 3). The species of *Macaranga kilimandischarica* was dominant because of its fast colonization in clear-cut areas and its requirements of high light and therefore tends to outgrow other trees (Fiala et al., 2011).

A biodiversity surveys done in 13 sites of Nyungwe Forest by Plumptre et al. (2002) recorded an herbaceous layer dominated by one species of *Pteridium aquilinum* which corroborates with the current study. A study curried out by Matos et al. (2002) recorded that fire events during dry seasons from 1991- 2000 in the National park of Tijuca (Brazil) has enabled dominant vegetation including *Pteridium aquilinum*. Fire was observed in 1993, 1995, 1999 years with 76 events/year including large and small events. The author stated that even if fire events are short, their frequency produce enormous changes in plant community. As pointed out by Cochrane and Schulze (1999), frequent fires may create forested areas with less tree density and reduce regeneration and tropical trees are vulnerable to fire (Uhl and Kauffman, 1990).

Our results suggest hence that, the *Pteridium* dominance has reduced the densities of wood species. The densities of phanerophytes (most shrubs and trees) were lower in dominated areas compared to the non-invaded ones. However, the removal of ferns has promoted *Macaranga* species.

Scali et al. (2019) experimentally examined seed germination, seedling survival and seedling growth of 14 woody species including *Macaranga capensis* in Bwindi National Park (Uganda). Experimental plots were under six field conditions of bracken fern stands including removing ferns by cutting fronds and leaving the litter intact. Authors recorded that *Macaranga capensis* germinated more frequently in that treatment than in the five other treatments. This corroborates with our results in Uwajerome plots where *Macaranga kilimandischarica* was dominant because the ferns were removed but litter remained. This confirms that *Macaranga* species cannot grow under bracken shade but when its fronds are removed, its opens up the light to *Macaranga* which tends to outgrow other trees. Another study done by Miatto et al. (2011) in Brazilian Cerrado showed that the bracken dominance has changed the species composition and structure of the wood vegetation. In Cerrado sites, areas invaded by neotropical bracken had fewer woody plant species than the non-invaded areas. This corroborates with our findings that bracken communities had restricted the growth of trees with the presence of few phanerophytes compared to the non-bracken community.

Species diversity was shown that *Pteridium aquilinum* and *Microglossa parvifolia* and *Pteridium aquilinum* and *Lycopodium clavatum* communities in both Mubuga highland and lowland were less floristically diversified: diversity index equals to **1.538** and **2.925** respectively than the community without ferns: diversity index equals to **2.940** (Figure 4). The most diversified of all was the *Macaranga kilimandischarica* and *Pteridium aquilinum* community which constitutes ferns -cut area: diversity index equals to **3.251** with **61** species (Figure 4 and Figure 6). Miatto et al. (2011) have demonstrated Pteridium invasion can impact and effect the vegetation structure, but also is reducing floristic diversity. Pakeman and Marrs (1992) also reported that the cutting of bracken stands can reduce frond density and break up the litter layer and those can accelerate colonization by other species. There is evidence that if *Pteridium* cover is reduced, especially where the litter layer has been disturbed example by

Table 6. Percentage of floristic data in community IV.

Ecological strategies		%	Biological forms		%	Plant succession		%	Plant distribution		%	Conservation status		%
R	24	46	Pha	27	52	Pf	30	58	Cos	1	2	Lc	46	88
C	28	54	Cha	16	30	Sf	22	42	Pan	3	6	VU	2	4
			The	1	2	Pn	0	0	Trop	0	0	EN	4	8
			Ge	1	2	Epf	0	0	Af-trp	14	27	CRE	0	0
			Hcry	4	8				AME	21	40			
			Ep	3	6				ARE	13	25			
Tot. of species	**52**	**100**		**52**	**100**		**52**	**100**		**52**	**100**		**52**	**100**

R: Ruderal; **C**: Competitive; **Pf**: Primary forest; **Sf**: Secondary forest; **Pn**: Pioneer; **Epf**: Earlier primary forest; **Pha**: Phanerophyte; **The**: Therophyte; **Cha**: Chamaephyte; **Ep**: Epiphyte; **Hcry**: Hemicryptophyte; **Ge**: Geophyte; **COS**: Cosmopolitan; **PAN**: Pantropical; **ARE**: Albertine Rift Endemic; **Af-trp**: Afrotropical; **Trop**: Tropical; **AME**: Afromontane Element; **CRE**: Critical Endangered; **EN**: Endangered; **VU**: Vulnerable; **LC**: Least Concern.

animal tracks, there can be rapid tree invasion and also experiments done for reducing *Pteridium*, mortality of seedlings is reduced and their performance increases (Marrs and Watt, 2006). Our results also found that bracken-cut area was the more diverse site than bracken vegetation. As bracken was cut in Uwajerome site (WCS, 2013), a natural regeneration was proceeded owning more species than before. The increase of species in bracken – cut area (**61** species) compared to other communities is due to the advantages of cutting mechanism cited above.

Phanerophytes (shrubs and trees) were less represented in fern vegetation contributing 38%, 17% and 35% of the total species in communities I, II and III respectively and most abundant in community IV with 52 % of total species (Figure 7). This agrees with the theory that bracken fern, once established, inhibits further colonization by other species including trees due to its large accumulation of litter which prevent other species from colonizing (Pakeman and Marrs, 1992) and the suppression of tree colonization makes treeless situation in bracken vegetation (Marrs and Watt, 2006).

