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Growth performance and leaf physiology among native and exotic tree species towards wetlands conservation: case of Nyandungu wetland

A thesis submitted in partial fulfillment of the requirements for the degree of Master in Biodiversity Conservation and Natural Resources Management

By

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DECLARATION

I, Mr. Nathan AKIMANA, declare that this master's dissertation "**Growth performance and leaf physiology among native and exotic tree species towards wetlands conservation: case of Nyandungu wetland**" is the result of my own work in partial fulfilment of the requirements for the award of a master's degree in Biodiversity Conservation and Natural Resource Management at the University of Rwanda, College of Science and Technology and has not been submitted for any other degree at the University of Rwanda or any other institution. All sources that I have used or quoted have been indicated and acknowledged in the references.

Date: …………….

Signed by:

Student: Nathan AKIMANA (220017637)

....

APPROVAL

This is to certify that a dissertation entitled "**Growth performance and leaf physiology among native and exotic tree species towards wetlands conservation: a case of Nyandungu wetland**" is a record of the original work done by Nathan AKIMANA as part of final project in partial fulfillment of the requirements of the award of master's degree in Biodiversity Conservation and Natural Resources Management, at University of Rwanda.

This research report has been submitted for examination with the approval of:

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May God bless you all!

DEDICATION

To: Mukunde

My love, my life, my light!

ABSTRACT

Wetlands are one of the most valuable component of watershed, for many years some of them were degraded mostly due to human activities such as agriculture, mining, industrial activities, etc. in their restauration plants should be used being native or exotic species.

The present study aimed at documenting and identifying native and exotic tree species; to evaluate growth rates using DBH and height measurements and examine the leaf temperature of native versus exotic tree species. Data were collected in the short wet season of the year 2022, namely mid-September path to path with GPS, book of flora identification key, tape, and infra-red thermometer.

A total of 50 tree species were identified of which 80% of them were native whereas 20% were exotic. The identified species were classified into 27 families, and the family of Fabaceae was the most dominant, with 22% of tree species with 10 native species and 1 exotic species, while the other families comprised between 1 species to 5 species. The native tree species are more frequent in Nyandungu wetland than exotic tree species which is result of restoration effort.

DBH values were measured for 16 tree species, including nine native species, and seven exotic species. The tree DBH was measured for trees of the aged six years and ranged from 5.7 to 25.8 cm, the DBH was found to be higher in native species than in exotics. Leaf temperature ranged between 19.7 to 27^{o}C. The leaf temperature results showed no variation in species being native or exotic. These findings on the growth performance of native tree species serve as a baseline for further functional studies on wetlands conservation. However, our results did not show a significant difference in leaf temperature between native and exotic tree species in Nyandungu wetland eco-tourism park hence both exotic and native tree species in wetlands restauration and conservation both species should be used regarding their adaptation.

Keywords: Conservation, native and exotic tree species, wetlands.

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LIST OF ABBREVIATIONS

REMA: Rwanda Environment Management Authority

DBH: Diameter at Breast Height

ARCOS: Albertine Rift Valley Conservation Society

GEF: Global Environment Facility

DP: Gross Domestic Product

1. GENERAL INTRODUCTION

1.1 Background of the study

Forests are one of the few ecosystems that benefit humans and provide numerous biological, ecological, and environmental services. Forests are vital to the economy as a supply of lumber, pulp- wood for paper production, fuel, and various non-wood items. Forests also serve as the foundation for many other commercial and non-economic assets, such as tourist resources. wildlife habitats, and water resource preservation. Forest ecosystems are a reservoir of terrestrial biodiversity, accounting for roughly 90% of all terrestrial species on the planet, and as such, they are necessary, self-sustaining reservoirs of genetic resources. Deforestation and forest degradation contribute to climate change through carbon emissions to the atmosphere and biodiversity loss. On the other hand, reforestation and afforestation can help restore and conserve biodiversity, mitigate climate change, and enhance ecosystem services (Ali et al., 2024).

Temperature influences root development, soil microbial activity, and plant biochemical processes, all of which have an impact on nutrient intake. In general, warmer temperatures promote microbial activity and root growth, which increases the availability of nutrients in the soil. Furthermore, ideal temperatures maximize the efficiency of nutrient uptake. Temperature also affects the rate of nutrient uptake and assimilation inside plant tissues. Extreme heat, however, can interfere with the mechanisms that allow nutrients to be absorbed, which can result in nutrient shortages and stunted growth. As a result, keeping leaves at their ideal temperature is crucial to ensure that plants absorb and use nutrients effectively (Yu et al., 2015).

As a result of its direct impact on vital physiological processes like photosynthesis, transpiration, stomatal conductance, and nutrient uptake, maintaining the ideal leaf temperature is essential for the health and yield of plants. Plants can improve their development and productivity in a variety of environmental situations by striking a balance between optimizing energy capture and reducing water loss (Yu et al., 2015).

Understanding the causes and scope of wetland degradation is essential before beginning wetland restoration efforts. Wetlands all around the world have been severely harmed by human activities like pollution, drainage, agriculture, urbanization, and habitat degradation. In addition, wetland loss and degradation may be made worse by natural occurrences like hurricanes, floods, and sea level rise.

Setting restoration objectives, creating a thorough restoration plan, and evaluating the biological state of the degraded wetland are all part of restoration planning. Hydrological studies, soil analyses, biodiversity surveys, and stakeholder involvement are commonly included in this process to make sure that restoration activities are in line with ecological, social, and economic goals (Stelk, M.J *et al*, 2017).

Depending on the unique qualities and requirements of the wetland, a variety of restoration methods may be used. Hydrological restoration, vegetation restoration, soil restoration, and habitat building are examples of common restoration techniques.

Making appropriate management decisions, evaluating progress, and spotting possible obstacles all depend on tracking how well restoration efforts are working. Monitoring may entail tracking over time changes in wildlife populations, water quality, hydrology, vegetation composition, and other ecological indicators. Adaptive management enables restoration plans to be modified in response to changing ecological conditions and monitoring data.

Reversing wetland degradation, maintaining biodiversity, improving ecosystem services, and fostering ecological resilience in the face of environmental change all depend on wetland restoration. Stakeholder participation, adaptive management, and scientific knowledge combined can make successful wetland restoration projects beneficial to the long-term sustainability and health of wetland ecosystems (Stelk, M.J *et al*, 2017).

