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Mapping the Impact of Exotic Plant Species on Native Vegetation in Gishwati – Mukura National Park, Rwanda

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Abstract: Exotic tree species present the characteristic of invasive species due to their easy establishment to new area, and they can show the matter of reduction in native plant species diversity. However, little is still known on the exotic plant species in Rwanda especially in national parks. This study aims to (a) find out the exotic trees-shrub species, their locations and produce the thematic maps of the park surface area covered by those plants (b) identify the native plant species distributed within the area invaded by exotic plant species; and (c) determine the effects of exotic trees-shrub species on native vegetation by comparing key dimensions, observable characteristics and maps across the areas hosting exotic plant species. The study covers Gishwati Mukura National Park (GMNP) in the North-Western Rwanda. Data collection process covered field practices and measurements, computer-based analysis and image interpretation for mapping, plot data measurements in the blocks occupied by alien invasive plant species and literature review. The results identify 18 exotic plant species that occupy an area of 263.8 hectares (242.2 in Gishwati forest and 21.6 in Mukura Forest) and scattered exotic trees. Exotic plants that occupy big blocks have negative effects on native tree species they share the same habitat and low negative impacts in an area dominated by native plant species. For example, there was negative relationship with – 0.34 between the species richness of exotic and native plant species (> 10m DBH) in the same shared plots. The native shrubs and small trees (<10m DBH) are affected by exotic plant species at low level in growing whereby the average height of native shrubs and saplings recorded in exotic plant blocks was 1.6m of height while it was 1.5m in native plan blocks. As exotic plant trees reveal decreasing trend, more attention needs to be attributed to these plants.

Key words: Exotic (alien) plant species, Gishwati, Mukura National Park, Native plant species

Introduction

Exotic tree species are existing with a sequence of life-history traits that are characteristic of invasive species due to their easy establishment, fast growing, high introduction effort to new area, and low or middle shade tolerance (Dodet and Collet, 2012). The exotic trees species can show the matter of loss of habitat for species sensitive to forest management, reduction in species diversity, possible for hybridization and invasion (Salmón et al, 2016).

In Rwanda, exotic invasive issue is one of major challenges the biodiversity is facing today as a total number of 32 major exotic-invasive plant species in Rwanda are identified (REMA, 2016). Prior to became a national park, Gishwati and Mukura forests have lost almost their entire surface areas due to settlement, mining and farming activities of refugees inhabited there after genocide against Tutsi in 1994 (Plumptre et al, 2001). These activities have drastically led to decreasing trees density in Gishwati – Mukura forests followed with intensive soil erosion and flooding. Exotic trees plantation in Gishwati Mukura National Park started in 1990s and continue in 2000s (Kuria et al., 2013).

Compared with that of native species, exotic tree species have been used due to their fast growth, soil retention and enhanced productivity (Salmón et al, 2016, Feyera et al, 2002). The report of REMA (2016) suggested the continuous studies and awareness to further detect invasive species to help the Government of Rwanda to manage those exotic plants. This research was undertaken to maps where the exotic trees species are in Gishwati-Mukura National Park and assessing their impacts on other plant species sharing with them the same habitat. There has been a little attention given to the research on alien invasive plant species in the management of forestry areas in Eastern Africa (Lyons and Miller, 2000), and this gap may lead to the loss, rarity or extinction of some native plant species in forests mainly protected areas of the region.

The Government of Rwanda has pledged to conserve its biodiversity in sustainable ways and put possible effort in preserving, upgrading, and enhancing ecosystems as well as putting efforts in reducing impacts of exotic-invasive species. The previous efforts conducted for the rehabilitation of degraded forests have include the afforestation of non-native plant specifies which likely ended up with broad relying on exotic species that may affect the native species structure and the associated eco-services, if there is not enough scientific guidance on that (REMA, 2016).

Although it is known that the arrivals of exotic plant invasive species in Gishwati-Mukura National Park resulted from human importation, there was no documentations about current size, species involved, their distributions, and their impacts on biodiversity or habitat. Therefore, this study assessed and provided the results on those gaps for exotic plant species, their impacts and proposed management measures for alien invasive species in Gishwati-Mukura National Park.

2. Methods and Materials

2.1 Description of study area

Gishwati-Mukura is a fragmented mountain rainforest forest located in Rutsiro and Ngororero districts in western province of Rwanda, at lat -1.821307°, long 29.356296°, and lat -1.982464°, long 29.504869°. The altitudes vary from 2000 to 2700 meters above sea level. It covers a total area of 35.5 square kilometers, with two separate forests– the bigger Mukura (19.8 square kilometers) and the smaller Gishwati (15.7 square kilometers). It has a buffer zone of 9.62 square kilometers.

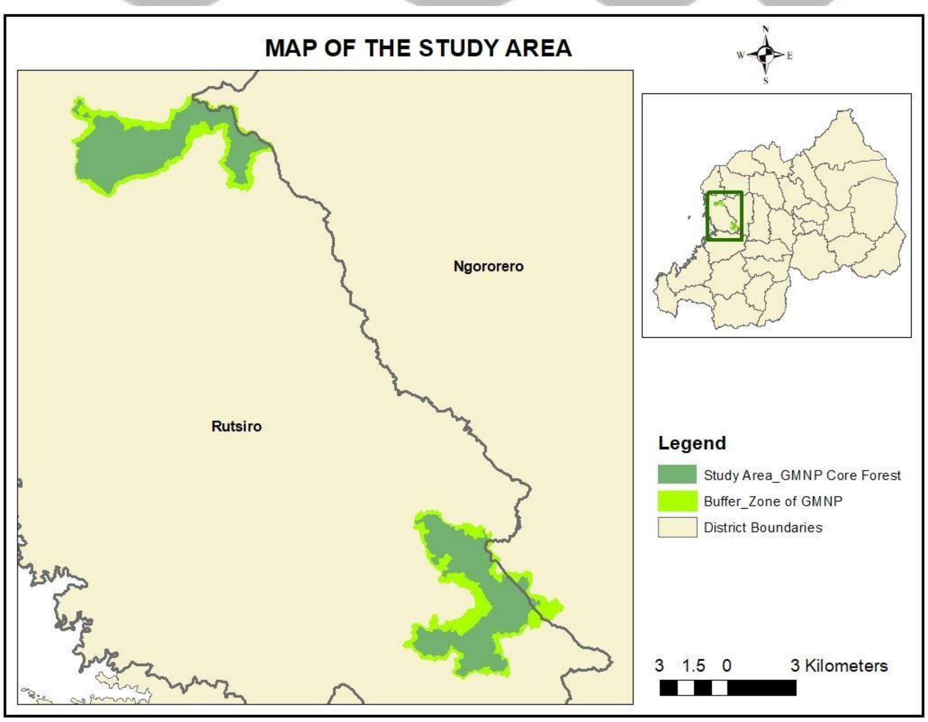

Figure 1: Map indicating the location of the study area.

