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IMPACT OF REMOVING *EUCALYPTUS MAIDENII* IN REGENERATED NATIVE SPECIES IN GISHWATI-MUKURA NATIONAL PARK, RWANDA

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ABSTRACT

This study assessed the impact of removing Eucalyptus maidenii in the natural regenerated native species in Gishwati-Mukura National Park, Northern-Western Rwanda. Data were collected in the areas where Eucalyptus maidenii species were removed and were compared to the areas still occupied by Eucalyptus maidenii species. Data were collected using random sampling in quadrat plots of 10 m and sub-quadrat of a 1 m square. Within each site, herb species and woody plant species having the diameter at breast height (DBH) less than 2 cm were inventoried. Sampled plant species were analyzed focusing on abundance and diversity indices using bio-professional software. A total of 347 and 391 native woody species were identified in the areas where Eucalyptus maidenii were removed compared to 26 and 38 native woody species identified in the areas still occupied by Eucalyptus maidenii in Mukura and Gishwati correspondently. In relation with herb species, a total of 1,000 and 1,142 herb species were recorded in the areas where the Eucalyptus maidenii were removed compared to 227 and 323 herb species identified in the sites still occupied by Eucalyptus maidenii species in Mukura and Gishwati respectively. The herb species regenerated in the areas which were occupied by Eucalyptus maidenii were significantly different from the herb species regenerated in areas under Eucalyptus maidenii species. Further, higher plant species richness was recorded where Eucalyptus maidenii was removed. This study recommends avoidance of Eucalyptus maidenii planting in natural forests due to their effects on species richness of natural woody and herb species.

Keywords: Abundance, diversity, exotic, richness

Correct Citation of this Publication

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INTRODUCTION

Eucalyptus tree species originates from Australia and they were introduced in Rwanda since 1920s (Nsengimana, 2020).They were mainly planted for timber, fuelwood, and stakes for climbing beans (Mugunga, 2016;

Gessesse Dessie, 2011; Iiyama *et al*., 2018). The species were quickly adopted in Rwanda as they were appreciated for their high growth rate, and high production associated with high adaptations to different environments of Rwanda. However, negative effects on the environment caused by *Eucalyptus* species, particularly *Eucalyptus maidenii* were also reported (Calvino-cancela *et al.*, 2013). These include the loss of habitat for native species both plants and animals, and hence contribute to the understory biodiversity loss (Demers *et. al.*, 2016), and changes in soil quality (Hua-Feng Wang *et al*. 2011), mainly due to the chemical substances contained in the leaves of *Eucalyptus maidenii* (Chu *et al.*, 2014).

To enhance environmental conservation, different activities were initiated to remove *Eucalyptus* and restore natural environments occupied by these tree species. Restoration was appreciated to retrieve ecological functions of the area including carbon sequestration, and supporting wildlife biodiversity (Musabyimana,2014). Restoration contributes also to the recovery of degraded ecosystems, provision of suitable habitats for wild biodiversity, maintenance of ecological integrity (Sabogal et al., 2015) and helps degraded ecosystems to bounce back to nearby their natural state (Bullock *et al.*, 2011). Further, restoration is appreciated to offer food, suitable ecological niches, medicine, fodder for livestock, fruits, gums and fuel wood (Jabeen *et al.*, 2009). These were supported by different studies in different countries such as the ones conducted in North America, *(Maynard-bean et. al.*, 2019), Southern Western India (Selwyn and Ganesan, 2009), and China (Chu *et al*., 2014).

In Rwanda, the Landscape Approach to Forest Restoration and Conservation (LAFREC), a five years' project operating under Rwanda Environmental Management Authority (REMA) supported by the Global Environmental Facility (GEF) through the World Bank had the mandate to rehabilitate the Gishwati-Mukura landscape. The main goal was the conservation of the area through the increase of the forest cover, mitigate for climate change and restoration of degraded sites in the area (Musabyimana, 2014). The removal of *Eucalyptus maidenii* in the Parks started in 2015 while the regeneration of native tree species started in 2016. However, the effectiveness of the removal of *Eucalyptus maidenii* species on ecological functions and environmental balance remains a research of interest.