1.2 Problem statement

The wetland ecosystem and its resources are under threat from human as well as natural influences (Kumar *et al.* 2018). The rapid increase in the human population has resulted in acute pressure on wetlands. People tend to destroy wetlands by using them for intensive agriculture or fish production, by filling them to create land for industrial or urban development or use them as fill in the ground for dumping garbage (Kunjani *et al.*, 2003). The major causes of the decline and loss of wetland resources are due to loss, fragmentation, and modification of habitat, unsustainable use of water resources, siltation, over-exploitation, unplanned development and hazard implementation of development activities, unregulated garbage and sewage disposal. The alteration of the wetland ecosystem is reflected in the conservation status of different countries' environments (K Joshi *et al.*, 1998).

Currently, in Rwanda, a total area of 165,000 ha is covered by wetlands (Chemonics International Inc, 2008). In East Africa, where Rwanda is situated, wetlands have been lost and degraded as a result of human activities (Nsabagasani *et al*., 2008). This includes a ray of construction and development projects (roads and other infrastructures), cultivation, siltation , pollution, drainage (because of soil erosion), and the introduction of alien invasive species (Nsabagasani *et al*., 2008). Different indispensable measures for the sustainability of wetlands have been identified and the method proposed among them; conducting research, specific technical surveys for wetland biological diversity, and revision of policies and strategies (Nsabagasani *et al*., 2008).

Although, research and surveys were done in different wetlands of Rwanda, little is known about the growth performance and leaf physiology between exotic and native tree species toward the conservation of wetlands. Therefore, our study aims at broadening the understanding of the growth performance and leaf physiology of native tree species versus exotic tree species towards the conservation of the recently established Nyandungu Urban Wetland Eco-Tourism Park in Rwanda.

1.3 General objectives

The overall objective of this study is to assess growth performance and leaf physiology of native tree species versus exotic tree species towards the Nyandungu wetland conservation in order to determine the favorable tree species for wetlands conservation.

1.4 Specific objectives

- To investigate the growth rate among native and exotic tree species
- To measure leaf temperature of tree species in the study area.

1.5 Research questions

1. What are native and exotic tree species richness found in Nyandungu wetland?
2. Do the native tree species found in Nyandungu have a high growth rate than exotic tree species?
3. Is the leaf temperature higher in native species than in exotic species?

1.6 Research hypotheses

Native flora contributes to wetlands conservation more than exotic species.

Native tree species has higher leaf temperature than exotic tree species

1.7 Significance of the Study

Wetlands are habitat for a large number of species being aquatic or terrestrial fauna and flora. Wetlands are important in flood protection, water quality enhancement, shoreline erosion control, aesthetics, recreation and natural products. Therefore, investigating the relationship between growth and leaf physiological indicators between native and exotic trees and their contribution to wetlands conservation is so important.

2. LITERATURE REVIEW

2.1 Introduction

Plants that use resources efficiently has demonstrated successful survival in terms of growth rate, and reproductive ability, particularly in changing environment (Baruch & Goldstein, 1999; Pattison *et al.*, 1998). In a given ecosystem, is very important in determining the growth rate as well as maintaining the functional composition among tropical forests and exotic species have adapted to exhibit life history and morphological features which help them to out-compete native species (Cox *et al*., 2008, Williams *et al*., 2007). Such morphological features include more prolific seed production and dispersal, longer flowering periods, higher rates of seedling recruitment, more efficient leaf arrangement, faster growth rates, better recovery from leaf loss, or greater phenotypic plasticity (Ehrenfeld, 199, Williams *et al*., 2007, Fogarty & Facelli, 1999).

Researchers continued to emphasize that exotic species can survive and maintain their fitness in both rich and poor resource environments (Richards *et al*., 2006). Worldwide comparative studies have been conducted to reveal the reality regarding physiological traits related to carbon gain in exotic and native flora communities. Furthermore, features such as elevated photosynthetic rates and water use efficiency have been shown to grant an advantage to exotic species over natives, and hence contribute to invasion success (McAlpine *et al.*, 2008).

Although many aspects concerning has been done to provide scientific evidence on how exotic invade native species based on the high physiological rate of exotic species leading to high growth, reproduction, and adaptability to the environment than native, however, there is still much greater attention and gapes to be covered. For instance, many studies reflecting wetlands ecosystem status have been taken into account (McAlpine *et al*., 2008).

Wetland research is currently receiving a lot of attention from scientists around the world. Some developed nations have made significant theoretical advances in their wetland park research and exploration, and wetland park theoretical and practical studies have made significant strides thanks to the efforts of scientists from many different nations (Li *et al*., 2022). Wetland ecosystems have played a crucial role in the growth and survival of cultures throughout human history. Since the dawn of civilization, numerous cultures have discovered how to coexist peacefully with wetlands and to grow economically from their surroundings, other cultures quickly drained the environment, leaving behind marshes. As opposed to what is usually done in the West, Eastern civilizations tended to work within the aquatic terrain, though sometimes in a tightly regulated manner (Mitsch & River, 2005).

2.2 Flora and fauna communities in Nyandungu urban wetland eco- park

The vegetation of the Nyandungu wetland eco-tourism is characterized by two types of vegetation such as natural and anthropogenic based vegetation and flow flora communities (Gakuba, 2012). The natural vegetation is mainly growing in wetlands whereas the anthropogenic-based one is occurring in more or less dry areas. The natural vegetation found in the area includes xerophytes trees: *Vachellia hockii*, *Vachellia abyssinica*, *Euphorbia grantii*, and the most dominant vegetation is *Cyperus papyrus* and *Phragmites mauritianus*. The remaining space is grassland used as a pasture and fodder collection for livestock, however, there are some other replanted trees such as *Casuarina equisetifolia*, *Cassia spectabilis*, *Grevillea robusta*, *Euphorbia tirucali*, *morus alba* are also present in the area (Gakuba, 2012).