Source: Authors, 2024

The park is in Eastern Africa's tropical Afromontane region and is part of the Albertine Rift biodiversity hotspot which includes a number of Albertine endemic species. The park is the home to endangered chimpanzee (*Pan troglodytes schweinfurthii)* and golden monkey (*Cercopithecus mitis kandt*), and vulnerable l'hoesti monkey (*Cercopithecus lhoesti*). Gishwati and Mukura landscape were covering approximately 25 3,000 hectares before 1980s and got reduced to 3,558ha due to different human activities including illegal mining, agriculture grazing and settlements, which with the time, the restoration activities resulted with planting exotic plant species (Arakwiye et al, 2021).

2.2 Data Collection

2.2.1 Mapping

The field data relating to surface areas of exotic plant blocks were mapped and recorded by using field mobile GPS as it increases accuracy because it is done by walking along the features, their boundaries, or their perimeters (Gao, 2002). This data collection approach was used in order to reduce confusion between plant species types because neighboring tree crowns of exotic or native plant blocks are not demarcated and their boundaries might be mixed with each other. Scattered GPS waypoints were collected for solitary exotic trees-shrub species distributed in different areas of the core forest.

Remote sensing images were downloaded from earth explorer and adjusted with the data collected from the field through Geographic Information Systems (GIS) as both methods currently are included into natural resources and environmental monitoring (Gao, 2002). At least the image with low percentage of cloud under 10% was collected in order to reduce errors in image interpretation.

The Landsat-8 images acquired from USGS earth explorer were extracted by mask for fitting the created invasive exotic plant polygons got from field exotic boundaries delineation by using GPS and GIS (Franklin 2013, Gascón and Eva, 2014). Therefore, the images and LULC of Rwanda of the years 2002, 2012, and 2022 were taken as sample to map the land cover and observe the changes in Gishwati-Mukura National Park in order to support the information collected from the field.

2.2.2 Plots and tree-shrub measurements

During field data collection, the following dimensions and information were taken while collecting data in plots.

DBH: The Diameter at Breast Height (the trunk at 1.3 m height above the ground) for all tree trunks of 10 cm DBH and above were measured (White and Edwards, 2000; Lazaro-Lobo and Ervin, 2020) within all big plots of 10m*10m in exotic and native plant blocks. No DBH measurements were taken for the trees of below 10 cm of DBH.

Height: The height of all trees/shrub categories (poles, seedlings, and saplings) were measured for all big and small plots. Height was measured by using a laser rangefinder, optical (visual) or by the stick (Gillison, 2006), as wells as eyesight (Abe et al., 2020). Mostly in dense canopy cover, the measurement of height is not possible and it is recommended to do so through visual estimations by data collectors (Gascón and Eva, 2014). In case the height measurement is done by visual estimates, three field persons have observed, discuss, averaging and agree on exact dimension to write (Jalonen et al, 2016)

Canopy cover: canopy cover of each species recorded in big plots was estimated with the visual calculations at least assessed by three persons, and then the estimations was rectified through simultaneous adjustments and discussions. (Jalonen et al, 2016)

Identification of tree species: The trees and shrubs species recorded from all plots were identified in both Latin and vernacular (local) names and then when the species is unknown, leaves fruits or stems were collected for further identification and consultation (Gascón and Eva, 2014).

Counting: in each small and big plots, all tree-shrub poles, seedling and saplings were counted for both exotic and native species (Dyderski and Jagodzinski, 2020).

Habitat description: the locations of measured plots were described in order to indicate the status of its surroundings. The recorded descriptions are as follow: tall closed forest, short closed forest, short open forest, grassland, among other important descriptions.

Images of the plant species: there was take of sample of pictures for some species of exotic species or native species to help explaining field realities.

Collection of plant parts: when the species of a tree was not directly identified in the field, leaves, stems, fruits or other important parts were collected for later identification and consulting plant experts.

2.3 Data processing and analysis

2.3.1 Maps building

We used ArcGIS to add, visualize and analyze the GPS data collected from the field and other imagery data downloaded from earth explorer to find observe the changes in the use of Gishwati-Mukura National Park for the year 2002, 2012 and 2022. ERDAS software was also used to support ArcGIS in analyzing image data especially classifications. Google earth pro was used to help reading image for classification.

A field-based map of the study area was combined with satellite images and as suggested by Xiao and Wang (2021) the analysis of images focused on the ones which fit the polygons created from the GPS data collected from the field. Thus, we calculated the total area covered by exotic tree-shrub species by summing the areas of all polygons covered by exotic plant species (Trueman et al, 2014) and keep points for the distribution on scattered or solitary trees. The individual scattered trees were mapped and symbolized by a dot, and then blocks symbolized with polygons.

2.3.2 Analysis of data collected from plots

Species richness, abundance and evenness/relative abundance: this was regarding to the number of different plant species recorded in the big and small plots, number of individuals recorded per species and their relative abundance (Cynthia and Huebner, 2007, Schulz et al, 2009).

Canopy Cover: This was calculated on average of all species canopy closure recorded from all plots in order to have a picture on the level of dominance of one or another plant species from the study area (Rawlins et al, 2018). This was to describe how the recorded species is dispersed in the layers of heights (Schulz et al, 2009)

Correlation analysis: This was to assess whether exotic plants species affect the native species in different ways in term of richness and abundance (Didham et al, 2005) in big and small plots for poles, saplings and seedlings (counting and compare in native blocks and exotic blocks the height, number of species, number of individuals, coverage, growth size, canopy coverage).