This study assessed the effects of removing *Eucalyptus maidenii* species in natural regenerated native species in the Gishwati-Mukura National Park, Northern-Western Rwanda. The specific objectives were to : (a) compare the abundance of regenerated herbs and woody tree species in the areas where *Eucalyptus maidenii* were removed; and (b) compare the herb and woody trees species diversity regenerated in the areas where *Eucalyptus maidenii* species were removed. For each objectives, findings were compared with abundance in the areas still occupied by exotic tree species. The main purpose was to identify the diversity and abundance of native woody and herb species under the regenerated areas compared to the areas still dominated by *Eucalyptus maidenii* species in Gishwati-Mukura National park.

MATERIAS AND METHODS

Study area

The study was conducted in Gishwati and Mukura forests located in Northern-Western part of Rwanda (Figure 1), between 1°49' S and 29°22'E, at the altitude ranging between 2000 m and 3000 m. The average annual temperature is 10°C, and the rainfall is ranging between 1200 -1500 mm per year (Forest and hope of Association, 2017). The soil type of is umbrisol that has been formed from the decomposition of organic matter which in turn enriched the soil in nutrients (Kisioh, 2018). Gishwati and Mukura forets were declared Gishwati - Mukura national park by the law Nº45/2015 of 15 October 2015 in the gazette of 01 February 2016.

The forest was one continuous forest before being affected by human activities (Musabyimana, 2014). Gishwati was the secondary large forest in Rwanda dominated by indigenous mountain rain forest, covering around 100,000 hectares. In 1970s, the forest was reduced to 28,000 hectares due to the conversion of natural land into cattle ranching, settlements, and small farms. Around 12.5% of the forest was replaced by pine and *Eucalyptus maidenii* (Kisioh, 2018). In 1980, around 70% of Gishwati natural forest was converted into pasture land, and *Eucalyptus maidenii* species were planted alongside cattle ranching (Kisioh, 2018). After 1994, both Gishwati and Mukura natural forest were cleared for agricultural activities. Later the two forests were restored by planting exotic species mainly *Eucalyptus maidenii* and *Acacia mearnsii* tree species (Kisioh, 2018).

Mukura Forest Reserve, the neighboring of Gishwati, had a total area of 2000 hectares around 1951s. Due to human activities, it has been reduced to 1,200 hectares mainly due to encroachment and agricultural activities, cutting trees for timber, rope, and stick (Kisioh, 2018). Later, tree planting dominated by *Eucalyptus maidenii*, *Acacia mearnsii* and *Acacia melanoxylon* took the rise in degraded lands (Richardson and Pys, 2006). These species continued to spread by themselves due to the seed dispersal capacity, and competition with native species (Kisioh, 2018). The remaining Gishwati and Mukura natural forests supports an isolated population including chimpanzees (*Pan troglodytes*), golden monkeys (*Cercopithecus mitis kandti*), L'Hoest's monkeys (*Cercopithecus l'hoesti*), and more than 130 species of birds (Chancellor *et al.*, 2012). The remaining patch of Mukura forest hosts an interesting biodiversity, including 243 plant species (Rwanda, 2011). A recent study indicated that Gishwati-Mukura is a home of around 155 bird species (Inman and Ntoyinkama, 2020). The removal of *Eucalyptus maidenii* exotic species was done by debarking and stump up rooting was started in 2015 at Gishwati-Mukura National Park.