The diversity of plants found there includes: *Bidens pilosa*, *Galisonga parviflora*, *Rhynchelytrum repens*, *Clerodendrum rotundi*, *Vernomia amygdalina*, *Solanum aculeastrum*, *Commelina beungalensis*, *Digitaria spp*; *Urochloa brizantha*, *Leetonia nepetifolia* , *Sida cordifolia*; *Tagetes minuta*; *Ocimum suave* whereas exotic flora communities are *Senna spectabilis*, *Grevilea robusta*, *Casuarina equisetifolia*, *Morus alba* (Gakuba, 2012). On the other hand, the fauna communities inhabiting Nyandungu Urban Wetland Eco-Park include various taxa such as small mammals (e.g., Hares, *Civettictis civetta*), amphibians, reptiles, termites, and avifauna communities such as *Falca abyssinica*, *Corvus albus*, *Milvus egyptius*, *Francolinus nobilis*, *Numida meleagris*, *Baleanica regulorum*, *Bubulcus ibis* (Gakuba, 2012).

2.3 Typology and distribution of wetlands in Rwanda

In general, the word ‘’wetland’’ encompasses wetlands and marshes, generally located away from the coastal zone (Nabahungu *et al.,* 2021). The Ramsar Convention on wetlands has agreed to an even wider definition of wetlands that includes lakes and rivers as well as artificial wetlands such as reservoirs and rice fields (Ramsar Convention Secretariat, 2016). The definition used by the Ramsar convention is gaining wider acceptance. However, in the literature, it is not always clear which definition was used and this causes confusion and uncertainty when inventory data from different sources are compared (Nabahungu, 2021).

In “The Law Determining the Use and Management of Marshlands in Rwanda’’ “Marsh” means a plain area between hills or mountains with water, high biodiversity, and vegetation associated with marsh environments. For the English language version of this law, the term “marsh” is considered to be synonymous with the term “wetland” which is used in the English language version of “The Land Law” and in “The Environment Law”. Thus, in Rwanda “wetland” means all lowlands and comprises the complete valley bottom, both the well-drained and the wet part (Nabahungu, 2021).

For sustainable wetland use and management, it is important to know the physical and ecological characteristics of a wetland. REMA (2009) distinguished seven wetland types based on factors such as relief, altitude, soil type, vegetation, hydrology, surface area, catchment slope, and population density (Table 1).

2.4 Wetlands status of Rwanda

Rwanda has a very rich wetland cover of approximately 280,000 ha and this accounts for about 11% of the total land of the country (Nile Basin Initiative, 2019). Rwanda has been divided into two drainage basins which include the Nile to the east which covers a total of 67% while delivering 90% of the national waters and Congo to the west covering 33% while handling all national waters. These wetlands provide critical habitats for wildlife and biodiversity, they maintain important hydrologic processes which are essential in cleaning and protecting the surface and groundwater, and they support a variety of local livelihoods (“Nile Basin Initiative,” 2019).

Despite these benefits, these wetlands are experiencing a myriad of challenges as a result of land use conversions, over-utilization of and competition for resources, and climatic factors (REMA, 2009).

Rwanda's wetlands are the fastest lost and degraded compared to any other ecosystems in the country. Currently, more than half of the wetlands in Rwanda are being used for agricultural activities and energy production (REMA, 2009).

2.5 Wetlands types in Rwanda

The word wetland refers to all areas with water covered occasionally, seasonally, or in perpetuity, such as, respectively, tidal flats, and flooded areas near rivers, rice paddies, swamps or lakes. Wetlands are classified according to characteristics such as soil type, vegetation, hydrology, and climate zone (Aboniyo *et al.*, 2017).

Table 1: Wetland types in Rwanda: altitude, soil type, functions, and corresponding agro-climatic zones

Type	Altitude	Soil type	Vegetation	Agro-climatic zone
High altitude wetlands	>1800	Histosols	Various vegetations	Crete zone Volcanic land
Mid-altitude Impala wetlands	1550-1800	Histosols	*Cyperus papyrus, Syzygium*	Impala
Mid-altitude wetlands along Lake Kivu	1400-1500	Inceptisols, Nitosols	*Cyperus papyrus, Cyperus latifolius Typha*	Kivu Lake border
Mid-altitude central plateau wetlands	1400-1800	Inceptisols,	*Cyperus latifolius*	Central plateau
Low-altitude wetlands of Akanyaru, Nyabarongo, and Akagera	1200-1500	Histosols	*Cyperus papyrus Phoenix reclinata Syzygium,cordatum*	Mayaga, Bugesera
Low-altitude wetlands in the East	1200-1500	Vertisol	*Typha domingensis*	Eastern Plateau and Savannah
Low-altitude wetlands of Imbo	< 1000	Vertisol	*Typha mauritianum*	Imbo

Adapted from REMA (2009).

The biggest wetlands are floodplain wetlands of low altitude associated with major lakes such as Lake Cyohoha, Rweru, Mugesera, Nasho, and rivers, such as Nyabarongo, Akanyaru, Mukungwa, Base, Nyabugogo, among others (REMA, 2021) .

The marshlands are the most physically and chemically heterogeneous of all aquatic ecosystems in Rwanda. They are in effect seasonal wetlands. During the rainy season, the water level is either at or above the lowest ground surface, and the flood plains are not very long or wide (usually less than 200 meters wide). (Chemonics International Inc, 2008).

The wetlands inventory that was herd by REMA in 2008 in partnership with the Integrated Management of Critical Ecosystems (IMCE) project supported financially by GEF and the World Bank. The results of the inventory showed that Rwanda has 860 marshlands and 101 lakes occupying a total surface of 278,536 ha (10.6 percent of the country's surface area), and 149,487 ha, respectively (REMA 2008). This inventory also found 861 rivers totaling 6,462 km in length. 41 percent of the inventoried marshlands are covered by natural vegetation, 53 percent are under cropping, (which represents about 148 344 ha) and about 6 percent are fallow fields (Aboniyo *et al.*, 2017).

Despite their importance, some wetlands in Rwanda face pressure from inappropriate forms of agriculture (uncontrolled fertilizers and pesticides), soil erosion, peat extraction, illegal mining, illegal infrastructure, and pollutants from industrial wastewater discharge (organic waste, pathogens, and heavy metals) among others (Aboniyo *et al.*, 2017). Wetlands degradation and pollution have a significant impact on water quality and quantity. The declining capacity for wetlands to provide critical ecosystem services has resulted in increased flooding and attendant damage to infrastructure lives reduced productivity, and silting of water bodies (Aboniyo *et al.*, 2017).