Instruments used: Computer, excel sheets were created to enter the data. GIS tools were used to analyze the maps.

3.Results

3.1 List of recorded exotic trees-shrub species in Gishwati Mukura-National Park

For this research, 18 exotic plant species from 14 families, have been identified in this study. 12 species are trees and 6 species are shrubs.

Table 1: Recorded exotic trees-shrub species

No.	Family Name	Species Name	Common Names	Establishment in the field
1	Fabaceae	*Acacia melanoxylon*	Australian blackwood,Kasiaya	Blocks (plots) and Scattered trees
2	Betulaceae	*Alnus acuminata*	Runusi	Blocks (plots) and Scattered trees
3	Myrtaceae	*Eucalyptus sp.*	Inturusu, Intusi	Blocks (plots) and Scattered trees
4	Fabaceae	*Acacis mearnsii*	Black wattle, Green wattle,Indakatsi	Blocks (plots) and Scattered trees
5	Theaceae	*Camelia sinensis*	Tea plant,Icyayi	Blocks (plot)
6	Cupressaceae	*Cupressus lusitanica*	Cypress,Isipure	Blocks (plots) and Scattered trees
7	Proteaceae	*Grevillea robusta*	Gereveriya	Blocks (plots) and Scattered trees
8	Lauraceae	*Persea americana*	Avocado,Avoka	Scattered trees
9	Pinaceae	*Pinus patula*	Pine,Pinusi	Blocks (plots) and Scattered trees
10	Casuarinaceae	*Casuarina equisetifolia*	Australian beefwood	Scattered trees
11	Solanaceae	*Solanum aculeastrum*	Soda apple	Scattered shrubs
12	Fabaceae	*Calliandra calothyrsus*	Fabaceae	Scattered trees
13	Adoxaceae	*Sambucus canadensis*	American black elderberry	Scattered shrubs
14	Scrophulariaceae	*Budleja davidii*	Summer lilac, Butterfly-bush	Scattered shrubs

15	Caricaceae	*Vasconcellea pubescens*	Mountain papaya,Ipapayi	Blocks (plots) and Scattered shrubs
16	Fabaceae	*Calliandra calothyrsus*	--	Scattered trees
17	Meliaceae	*Cedrela sp.*	--	Scattered trees
18	Solanaceae	*Solanum chrysotrichum*	Giant devil's fig	Scattered shrubs

Source: Primary data

3.2 Locations of exotic trees-shrubs species in Gishwati Mukura National Park

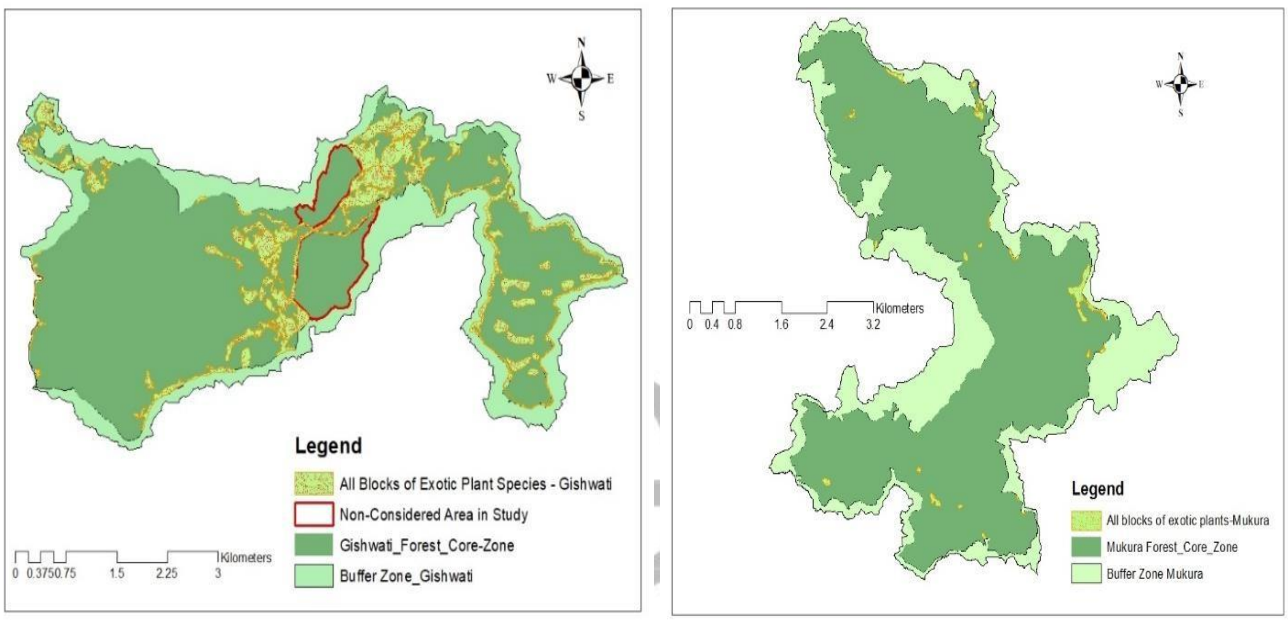

Figure 2: :Maps of all exotic plant blocks – Gishwati and Mukura Forests

Source: Primary data

Table 2: Species of exotic plants recorded in blocks (plots)/parcels

Exotic Plant Species	Area in Hectares	Percentages
Acasia mearnsii	4.3	1.6%
Acasia melanoxylon	166.8	62.5%
Alnus Accuminata	62.8	23.5%
Camellia sinensis	1	0.4%
Eucalyptus sp.	6.5	2.4%
Grevillea robusta	2	0.7%
Pinus patula	22.5	8.4%
Vasconcellea pubescens	0.2	0.1%
Cupressus lusitanica	0.7	0.3%
Total	**266.8**	**100%**

Source: Primary data

The area in table above covers only the exotic plant species recorded in blocks, and do not cover the scattered trees.