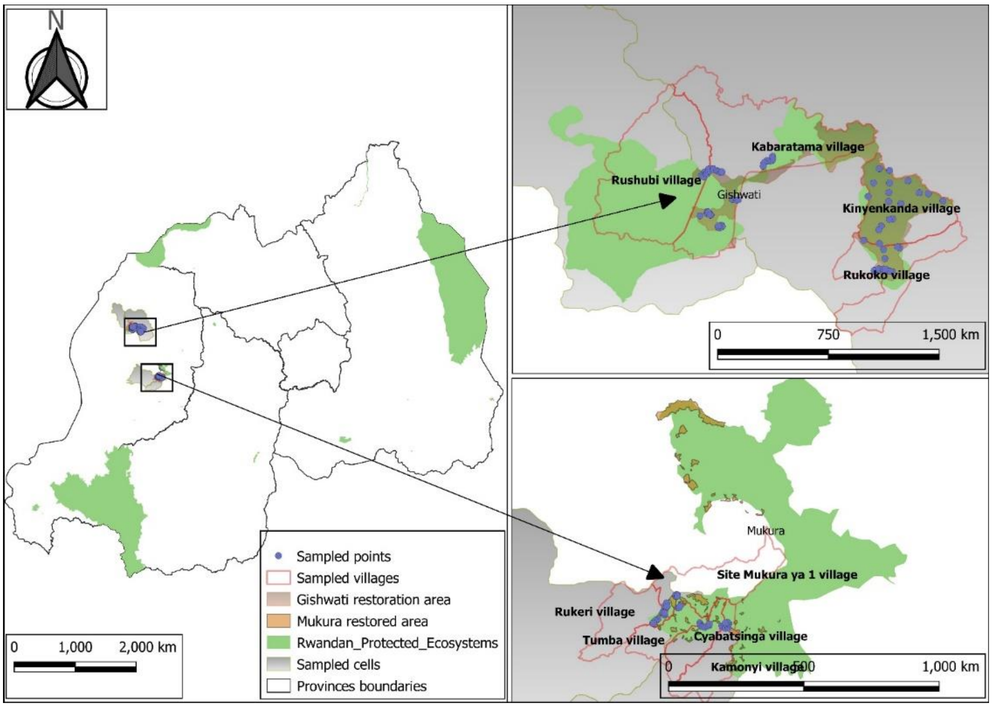

Figure 1: Location of sample plots at Gishwati-Mukura National Park (Adapted from Rwanda base map 2014).

Experimetal design

Eucalyptus maidenii species was removed in patches of Gishwati-Mukura National Park with a total of 63ha. A purposive sampling method was used to locate the areas where *Eucalyptus maidenii* were removed. Thereafter, simple random sampling method was used to locate the plots where each plot had equal probability of being selected to represent the population (West, 2016). The areas removed by *Eucalyptus maidenii* were identified together with the local community. Within each site, a quadrat plot of 10m separated by 50m from others was randomized on the site, and woody plant species having DBH less than 2 cm were inventoried. Inside each quadrat, a one-meter square sub-quadrat was used for herb species inventory and identification. Nine sampling sites were in the areas where *Eucalyptus maidenii* species were removed, while other nine sampling sites were located in the areas still occupied by *Eucalyptus maidenii*. In each site, 4 sampling points were established totaling 72 sampling points.

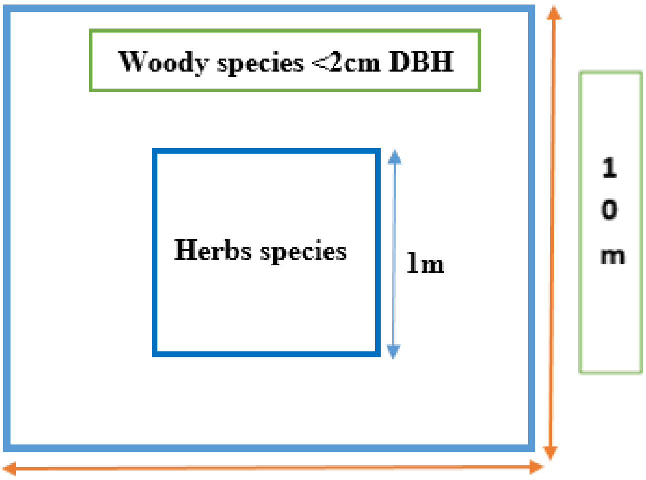

Figure 2: Experiment design in the study areas

Data collection

Data were collected within Gishwati –Mukura National Park. The number of stems and their species name were collected in the areas where *Eucalyptus maidenii* species were removed and were also collected in the areas still occupied by *Eucalyptus maidenii* with the main purpose to assess the effect of exotic tree species on native tree species. Local people from the communities around the park who participated in the removal of *Eucalyptus maidenii* helped to localize the sites.

Both scientific and vernacular species names were identified and recorded for native tree and herb species following the identification key developed by Fischer and Killmann, (2008) and Plant List Database (www.theplantlist.org, 2013). Further, tree DBH was measured using small digital caliber of high-quality carbon steel, heat treated and quenched to provide a precise measurement of an object with an increment of 0.01 mm. The number of native plant stems present at each sampling point and sampling site were counted.

Data analysis

The herb species, and woody plant species were identified to species level. Counted numbers were used to calculate the abundance, Shannon diversity (H') and evenness indices (J) for each sampling point, sampling site. Then after, the mean abundance and diversity were calculated for the sites where *Eucalyptus maidenii* were removed and compared with the abundance and diversity in the areas still dominated by *Eucalyptus maidenii* species. Further, the Bray-Curtis similarity cluster analysis and rarefaction curves were analyzed using the bio-professional software version 2. The one-way ANOVA was used to test for significance difference in the abundance of identified regenerated plant species.