Climate changes, coupled with population growth, are additional threats to wetlands and freshwater resources. Therefore, sustainable practices which support healthy wetlands to complete their respective functions and come up with goods and services to sustain human life are coming to the fore. Rwanda has shown commendable political will and taken tangible actions to address wetlands degradation and unsustainable use of water resources (*Rwanda Environment Management Authority (REMA): Biodiversity Conservation*, n.d.)

2.6 Wetland protection status in Rwanda

Rwanda is aware of the value of wetlands and the necessity for proactive management of them. For instance, existing law distinguishes wetlands into those that are entirely protected and those that are not. The subsequent group is further broken down into those with the status of use without conditions and individuals with the status of use under certain conditions The Prime Minister's Order, which was issued in 2017 specifies all marsh areas, their features, boundaries, and the methods for using, developing, and managing them (ARCOS, 2021) .

In the short term, any illegal actions in wetlands must be avoided in order to preserve their sustainable use. Over the long term, working together is needed so that other unsustainable activities operating within wetlands come to an end (ARCOS, 2021).

Only with the cooperation of all partners and stakeholders will these aims be achievable. Achieving these goals will only be possible with the involvement of all partners and stakeholders. The cooperation with local government authorities will ensure the true value of wetlands to our socio-economic development is understood and act accordingly (ARCOS, 2021).

For long-term water resources, wetlands must be preserved. Over a thousand years, peat soil has accumulated in certain marshes in thick layers. In order to generate energy, peat soil will be used in a number of areas as part of Rwanda's peat-to-power strategy. In order to enhance the soil structure and nutrient management of hillside agriculture, peat is frequently employed as manure. In particular, the higher-elevation marshes in Rwanda's north are entirely made of peat, an organic substance. The organic content in these wetlands oxidizes (burns), causing them to deteriorate until nothing is left (ARCOS, 2021).

2.7 Functions and values of wetlands in Rwanda

Because of their elevated levels of nutrients, marshlands found in freshwater are one of the most fruitful ecosystems on earth. They buoy up a wide attire of fauna communities that in turn support an extensive variety of wildlife within this important wetland ecosystem. As a result, marshlands support a wide range of life that is disproportionate to their size. Moreover to their worthwhile ecosystem importance, non-tidal marshlands help to reduce flood damage and prevent excess nutrients from surface runoff (Nabahungu, 2021).

Wetlands that carry the biodiversity criterion have ecosystems containing specific flora and fauna. The destruction of those ecosystems ends in the pruning or loss of biodiversity. Some species of plant communities in wetlands are recognized by law as endemic and classified by the Convention on International Trade in Endangered Species (CITES) to ensure their protection. Wetlands with a biodiversity criterion are periodically home to migratory birds and are considered ecosystems of international importance under the Ramsar Convention (REMA, 2009).

Wetlands in Rwanda have been used in different ways and have a great role to play in the national economy. Most of the ecosystem services related to wetlands accrue to local or national beneficiaries. Rwandan cities depend on wetlands for their water supplies and electricity generation. The main functions of wetlands in Rwanda include agriculture production, hydrological functions, biodiversity reservoirs, peat reserve, mitigation of climate change, leisure and tourism, and cultural value (REMA, 2006).

In Rwanda where many local communities face vulnerability, poverty and food insecurity, these goods and services make an important contribution to the improvement of livelihood. In addition, the conversion of wetlands to agricultural production has grown rapidly over the last two decades due to the drastic sacristy of cropland. To a high level, the Rwanda, through agencies like REMA supports this wetland development in order to improve agricultural production, for the improvement of the rural economy and poverty reduction (REMA, 2006).

2.8 Native and exotic tree species in Rwanda

Forests and woodlands of Rwanda are categorized into four classes, including the natural forests of the Congo Nile Ridge such as Nyungwe National Park (NNP) Gishwati-Mukura National Park; the Volcanoes National Park (VNP), the natural forests in savannah and gallery-forest of the Akagera National Park (ANP) and remainder is made of savannahs and gallery forests of Bugesera, Gisaka and Umutara and other forest plantations composed mostly by exotic species such as *Eucalyptus spp, Pinus spp, Grevillea robusta*, etc. and trees dissipated on farmlands (agroforestry) generally on anti-erosion ditches (REMA, 2009).

According to a mapping inventory conducted by MINITERE in 2007, which was done for forests with a surface of 0.5 ha and with an overall coverage of over twentieth percent, the country of Rwanda's forests was estimated to be 240,746 ha in 2007, or roughly 10% of the area of the country's dry lands (23,835 sq.km) (Chemonics International Inc, 2008).

However, forests cover land has increased considerably. According to a recent inventory forests are estimated to occupy 724,695 hectares (30.4 percent) of the total land area of which 387,425 hectares (53.5 percent) are plantations and 130,850 hectares (18.1 percent) are natural mountain rainforests, 161,843 hectares are wooded savannah (22.3 percent), 43, 963 hectares are shrubs (6.1 percent) and 614 hectares are Bamboo stands. The forestry industry supported the agriculture industry, which accounted for 26% of the country's GDP in 2020, and added 6% to the GDP overall. Additionally, woods serve as the foundation for the nation's tourism potential and supply around 86% of the country's primary energy, primarily for domestic cooking (REMA, 2021).

However, forest resources in Rwanda include also small woodlots and agro-forestry resources which were not considered in the inventory. The table 2 shows the forest classification in Rwanda, based on the national inventory of forests in Rwanda done in 2019. This classification shows that forests plantations compose the major parts of the forest land cover in Rwanda (53.5%), followed by wooded savannah (22.3%) and natural forests (18.1%%)

Table 2: Types of forests in Rwanda

Forest cover type	Total area in ha	Percentage (%)
Bamboo stand	613	0.1
Forest plantation	387,425	53.5
Natural forest	130,850	18,1
Shrub	43,963	6.1
Wooded savannah	161,843	22.3
Grand total	724,695	100.0

(Ministry of Environment, 2019)

2.9 Functional diversity in tree species

Functional traits are a species' morphological, physiological, or phenological characteristics that influence growth, reproduction, or survival (Violle *et al.*, 2007). These traits mediate species' responses to environmental changes, revealing how different ecological strategies are constrained in community assembly (Paine et al., 2015, Lasky *et al.*, 2014). Moreover, changes within the functional composition of forest communities along environmental gradients may point to mechanisms behind alterations in ecosystem functioning and services (Díaz & Cabido, 2001; Soudzilovskaia *et al.*, 2013). Studies that combine richness, community composition, and functional trait analysis are rare but have the potential to provide a more holistic understanding of how habitat characteristics impact biodiversity (Lasky *et al.*, 2014).