2002 to 2022 LULC Changes

The images and LULC Rwanda classified for the years 2002, 2012 and 2022 are showing the great positive impact of the planted exotic trees as it helped to improve the vegetation in Gishwati and Mukura Forest over the year. The large area was not covered by forest in 2000s. Although the classified images have shown that kind of improved, our study revealed that it is the improvement and propagation of exotic plants than native plant species in in some areas of GMNP than native which can result in having many exotic plan species.

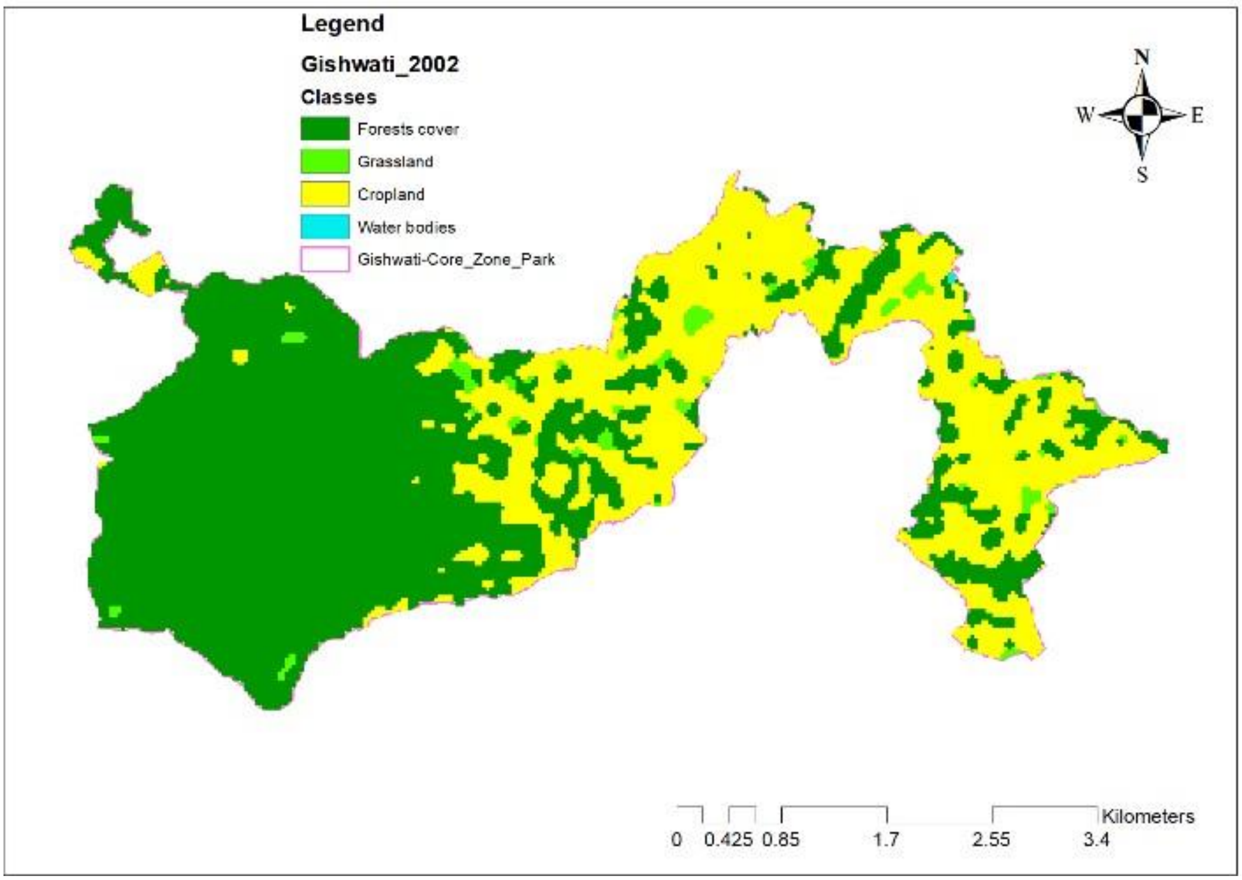

Figure 3: LULC Change in Gishwati forest in 2002

Source: Primary data, extracted from Landsat-8

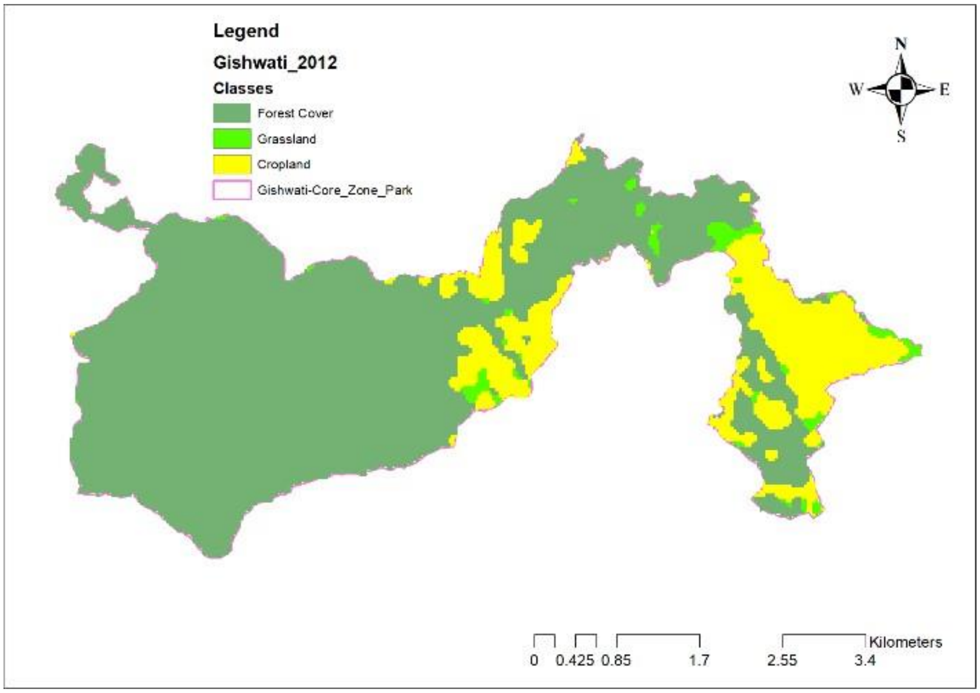

Figure 4: LULC Change in Gishwati forest in 2012.