RESULTS

Abundance of native herbs species

A total of 1,142 individual herb species (71.43 ± 4.17; mean ± *SD*) was identified at Gishwati while1,000 individuals herb species (50.02±6.03) were identified in Mukura, specifically in the sites where *Eucalyptus maidenii* were removed. These abundances were higher compared to those found in the areas still occupied by exotic tree species, mainly *Eucalyptus maidenii*, where 323 individual herb species (20.34 ± 1.91) were identified in Gishwati, while 227 individuals (11.41±0.54) were identified in Mukura (Table1). Further, significant differences in herb species were found in the areas where *Eucalyptus maidenii* were removed compared to the areas where regenerated native species are still mixed with *Eucalyptus maidenii* species in Gishwati (P = 0.0014) and Mukura (P= 0.0002). Dominant herb species in the areas free from *Eucalyptus maidenii* are *Phyllanthus nummulariifolius, Coelachne africana*, and *Lycopodiella clavatum* found in Gishwati, while dominant herb species in Mukura include *Paspalum scrobiculatum, Phyllanthus nummulariifolius, Pycreus nigricans*, and *Virectaria major* (Table 1).

Table 1: Inventory of herb species in *Gishwati-Mukura National Park*

Herb species name	Gishwati				Mukura			
	A		B		A		B	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
A splenium friesiorum	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Alchemilla ellenbeckii	0.00	0.00	0.00	0.00	2.00	3.46	0.00	0.00
Alchemilla johnstonii	0.00	0.00	8.80	10.05	2.00	2.83	1.80	1.79
Alectra sessiliflora	6.00	5.48	0.00	0.00	4.40	6.58	0.00	0.00
Asplenium friesiorum	0.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Asplenium kuhnianum	3.75	7.50	0.00	0.00	0.80	1.79	0.00	0.00
Botrioclyne longipes	0.00	0.00	0.00	0.00	3.60	5.37	0.00	0.00
Brillanthaisia nitens	0.00	0.00	0.00	0.00	3.20	4.60	0.00	0.00
Canarina eminii	2.50	5.00	0.00	0.00	0.00	0.00	0.00	0.00
Carex conferta	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Clematis simensis	0.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Coelachne africana	104.30	63.40	11.70	3.86	19.60	5.41	9.40	11.70
Conyza welwitschii	0.00	0.00	0.00	0.00	0.40	0.89	0.00	0.00
Crassophorum paludum	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Crassophorum vitellinum	0.75	1.50	0.00	0.00	0.00	0.00	0.00	0.00
Cyanotis barabata	5.75	7.80	1.75	2.06	3.00	5.66	0.41	0.89
Digitaria abyssinica	0.00	0.00	0.00	0.00	3.00	6.71	0.00	0.00
Drymaria cordata	3.25	3.77	0.50	1.00	10.2	11.08	0.00	0.00
Epilobium salignum	0.00	0.00	0.00	0.00	0.00	0.00	2.60	3.29
Helichrysum foetidum	0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Helichrysum globosum	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Helichrysum helvolum	1.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrocotyle mannii	0.00	0.00	3.50	7.10	0.00	0.00	0.00	0.00
Hypericum scioanum	0.00	0.00	0.00	0.00	6.00	8.22	0.00	0.00
Impatiens burtonii	0.75	1.50	0.00	0.00	5.40	9.10	0.00	0.00
Impatiens gesneroidea	1.25	2.50	0.00	0.00	0.00	0.00	0.00	0.00
Impatiens kagamei	1.25	2.50	0.00	0.00	0.00	0.00	0.00	0.00
Impatiens niamniamensis	3.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00
Ipomea involucrata	13.30	3.86	0.00	0.00	5.00	2.35	0.00	0.00
Isachne mauritiana	0.00	0.00	9.50	13.2	0.00	0.00	1.64	3.58
Isodon ramosissimus	0.00	0.00	0.00	0.00	7.20	10.08	0.00	0.00
Kyllinga appendiculata	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Kyllinga stenophylla	11.30	19.31	9.75	14.7	7.00	4.00	4.62	4.22
Lindernia nummulariifolia	0.00	0.00	0.00	0.00	3.60	4.98	0.00	0.00