Knowledge of functional traits is important to understand the basis of species distribution, their response to environmental changes, biotic interactions, productivity, and their role in ecosystem processes. At a higher scale (communities), functional diversity is the key to defining the mechanisms that link biodiversity and ecosystem function. Therefore, understanding the effects of environmental drivers on ecosystem functions through plant functional characteristics is important to predicting the net provisioning of multiple ecosystem services and their productivity (Havugimana *et al.*, 2021).

Functional diversity might be a tool for predicting the functional consequence of species traits in ecosystem-level processes (Petchey & Gaston, 2002). Also, functional diversity has the potential to be a proxy for quantifying the niche space of a given assemblage and niche differentiation among member species in the functional space (Mouchet *et al*., 2010). Thus, functional diversity acts as an interface for an improved understanding of ecological processes (e.g., environmental filter effects and dispersal limitation) that govern species sorting in a community (Pakeman, 2011) and ecosystem functioning in terms of the complementarity of resource use and functional redundancy among component species (Díaz *et al*., 2007, Naeem & Wright, 2003).

Functional diversity measures are being rapidly developed in a multitude of ways that represent functional patterns among component species, such as functional richness, functional evenness, and functional divergence (Mouchet *et al*., 2010), The application of these approaches illuminates the functional diversity of taxonomic species and guides the investigation of mechanistic relationships between ecosystems and their biodiversity function. (Naeem & Wright, 2003, Balvanera *et al*., 2006 , Biswas & Mallik, 2011). The response of functional diversity (measured as species reassembly) to land use intensification, including forest practices, can be used to evaluate the impacts of anthropogenic disturbances on community/ecosystem properties (Flynn *et al.*, 2009).

Temperature changes might act as a selection pressure on plant functional traits. Therefore, the analysis of the variation of plant functional traits in response to this environmental factor and the implications of this variation for the capacity of populations to respond to changing environmental conditions is of great importance (Körner, 2007; Soudzilovskaia et al., 2013). Water loss from transpiration can cause variations in leaf temperature. As a result, variations in leaf temperature can serve as an indirect indicator of variations in leaf water content and transpiration (Körner, 2007).

DBH measurements are used to assess and contrast ecological parameters such as tree size, above-ground biomass, and carbon accumulation across sites, and measure how local environmental (e.g., rainfall, temperature, topography, and soil) and biological (e.g., presence of invasive species, forest edge types) factors impact the above parameters. DBH measurements of a single stem within a short period (within a day or week) may vary due to changes in water availability, transpiration rates, water potential between bark and xylem cells, the elasticity of wood tissue, thermal stress, and carbon additions or subtractions in the xylem cells (Daudet et al., 2005).

3. MATERIALS AND METHODS

3.1 Study area description

This study was conducted in Nyandungu wetland eco-tourism Park located in two districts of Kigali City, Gasabo district (Ndera sector), and Kicukiro district (Nyarugunga sector) in Kigali.

Nyandungu Eco-Tourism Park is a noteworthy natural landmark. This park is well-known for its breathtaking scenery, wide variety of plants and animals, and chances for outdoor recreation and ecotourism excursions. It's frequently regarded as a sanctuary for adventurers and environment lovers hoping to discover Rwanda's abundant biodiversity and stunning landscapes.

This area has more or less constant temperatures throughout the year (16 – 17°C in the high altitudes). The monthly mean temperature of the wetland is 21°C. Normally, the whole of Kigali City (2°S) with a mean altitude equivalent to 1,500 m, and located in the equatorial region, its tropical climate of Nyandungu is the same as that of the whole city which is characterized by long wet seasons and relatively low temperatures as a consequence of its altitude (Muhire & Ahmed, 2015). Its relative annual rainfall module is (996, 6 mm) and clayey sandy soils suggest a relatively low runoff despite its impervious character after uncontrolled urban development (Muhire & Ahmed, 2015).