Source: Primary data, extracted from Landsat-8

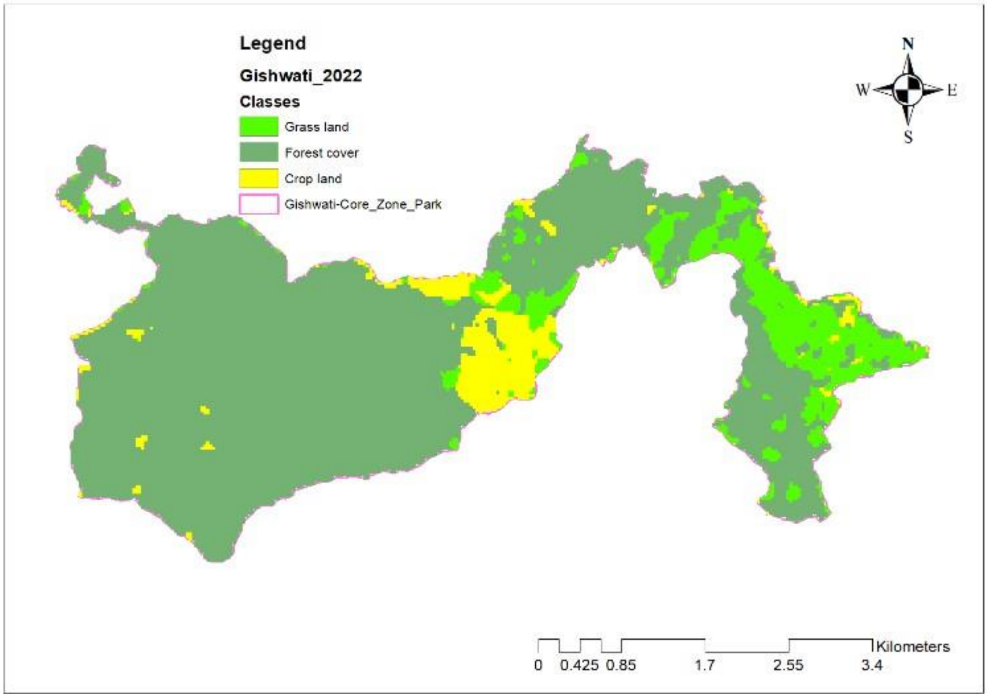

Figure 5: LULC Change in Gishwati forest in 2022.