Lotus becquetii	0.00	0.00	3.75	7.50	0.00	0.00	0.00	0.00
Lycopodiella cernua	0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Lycopodiella clavatum	15.00	30.01	0.00	0.00	0.00	0.00	0.00	0.00
Lycopodium clavatum	21.80	25.12	0.00	0.00	0.00	0.00	0.00	0.00
Mariscus tomaiophyllus	0.00	0.00	0.75	1.50	0.00	0.00	0.00	0.00
Mimulopsis excellens	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Otiophola pauciflora	15.50	31.02	0.50	1.00	0.00	0.00	0.62	1.34
Panicum eickii	0.00	0.00	0.00	0.00	0.61	1.34	0.00	0.00
Paspalum scrobiculatum	0.00	0.00	0.00	0.00	8.43	14.29	5.21	5.72
Pennistum clandestinum	0.00	0.00	13.5	12.9	1.44	1.95	0.43	0.89
Phyllanthus nummulariifolius	22.30	18.30	7.75	8.38	24.81	5.97	1.22	1.10
Plantago palmate	0.00	0.00	2.25	2.63	0.43	0.89	0.00	0.00
Plectranthus serrulatus	0.75	1.50	0.00	0.00	3.41	6.07	0.00	0.00
Pneumatopteris afra	3.50	7.00	0.00	0.00	0.00	0.00	0.00	0.00
Pteridium aquilinum	10.00	7.12	2.25	1.50	2.10	3.08	2.41	4.34
Pycreus nigricans	0.00	0.00	0.00	0.00	11.20	25.04	0.00	0.00
Rubus steudneri	3.25	2.36	0.00	0.00	0.00	0.00	0.60	1.34
Rumex abyssinicus	0.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Scleria distans	8.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00
Senecio maranguensis	7.50	9.88	0.00	0.00	10.40	7.92	1.22	2.68
Senecio subsessilis	0.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Solenostemon sylvaticum	2.25	4.50	0.00	0.00	0.00	0.00	0.00	0.00
Spermacoce princea	15.80	9.00	4.50	4.80	11.20	5.81	2.40	2.88
Swertia usambarensis	0.00	0.00	0.00	0.00	6.01	8.25	0.00	0.00
Torenia thouarsii	0.00	0.00	0.00	0.00	5.40	12.07	5.63	3.65
Vigna parkeri	0.00	0.00	0.00	0.00	1.40	1.95	0.00	0.00
Virectaria major	0.00	0.00	0.00	0.00	23.40	24.11	5.41	8.35
Total		**1142**		**323**		**1000**		**227**
Mean individual per plot		**71.43**		**20.34**		**50.02**		**11.41**
***SD* per plot**		**4.17**		**1.91**		**6.03**		**0.54**

Areas free from Eucalyptus maidenii (A) and area where Eucalyptus maidenii are mixed with regenerated native species (B) in Gishwati and Mukura.

Abundance of native woody species

We identified a total of 391 individuals of native woody species (23.63 ± 1.08) and 347 individuals of native woody species (18.11 ± 1.70) in the areas free from *Eucalyptus maidenii* in Gishwati and Mukra respectively. The abundance was less in the sites where *Eucalyptus maidenii* is still mixed with regenerated native tree species, where specifically 38 individuals of native woody species (2.42 ± 0.36) and 26 individuals of native woody species (1.34 ± 0.09) were identified in Gishwati and Mukura respectively (Table 2). Dominant woody species in the areas of Gishwati where *Eucalyptus midenii* were removed include: *Macaranga kilimandscharica*, *Bothriocline ruwenzoriensis*, and *Maesa lanceolate* native tree species, while Mukura was dominated by *Triumfetta cordifolia*, *Psychotria mahoni*, and *Bothriocline ruwenzoriensis* native woody species in the areas where *Eucalyptus maidenii* were removed (Table 2). Further, significant differences were found in the abundance of woody tree species in Gishwati (P = 0.0005) and Mukura (P < 0.001) when the areas dominated by *Eucalyptus maidenii* were compared with those where *Eucalyptus maidenii* has been removed.