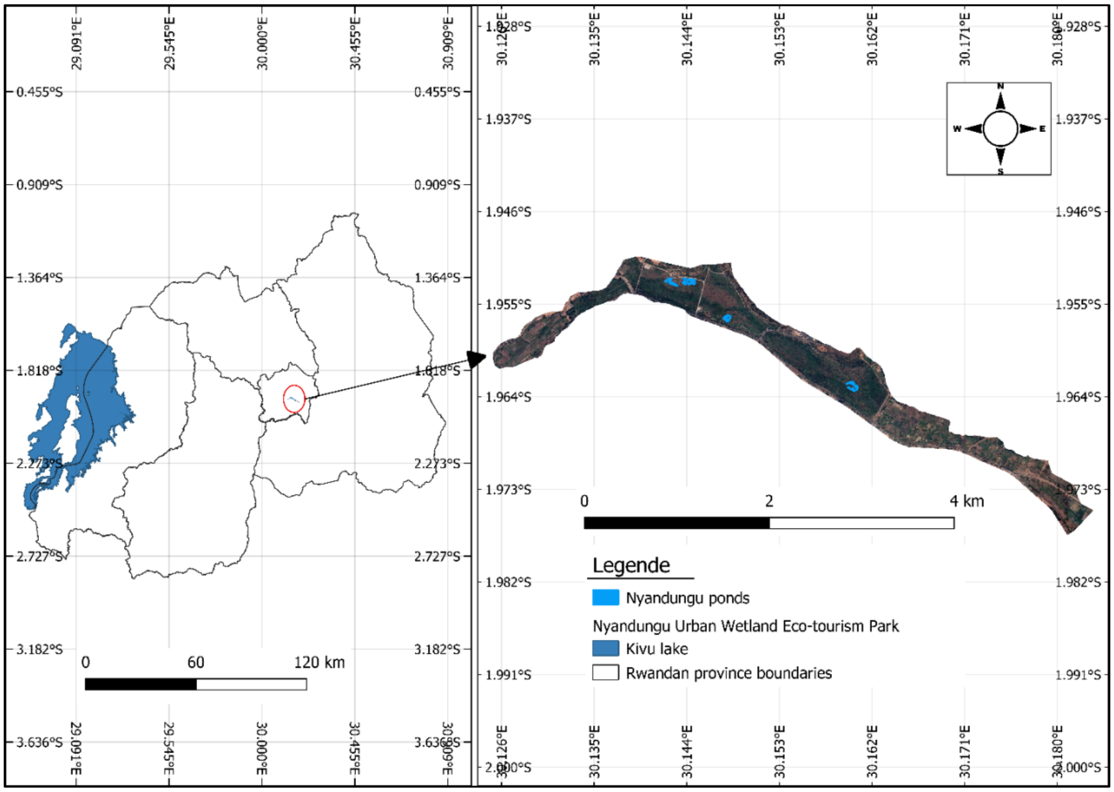

Figure 1: Map Nyandungu Wetland Ecotourism Park showing geographical location and hydrology

The park is divided into five sectors. The study was conducted only in two sectors according to the climate and soil conditions of the period of data collection. The following map shows the sampling area.

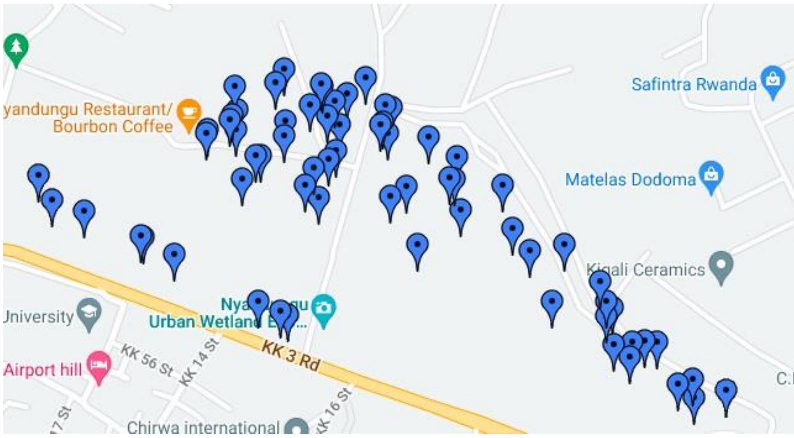

Figure 2: Figure representing the distribution of identified species in the wetland

3.2 Data collection and materials

Data were collected in a wet season of the year 2022 namely mid-September. Exotic and native tree species were identified in distinguished plots set in the various sectors within the study area. Nyandungu Wetland Ecotourism Park is divided into five sectors. During our data collection, two of them were easily accessible, whereas the remaining parts of the wetland were very wet. A GPS was used to record coordinates. During tree species identification a few steps were followed: Observation of the stems and branches and look for any distinctive features on the plant's stalks and branches that can offer hints as to what kind of species it belongs. Species with stems and branches that have hardwood were classified as trees. Flowers, fruits and leaf forms were mostly crucial in differentiating species within a family in some cases and thorns, barbs, hairs and any other defense-related mechanisms were observed.

The identification was completed by the use of textbook (Nduwayezu et al., 2009) and the assistance of a botanist

When measuring leaf temperature, an infra-red thermometer was used to take leaf temperature measurements of selected species being exotic or native but of the same age. The leaf was held horizontally, with the thermometer positioned at a 45◦ angle to position of the leaf and a distance of around 2 cm from the leaf surface to avoid leaf shading. To account for the influence of varying air temperature as well as wind speed, all temperature recordings were taken five individuals within one species and thereafter standardized (Mujawamariya *et al*., 2018).

DBH measures were recorded using a rope and a ruler. At breast height, the diameter of each tree was measured. This consists of approximately 1.35 m of height above the ground. After taking the measures of the circumference of the tree, by dividing the circumference by π which is 3.14, the diameter was calculated. The selected species were located in the same zone and were of 6 years old according to the agronomist of the park.

3.3. Data analysis

Data were processed and analyzed using Microsoft Excel (MS) with a generalized linear model.

4. RESULTS AND DISCUSSION

4.1 Tree species identification

Overall, a total of 50 tree species were identified from two sectors out of five sectors of Nyandungu Wetland. Table 3 presents tree species with scientific names, their families, and the origin or if they are native or exotic.

Of all species identified, 37 (74%) were native species while 13 (26%) were exotic species (Table 3).

Table 3: List of native and exotic plant species identified during the study and their respective families identified in the area.

Nº	*Scientific name*	Family	Origin
1	*Afrocarpus latifolius*	Podocarpaceae	Native
2	*Albizia adianthifolia*	Fabaceae	Native
3	*Albizia versicolor*	Fabaceae	Native
4	*Bambusa vulgaris*	Poaceae	Exotic
5	*Bambusa textilis*	Poaceae	Exotic
6	*Bersama abyssinica*	Francoaceae	Exotic
7	*Bridelia micrantha*	Phyllanthaceae	Native
8	*Calliandra houstoniana*	Fabaceae	Exotic
9	*Carissa edulis*	Rutaceae	Exotic
10	*Casuarina equisetifolia*	Casuarinaceae	Exotic
11	*Croton megalocarpus*	Euphorbiaceae	Native
12	*Dombeya torrida*	Malvaceae	Native
13	*Dracaena afromomtana*	Asparagaceae	Native
14	*Entada abyssinica*	Fabaceae	Native
15	*Erythrina abyssinica*	Fabaceae	Native