According Grime (1979) ruderals are species adapted to disturbed areas. This correlated with our study where ruderal species were abundant in bracken vegetation represented by the communities I, II and III with 71%, 88% and 73% of the species respectively (Tables 3, 4, and 5 and Figure 7) while competitive species were most abundant in community IV contributing 54% of the total species (Table 6 and Figure 7). Bracken fern dominance seen as a perturbation, similar to secondary forests, leads to a change in plant distributions patterns (Schneider, 2006). Nyungwe Forest belonging to the afromontane forest and the Albertine Rift region (Plumptre et al., 2002, 2006; Ayebare et al., 2018), the afromontane (**AME**) and Albertine Rift (**ARE**) species were supposed to dominate in areas sampled but in this study, those species were decreased gradually from the primary forest to the natural regenerations after removal of fern and after fires. In the primary forest, 40 % and 25 % of total species belonged to AME and ARE respectively while in the secondary forest of lowland of Mubuga site, they were 16% and 14% of total species respectively (Table 6 and Figure 7). The reduction of characteristic species distribution in *Pteridium* - dominated area is an indicator of extinction of some species. According the Rwanda Environment Management Authority (REMA, 2015), the threats that affected the Nyungwe forest were also affecting its biodiversity. Among them, wildfires caused a substantial loss of the forest. The burned area was immediately colonized with a fern species (*Pteridium aquilinum*) which formed a dense layer of 1–2 m in height, blocking out light and reducing or preventing the natural regeneration of tree seedlings. In this study, the same species was in general dominant in secondary forests represented by communities I, II and III. In the report on national list of threatened species established by REMA, 2015, the following species were recorded in Nyungwe forest as threatened species**:** *Lobelia milibraedii* (CRE), *Bersama abyssinica* (EN), *Caesaeria runssonica* (EN), *Chassalia subochreata* (EN), *Erica johnstonii* (EN), *Harungana montana* (EN), *Ocotea usambarensis* (EN), *Prinus africana* (EN) and *Lobelia petiolata* (VU). In this study, the same species were also found as threatened species in remaining forest community. It means tree species recorded as threatened species were more concerned at any disturbance that why fire events cleared up the dense forest and promoted *Pteridium aquilinum* which is wide tolerant and high competitive.

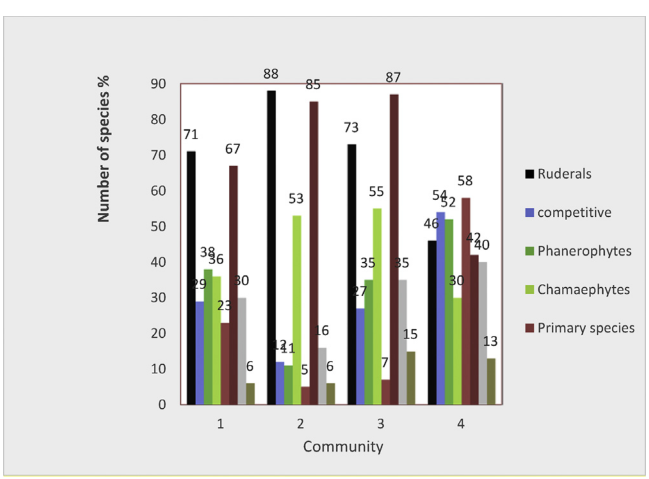

Figure 7. Species characteristics between communities.

5. Conclusion

A study was conducted in Nyungwe forest with the objective to investigate the effects of *Pteridium aquilinum* on vegetation after 1997–1998 years of wildfires. Ecological data were taken in Mubuga and Uwajerome sites. The data analysis was shown the dominance of *Pteridium aquilinum, Microglossa parvifolia, Lycopodium clavatum,* in Mubuga whereas *Pavetta rwandensis* and *Allophylus chaunostachys* were dominant Uwajerome site. However, the removal of *P. aquilinum* was promoted the dominance of *Macaranga kilimandischarica* and also increases species diversity. In forest community, phanerophytes and primary species remained dominant. Disturbed communities were dominated by ruderal species and most of them were chamaephytes and secondary species and afro-tropical species were also dominant. Majority of the encountered species were not threatened. In conclusion, the presence of *Pteridium aquilinum* changed the vegetation pattern of Nyungwe forest by suppressing phanerophytes communities and promoting chamaephytes and ruderal species, characteristic of disturbed areas but also of less trees.

5.1. Recommendation

Fire events always enable dominant species including *Pteridium aquilinum* which changes the vegetation structure. From this study, the following recommendations are made:

1 Control fires since it promotes bracken ferns in the forest
2 Device a mechanism of controlling further spread of the bracken fern
3 Device a mechanism of regenerating wood species in bracken community

Declarations

Author contribution statement

Jean Marie Vianney Senyanzobe: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Josephine Mumbe Mulei: Conceived and designed the experiments.

Elias Bizuru: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

Concorde Nsengumuremyi: Analyzed and interpreted the data.

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The authors declare no conflict of interest.

Additional information

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