Table 2: Inventory of native woody species

Species	Gishwati				Mukura			
	A		B		A		B	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Apodyte dimidiata	6.02	6.93	1.50	1.91	0.00	0.00	0.00	0.00
Bersama abyssinica	0.00	0.00	0.00	0.00	1.40	1.95	0.00	0.00
Bothriocline nyungwenzis	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Bothriocline ruwenzoriensis	16.00	7.62	0.30	0.50	5.80	4.09	0.40	0.89
Bothriocline ugandensis	2.01	4.00	1.31	1.26	0.00	0.00	0.00	0.00
Carapa grandiflora	0.40	0.89	0.00	0.00	0.00	0.00	0.00	0.00
Casearia runssorica	2.20	3.49	0.00	0.00	0.00	0.00	0.00	0.00
Clerodendron johnstonii	0.50	1.00	0.00	0.00	1.00	1.41	0.00	0.00
Clutia abyssinica	2.75	3.59	0.80	1.50	4.40	4.62	0.61	0.89
Croton megalocarpus	0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Dombeya goetzenii	0.00	0.00	0.00	0.00	3.40	3.61	0.82	1.79
Dombeya torida	2.01	4.00	0.00	0.00	0.00	0.00	0.00	0.00
Faurea saligna	0.25	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Ficus thonningii	0.00	0.00	0.00	0.00	0.60	1.34	0.00	0.00
Hagenia abyssinica	0.75	0.96	0.0	0.00	1.20	1.30	0.00	0.00
Harungana montana	0.00	0.00	0.00	0.00	0.20	0.45	0.00	0.00
Keetia gueinzii	2.03	2.83	0.00	0.00	2.80	2.39	0.00	0.00
Lobelia gibberoa	7.50	2.38	3.80	2.63	4.80	5.07	0.60	0.89
Macaranga kilimandscharica	17.80	9.67	1.50	1.00	4.40	2.30	0.21	0.45
Maesa lanceolate	9.25	2.63	0.00	0.00	6.20	1.10	0.00	0.00
Myrianthus holstii	0.75	1.50	0.00	0.00	0.00	0.00	0.00	0.00
Myrsine melanophloeos	0.00	0.00	0.00	0.00	2.60	4.34	0.60	0.89
Neoboutonia macrocalyx	0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Podocarpus falcatus	0.00	0.00	0.00	0.00	0.40	0.89	0.00	0.00
Polysias fulva	3.51	2.52	0.00	0.00	1.40	1.95	0.00	0.00
Psychotria mahoni	0.00	0.00	0.00	0.00	6.60	2.88	0.41	0.89
Pycnostachys goetzenii	3.75	4.50	0.00	0.00	0.00	0.00	0.00	0.00
Pycnostachys meyeri	2.04	2.45	0.00	0.00	4.80	4.44	0.21	0.45
Symphonia globulifera	3.25	2.99	0.00	0.00	0.00	0.00	0.00	0.00
Syzygium parvifolium	3.75	1.71	0.00	0.00	3.80	3.03	0.40	0.89
Tarbenaemontana stapfiana	0.75	1.50	0.50	1.00	0.00	0.00	0.00	0.00
Triumfetta cordifolia	4.75	9.50	0.00	0.00	8.60	4.22	0.60	1.34
Vernonia myriantha	0.00	0.00	0.00	0.00	2.40	5.37	0.41	0.89
Xymalos monospora	4.25	3.50	0.00	0.00	2.00	1.87	0.00	0.00
Total		**391**		**38**		**347**		**26**
Mean individual per plot		**23.63**		**2.42**		**18.11**		**1.34**
***SD* per plot**		**1.08**		**0.36**		**1.70**		**0.09**

The areas free from Eucalyptus maidenii (A) and the areas where Eucalyptus maidenii are mixed with regenerated native tree species (B) in Gishwati and Mukura.

Diversity and similarities of plant species in Gishwati-Mukura

The areas where *Eucalyptus maidenii* were removed had higher herb species diversity with H′= 1.346; J′=0.859 in Mukura and H′= 1.077; J′=0.716 in Gishwati compared to the sites where *Eucalyptus maidenii species* are still mixed with regenerated native tree species in Mukura (H′= 1.054; J′=0.876) and Gishwati (H′=1.034; J′=0.879). High percentage of similarity in herb species was also found in the sites where *Eucalyptus maidenii* were removed in both Gishwati and Mukura (43.63%) compared to (16.65%) in the sites still dominated by *Eucalyptus maidenii*. On the other hand, the high diversity of woody species was found in Mukura (H′ = 1.225; J′=0912) and Gishwati (H′ = 1.177; J′=0.842) where *Eucalyptus maidenii* species were removed compared to the areas where *Eucalyptus* *maidenii* is still mixed with regenerated native species in Mukura (H′ = 1.01; J′=0.969) and Gishwati (H′= 0.730; J′=0.863). The highest percentage of similarity in woody species was found amongst Gishwati and Mukura (51. 21%) in the sites where *Eucalyptus maidenii* were removed compared to 25.0 % in the sites still dominated by *Eucalyptus maidenii*.