16	*Euphorbia tirucalli*	Euphorbiaceae	Native
17	*Ficus benjamina*	Moraceae	Native
18	*Ficus ovata*	Moraceae	Native
19	*Ficus sur*	Moraceae	Native
20	*Ficus toningii*	Moraceae	Native
21	*Grevillea robusta*	Proteaceae	Exotic
22	*Grewia similis*	Malvaceae	Native
23	*Hagenia abyssinica*	Rosaceae	Native
24	*Kigelia africana*	Bignoniaceae	Native
25	*Gmelina arborea*	Verbenaceae	Exotic
26	*Maesopsis eminii*	Rhamnaceae	Native
27	*Maytenus senegalensis*	Celastraceae	Native
28	*Markhamia lutea*	Bignoniaceae	Native
29	*Millettia laurentii*	Fabaceae	Native
30	*Mitragyna rubrostipulata*	Rubiaceae	Native
31	*Olea europaea*	Oleaceae	Native
32	*Persea amercana*	Lauraceae	Exotic
33	*Polyscias fulva*	Araliaceae	Native
34	*Psidium guajava*	Myrtaceae	Exotic
35	*Rhamnus frangula*	Rhamnaceae	Exotic
36	*Rhus longipes*	Anarcadiaceae	Native
37	*Securinega virosa*	Phyllantaceae	Exotic
38	*Senegalia polyacantha*	Fabaceae	Native
39	*Spathodea campanulata*	Bignoniaceeae	Native
40	*Syzygium guineense*	Mrytaceae	Native
41	*Tabernaemontana stapfiana*	Apocynaceae	Native
42	*Terminalia mantaly*	Combretaceae	Exotic
43	*Trema orientalis*	Cannabaceae	Native

44	*Vachellia hockii*	Fabaceae	Native
45	*Vachellia kirkii*	Fabaceae	Native
46	*Vachellia sieberiana*	Fabaceae	Native
47	*Vernonia amygdalina*	Asteraceae	Native
48	*Vernonia lasiopus*	Asteraceae	Native
49	*Vigna unguiculata*	Fabaceae	Native
50	*Zanthoxylum chalybeum*	Rutaceae	Native

The dominant family was Fabaceae comprised of 11 (22%) tree species including 10 native species and 1 exotic species while the other families comprised between 1 species to 5 species (Table 4). The native tree species are more frequent in Nyandungu Wetland than exotic tree species (Table 4). Almost, all tree families comprise the native species except 5 families namely Poaceae, Francoaceae, Verbenaceae, Lauraceae and Combretaceae. They present 18.6% of the total families (Table 4).

On the other side, many tree families do not comprise the exotic tree species for about 74% of the total families namely, Asteracae, Phyllanthaceae, Casuarinaceae, Euphorbiaceae, Malvaceae, Asparagaceae, Moraceae, Proteaceacea, Rosaceae, Bignoniaceae, Rhamnaceae, Celatraceae, Rubiaceacea, Oleaceae, Araliaceae, Podocarpaceae, Anarcadiaceae, Apocynaceae, Lamiaceae and Cannabaceae (Table 4).

7.4% of the families comprise both native and exotic tree species from 2 families such as Fabaceae, and Rutaceae (Table 4).

Table 4: The distribution of native and exotic tree species in their families

No	Family names	Species types	Species numbers
1	Fabaceae	Native	10
		Exotic	1
2	Podocarpaceae	Native	2
		Exotic	0
3	Poaceae	Native	0

		Exotic	2
4	Francoaceae	Native	0
		Exotic	1
5	Asteraceae	Native	2
		Exotic	0
6	Phyllanthaceae	Native	1
		Exotic	0
7	Rutaceae	Native	1
		Exotic	1
8	Casuarinaceae	Native	1
		Exotic	0
9	Euphorbiaceae	Native	2
		Exotic	0
10	Malvaceae	Native	2
		Exotic	0
11	Asparagaceae	Native	1
		Exotic	0
12	Verbenaceae	Native	0
		Exotic	1
13	Moraceae	Native	4
		Exotic	0
14	Proteaceae	Native	1
		Exotic	0
15	Rosaceae	Native	1
		Exotic	0
16	Bignoniaceae	Native	2
		Exotic	0
17	Rhamnaceae	Native	1
		Exotic	0
18	Celastraceae	Native	1
		Exotic	0

19	Rubiaceae	Native	1
		Exotic	0
20	Oleaceae	Native	1
		Exotic	0
21	Lauraceae	Native	0
		Exotic	1
22	Araliaceae	Native	1
		Exotic	0
23	Myrtaceae	Native	1
		Exotic	1
24	Anarcadiaceae	Native	1
		Exotic	0
25	Apocynaceae	Native	1
		Exotic	0
26	Combretaceae	Native	0
		Exotic	1
27	Cannabaceae	Native	1
		Exotic	0

Richness of native tree species was recorded in the Nyandungu wetland. Interestingly, our findings are in the line with the conjecture that the management practices of native and exotic tree species by the farming community or conservation techniques vary across land use types in agricultural landscapes. However, in the case of Nyandungu wetland restoration, the main focus was on native trees as they are believed to be effective in wetlands conservation. Past studies reported native species as species that have considerably interacted/adapted to the local biota and abiota. Native trees are adapted to the local climate and landscape. Therefore, native species are those that have significantly adapted to or interacted with the local biota and abiota (and vice versa). While non-natives are species that have not significantly adapted or interacted with the local inhabitants or abiota (Hettinger, 2021). This scientific investigation is widely related to our findings and there is another hypothesis finding that during the first growing season, the non-native species suffered with getting the ability adaptation (Burgiel & Muir, 2010). In this case, Nyandungu Wetland is a new restoration area and almost species are at their young stages.

The dominant native tree species found in the Nyandungu wetland were distributed in the Fabaceae family which holds 21.5% of the identified species. In this context, the abundance of species of the Fabaceae family comes from the dispersal of their seeds which can be made easier by birds (Brǿnnvik & von Wettberg, 2019). Birds are very good at spreading seeds far and to the right environments (Brǿnnvik & von Wettberg, 2019). The reports from (Smýkal et al., 2015), the extremely large geographic spread of wild *Phaseolus vulgari*s (and possibly *Phaseolus lunatus* lima bean) from Mexico to the central Andes of South America is likely a key factor of bird dispersal of legumes in genera known to have cultivated species, and in *Phaseolus*, bird dispersal is likely widespread. It is possible to attribute the numerical domination of Fabaceae species to the fact that these trees are typically found on farmlands in the vicinity of Nyandungu Wetland.