Source: Primary data, extracted from Landsat-8

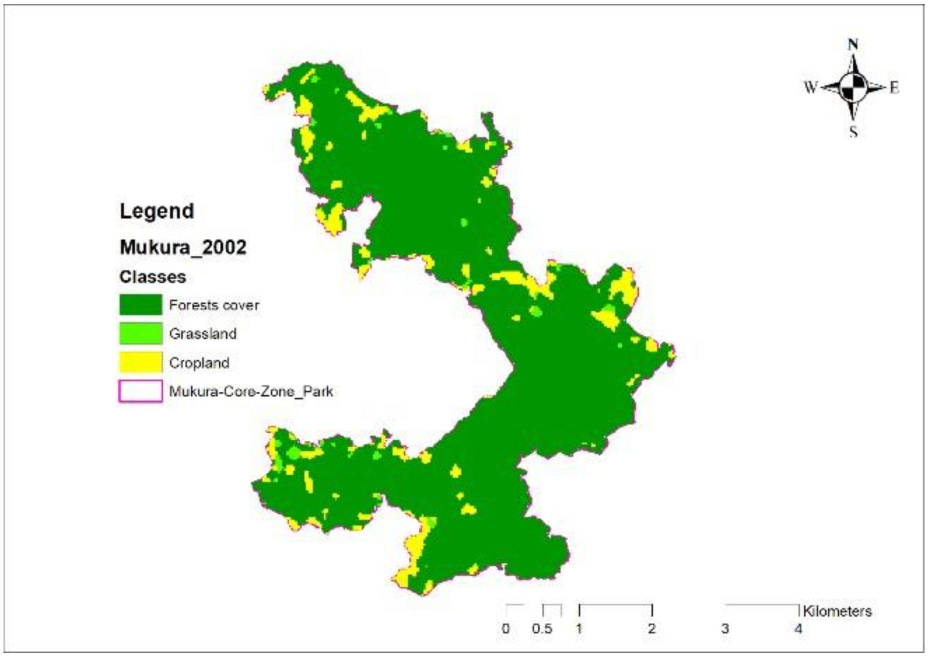

Figure 6: Map for change in Mukura Forest in 2002

Source: Primary data, extracted from Landsat-8

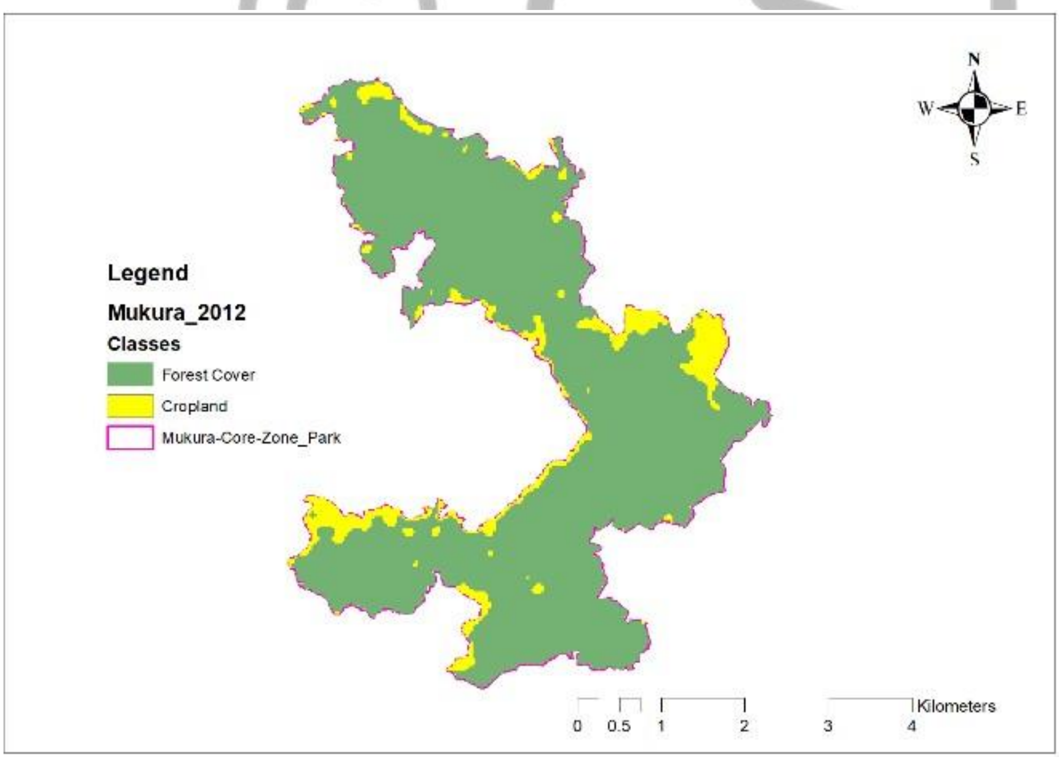

Figure 7: Map for change in Mukura Forest in 2012

Source: Primary data, extracted from Landsat-8

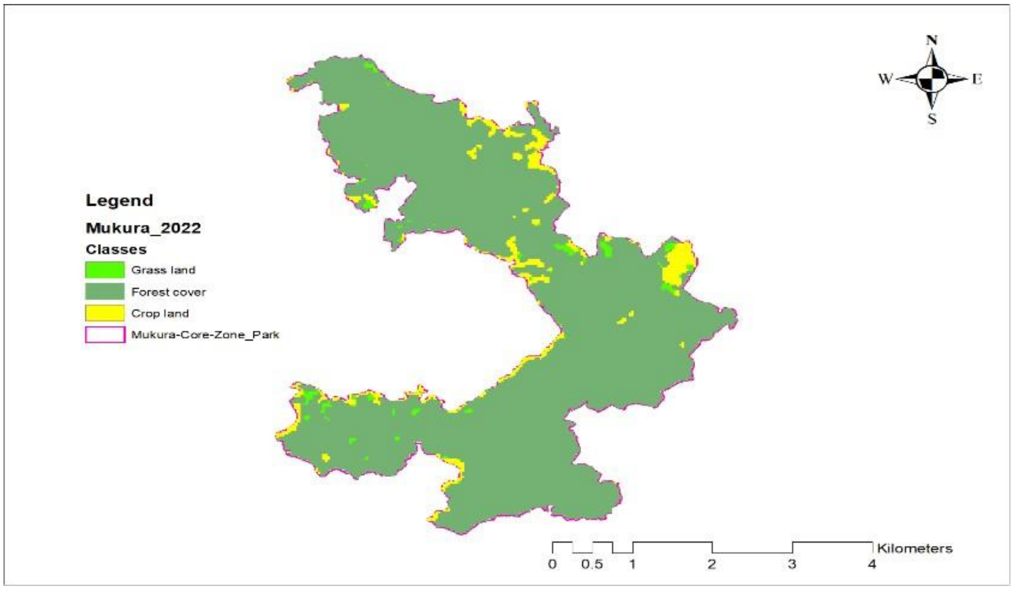

Figure 8: Map for change in Mukura Forest in 2022

Source: Primary data, extracted from Landsat-8

3.3 Distribution of scattered exotic trees-shrubs

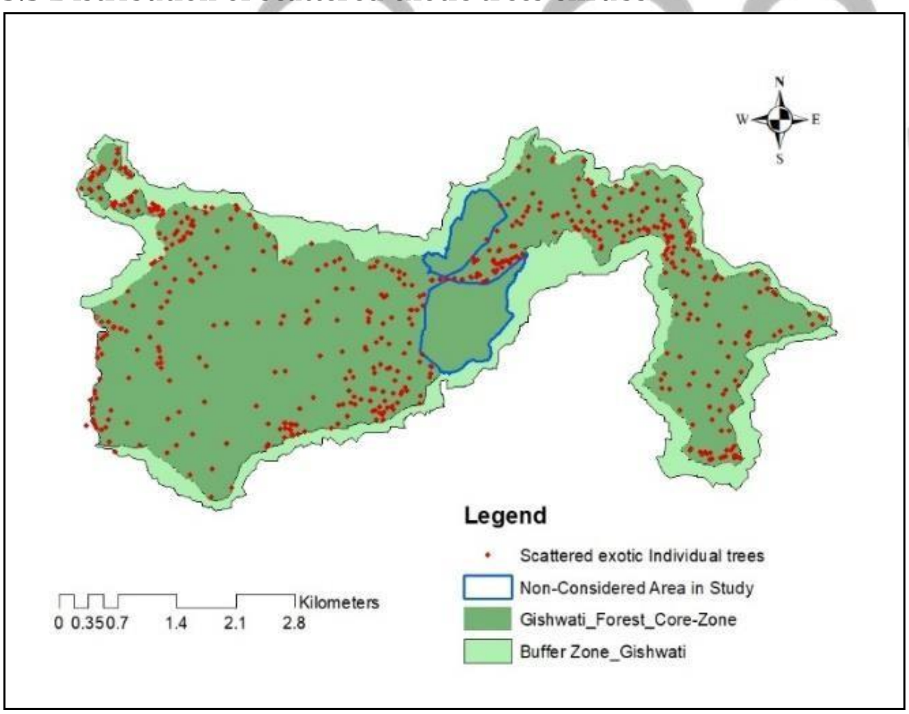

Figure 9: Scattered exotic trees in Gishwati forest.
Source: Primary data

The map is showing that the individuals' exotic trees are located throughout the park area especially in Gishwati forest. This means that the propagation can be high in the future.