Differences in the sites free from *Eucalyptus maidenii* compared to those where *Eucalyptus maidenii* species are still mixed with native species were indicated by the rarefaction curve (Figure2). The same trend was also found in woody tree species (Figure 3). In all these cases, sites free from *Eucalyptus maidenii* have more herb and wood tree species.

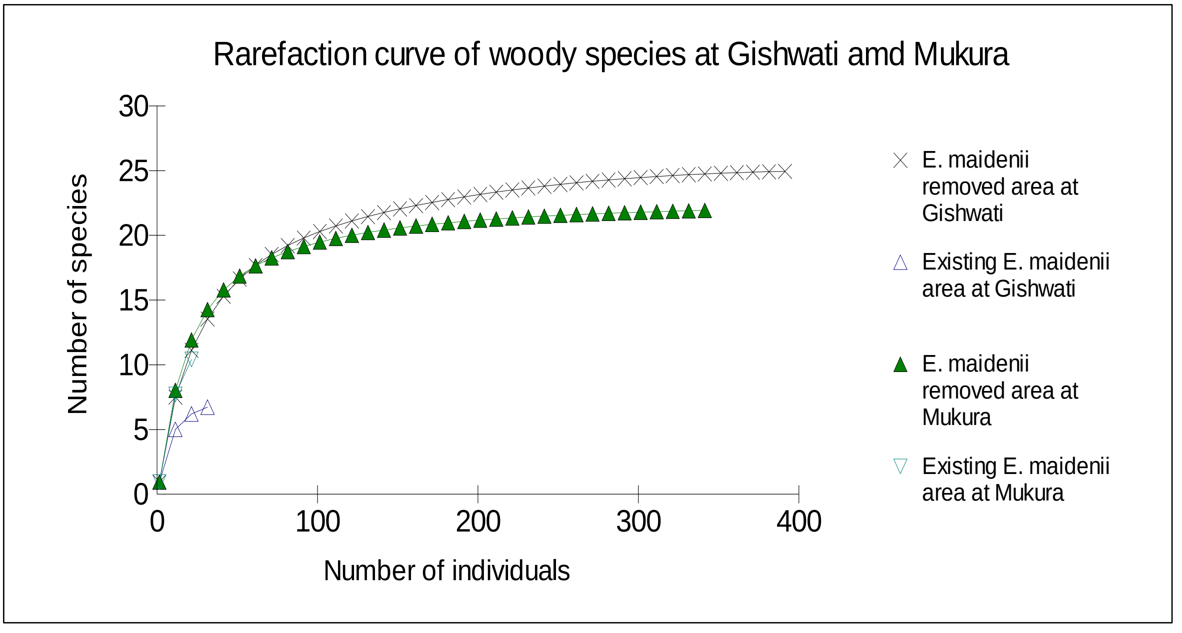

Figure 3: Rarefication curve based on Bray-Curtis similarity in abundance of herb species between the areas where *Eucalyptus maidenii* was removed and the existing *Eucalyptus maidenii.*

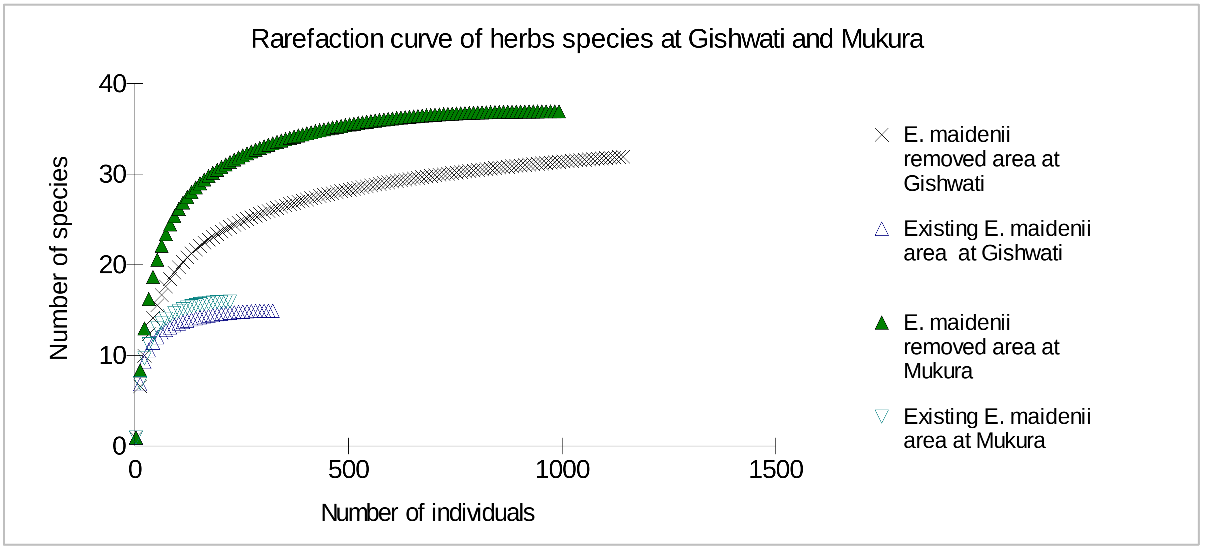

Figure 4: Rarefication curve based on Bray-Curtis similarity in abundance of woody species between the areas where *Eucalyptus maidenii* was removed and the existing *Eucalyptus maidenii*.

DISCUSSION

The number of herb species regenerated in the sites where *Eucalyptus maidenii* species were removed was significantly different from the herb species regenerated in the sites still dominated by *Eucalyptus maidenii* in Gishwati and Mukura. The low abundance of herb species in the sites under *Eucalyptus maidenii* was explained by chemical substance from the leaves of *Eucalyptus maidenii* which cause the allelopathy effect on native species (Chu *et al*., 2014). The allelo chemicals substance contained in the leaves of *Eucalyptus* species were found to contain terpene, (Zhang, 2012) which destroys the growth of many plants by habiting seed germination and seedling growth (Amenu, 2017). They also contain phenolics, terpenoids and their derivatives that are potential inhibitors of germination seedling for other plants (Colpas et al., 2003), and hence contribute to biodiversity loss (Amenu, 2017). According to Chu et al., 2014, the reduction of biodiversity might be related to the shading effect and high competition of *Eucalyptus maidenii* for water and soil nutrients in the area. Another study showed the negative effects of *Eucalyptus maidenii* can even be extended to the extinction of native species in the area (Kasenene, 2007). Findings of this study are also in line with other related studies (Barua et al., 2017;Selwyn and Ganesan, 2009; Barnett and Baker, 1991). The high regeneration is favored by the availability of the sun light able to reach the ground, the soil medium and the ability of seeds to germinate. They were also favored by seed dispersal factors such as wind, bird, and animal (Isabel and Pinto, 2018).

Further, Rwibasira *et al*., (2021) showed effects of long term effects of *Eucalyptus* plantation on chemical soil properties. In this regard authors showed that *Eucalyptus maidenii* increase soil acidity through high concentrations of exchangeable Al^{3+} and Fe^{2+} ions compared to native tree species and take up a big amount of water from the soil compared to natural vegetation. Such kind of competition may negatively affected the diversity of native species (Amenu, 2017). Another study has indicated that the plant species richness as well as woody species located understory are positively influenced by soil pH (Hofmeister *et al*., 2009). In this regard, changes in soil acidity impacts plant community abundance where several plant species cannot tolerate high levels of soil pH (Ádám *et al.*, 2018).

Furthermore, higher herb species diversity, richness, and abundance and similarities found where exotic tree species were removed were also in line with those observed by Smith and Zoología, (2019); Herizo, *et al* (2019); Proença *et al.*, (2010) and Calviño-cancela, (2013) where the influence of an open canopy was highlighted. Also Hofmeister *et al.*, (2009) showed that open canopy favor the development of understory species composition and richness. In addition, all these studies indicated high growth of regenerated tree species where exotic tree species were removed.

CONCLUSION AND RECOMMENDATION

The assessment of the impact of removing *Eucalyptus maidenii* species in natural regenerated native tree species in Gishwati-Mukura National Park showed that plant species diversity and abundance were mostly distributed in the areas where *Eucalyptus maidenii* species were removed. This was the same for native woody tree species specifically *Coelachne africana, Phyllanthus nummulariifolius* herbs and *Macaranga kilimandscharica, Maesa lanceolata.* The study concludes that there is an importance of removing exotic tree species from natural forests to maintain ecosystem goods and survives provided by native herb and tree species.

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