3.4 Comparison of exotic plant effects by using dimensions for data recorded in big plots

In this study, with the data collected from the blocks dominated by exotic plant species, the relationship between exotic and native tree species was investigated through comparing the number (richness) of exotic trees and native trees counted from each of 44 plots of 10m*10m (each one). The Pearson correlation coefficient was used to show the relationship between exotic and native trees species living within the same location of exotic plant's establishments.

$$r = \frac{\sum(x_i - \bar{x})(y_{i-\bar{y}})}{\sqrt{\sum(x_i - \bar{x})^2 \Sigma(y_{i-\bar{y}})^2}}$$

Where:

***r*:** correlation coefficient,

xi: number of exotic trees collected from 44 big plots from blocks of exotics,

yi: number of native trees collected from 44 big plots from blocks of exotics,

$\bar{x}$: mean of the number of exotic trees

$\bar{y}$ mean of the number of native trees

Seeing at the table on the annex, $\bar{x}$ = 11.13 , $\bar{y}$ = **1.45,** $\sum(x_i - \bar{x})(y_{i-\bar{y}})$ = **-188.73** , $\sum(x_i - \bar{x})^2$ = 1783.20 **,** $\sum(y_i - \bar{y})^2$ = 170.91

However,

$r = \frac{-188.73}{\sqrt{1783.20*170.91}}$, $r = \frac{-188.73}{\sqrt{1783.20*170.91}}$, $r = \frac{-188.73}{\sqrt{304766.71}}$, $r = \frac{-188.73}{\sqrt{304766.71}}$, $r = \frac{-188.73}{552.05}$

$\boldsymbol{r = -0.34}$

The correlation coefficient is showing that there is a negative correlation between native trees species and exotic trees species which are in the same set of area of exotic dominated plant species. This mean that the exotic specifies have negative impacts on richness of native species in GMNP.

The chart below also is showing that the richness of exotic and native trees of 10m DBH are correlated once they are together in the area established with native plant species in Gishwati-Mukura National Park.

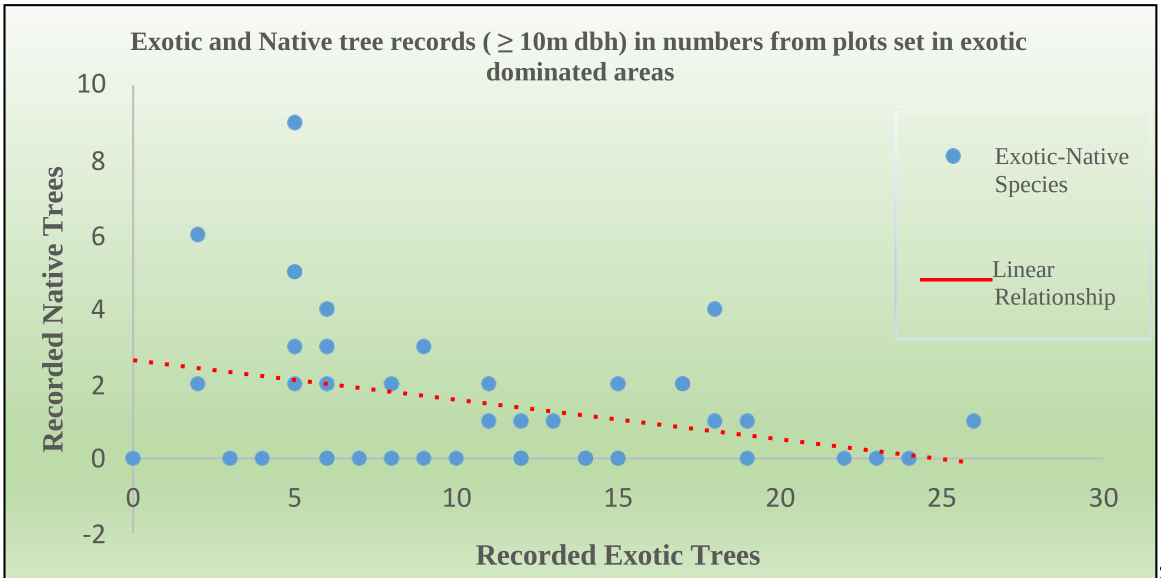

Figure 10: Native and exotic tree species record

Source: Primary data

In the above chart, the native species in exotic blocks are not at the same level like in native blocks in terms of species diversity and richness. The study also compares the averages of data recorded in 21 big plots set exotic plant blocks in native plant blocks.

As shown in below figure 11, the interactions of exotic plant species and native plant species can affect and/or not affect another side. According to the dimensions in the charts, exotic plant species are highly dominating native plant species once they are in their establishment zone that tents to outcompete native plant species. On the other hand, the native plant species have the high dimensions in their zone than exotics species which are in native plant zone. These results are in line with the results found by Yu et al (2018) who argued that the abundance of native plants canreduce the susceptibility exotic species invasion.

However, in comparison of the chart aggregates for native and exotic species there are some surpluses of exotic plants and exotic species are chowing some dominance in aggregates than native species either when they are found in native plant blocks or exotic plant blocks. This mean that once exotic plant species are not controlled and monitored it can be a harm in the future. This is like the findings of Abe et al (2020) on exotic plant and native plants that lived together over 19 years, they have found that though native species have increased, the growths of exotic plant species have eventually surpassed those of native tree species, and the exotic plant species have shown the high expansion than native plant ones.

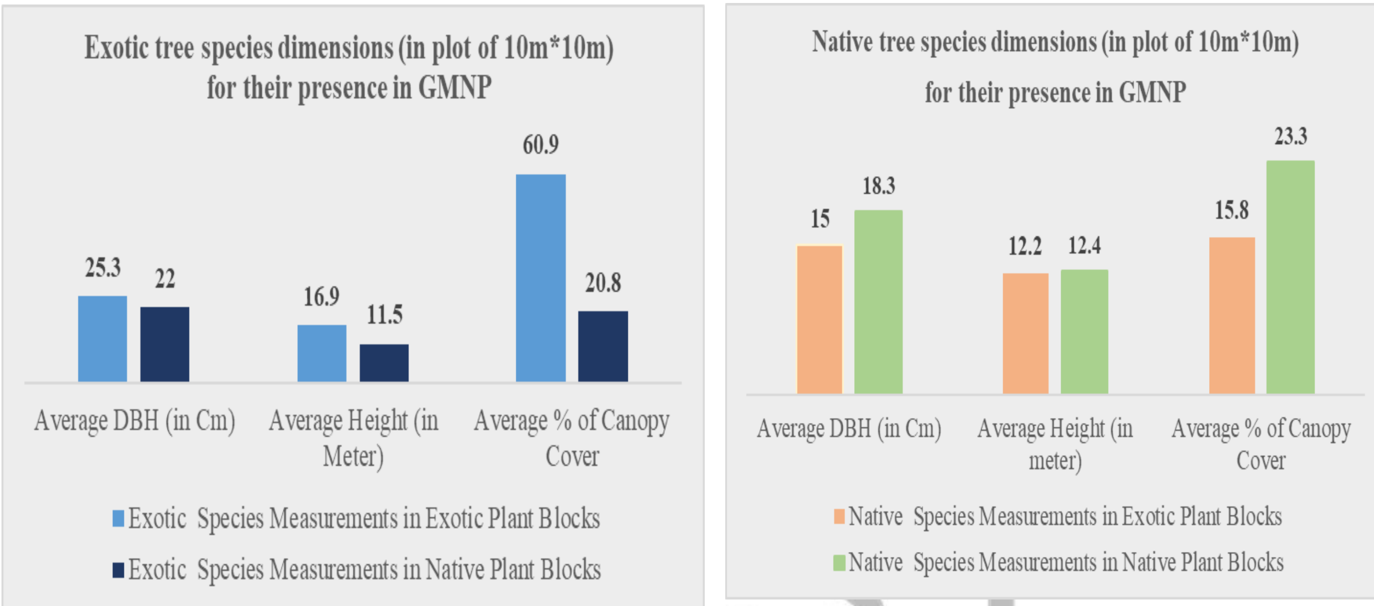

Figure 11: Native and Exotic tree dimensions

Source: Primary data

3.5 Comparison of exotic plant effects for data recorded in small plots

Although it is being shown that the shrubs recorded in small plots of 2m*2m were above in numbers in exotic plant blocks than the trees recorded in big plots of 10*10m, it analyzed that comparing the data recorded from small plots of exotics species with those ones recorded from neighboring native plant blocks, it is revealed that the number of native shrubs are also low in exotic blocks. The graphs here below are showing the cases for the data corrected in 21 small plots set in exotic plant blocks in comparison with other 21 small plots set in native plant blocks.

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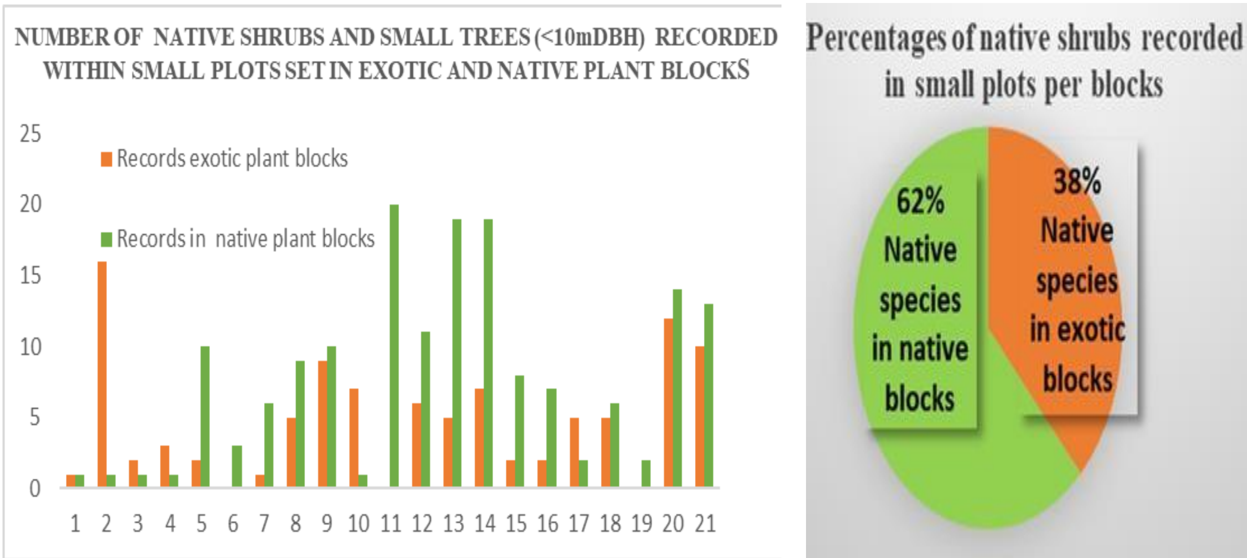

Figure 12: Record on Native and Exotic tree species

Source: Primary data

4. Conclusion

For this study, combination of field data collection, observations and image analysis has given the results that demonstrate that there are high negative effects than positive effects of exotic plant species towards the native plant species. This research found that once there is no early accent put on those exotic plant species, their harms can be cumulative in the futures. The research calls the continuous contributions on the management of exotic plant species in Gishwati-Mukura National Park and in Rwanda in general. It is concluded that exotic plant species are the issue of global concern to global biodiversity from country to country. Since the exotic plants in Rwanda have been detected as major threats to biodiversity and to other environment components, measures on the management on exotic pant species have been aligned and put in policies and laws. There still ongoing journey of understanding the impacts of exotic plants in many areas with hope that the concern will be put into considerations by many categories of persons. To ensure that the exotic plants found in Gishwati-Mukura National Park are controlled, contained, eradicated and prevented from spreading to new areas/their future propagation in order to minimize possible harm to other native species. The people who possess the lands around Gishwati-Mukura National Park should be careful and aware of exotic plant species so that the exotic plant species cannot expand towards their lands.

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