4.2 DBH measures in selected native and exotic species of Nyandungu wetland

DBH values were measured in 16 tree species including 9 native species and 7 exotic species and then distributed in 12 families (Table 5). The tree DBH ranged from 5.7 to 25.8 cm.

Table 5: DBH & Leaf temperature with standard deviation of different native and exotic tree species expressed in centimeters and degrees Celsius respectively

Species	Types	DBH (Cm)	Leaf temperature (^{0}C)
Erytrina abbysinica	Native	17.6	23.7±0.04
Vachelia abysinica	Native	14.8	24.3±0.03
Vachelia polyacantha	Native	12.7	23.6±0.04
Calliandra houstoniana	Exotic	5.7	21±0.02
Markhamia lutea	Native	13.5	24±0.05
Vernonia amygadalina	Native	6.7	24.1±0.04
Grevillea robusta	Exotic	25.8	24.1±0.04
Ficus benjamina	Exotic	6.2	24.5±0.03
Ficus thonningii	Native	19	27±0.05
Terminalia mantaly	Exotic	16.4	25.3±0.01

Polyscias fulva	Native	22.23	24±0.01
Trema orientalis	Native	24	22±0.02
Psidium guajava	Exotic	6.4	23±0.03
Persea americana	Exotic	14.4	24.4±0.03
Afrocarpus falcatus	Native	14.2	26.3±0.06
Casualina equisetifolia	Exotic	21	23.5±0.04

The arrangement of tree species from low DBH value to high DBH value are *Calliandra Houstoniana; Ficus benjamina*; *Psidium guajava*; *Vernonia amygadalina*; *Vachellia polyacantha; Markhamia lutea; Afrocarpus falcatus; Persea americana; Vachellia abysinica; Terminalia mantaly; Erytrina abbysinica; Ficus thonningii; Casualina equisetifolia; Polyscias fulva; Trema orientalis* and *Grevillea robusta* respectively (Table 5).

The trees whose DBH was >10cm are represented by 4 tree species such as *Calliandra houstoniana, Ficus benjamina; Psidium guajava* and *Vernonia amygadalina*. Among those four species, the exotic species counted more than the native species for about four against two (Table 5).

The average DBH ranged between 10 to 20 cm and a total of 8 tree species are included. They are *Vachellia polyacantha; Markhamia lutea; Afrocarpus falcatus; Persea americana; Vachellia abysinica; Terminalia mantaly; Erytrina abbysinica* and *Ficus thonningii* (Table 5). Controversy to the first class, in this class the native species are counted more than exotic and they were six against two respectively.

The highest diameter class according to our results ranged above 20 cm of DBH and 4 tree species are comprised here. The species with the highest diameter are *Casualina equisetifolia; Polyscias fulva; Trema orientalis* and *Grevillea robusta*.

Amazingly, the lowest DBH value is an exotic species as well as the highest DBH value is also an exotic species. It is a *Calliandra houstoniana* against *Grevillea robusta*. The DBH values varied within families in a given class, a typical example is Fabaceae and Moraceae in this study.

The DBH is a significant factor that can be used to calculate key forestry indices such forest growth stock, core area, biomass, and carbon stock. DBH parameters in our investigation showed exotic species to outgrow native species, but on some occasions, native species have great DBH than exotic ones. Researchers have discovered that environmental elements like terrain, soil, and climate have a significant impact on DBH. In various situations, trees of the same age might have significantly varied DBHs (Zhou et al., 2019).

With the tree DBH of our results ranging from 5.7 to 25.8cm, the dissimilar range was found by (Mugunga et al., 2022), from 5 to 97 cm in the research of Tree Species Diversity in a Naturally Regenerated Secondary Forest in the Ruhande Arboretum, Rwanda. Here the lowest DBH for both studies are quite similar but the highest DBH are different.

Several factors can explain the intra- and inter-tree variations of wood density. According to Xu *et al*. (2015), there is a relationship between wood density and several traits across plant growth including functional diversity, and environmental factors also can affect plant growth including light, temperature, water, humidity, and nutrition.

4. 3 Leaf temperature variation in tree species of Nyandungu Wetland

The leaf temperature calculated in 16 tree species was concentrated between 22 to 27 ^{o}C. Five young leaves were selected at each of the selected species, with standard deviation the values of leaf temperature were determined. All leaf temperature values obtained are arranged from *Calliandra houstoniana; Trema orientalis; Psidium guajava; Casualina equisetifalia; Vachellia polyacantha; Erytrina abbysinica; Polyscias fulva; Vernonia amygadalina; Grevillea robusta; Acacia abysinica; Persea americana; Ficus benjamina; Terminalia mantaly; Afrocarpus falcatus; and Ficus thonningii* respectively.

A higher leaf temperature was recorded in *Ficus thonningii* which is native by nature as well as a lower leaf temperature in *Calliandra houstoniana*, the exotic species by nature.

In general, the leaf temperatures were measured without recording the air temperature because the aim was to know the leaf temperature as one among leaf physiology instead of comparing leaf and air temperatures.

These different biological processes (temperature to induce transpiration and water use efficiency) are quite corrected (Hatfield & Dold, 2019). Leaf temperature values shows no dependence on species being native or exotic.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Wetlands play an important function in water treatment and purification and serve as sources of water for the lakes and connecting rivers in the country. But they, too, are under pressure from many sources. This study identified 51 tree species consisting of 41 tree native species and 10 exotic tree species distributed in two sectors out of five sectors of Nyandungu wetland. These tree species belonged to 27 families where Fabaceae was more frequent than others in the area. Within the study area, among 16 tree species; DBH ranged from 5.7 to 25.8 cm and leaf temperatures varied from 19.7 to 27^{o}c. These two parameters were assessed to identify the growth rate and leaf physiology of tree species. Generally, DBH was greater in native than in exotic tree species. However, our results did not show a significant difference in leaf temperature between native and exotic tree species in Nyandungu wetland eco-tourism park hence both exotic and native tree species in wetlands restauration and conservation both species should be used regarding their adaptation.

5.2 Recommendations

The following recommendations are suggested:

1. Further research should be done emphasizing physiological differentiation among native and exotic species.
2. Similar studies should be done in other restored wetlands in Rwanda.

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APPENDIX

1. Research permit letter given by REMA

Republic of Rwanda

RWANDA ENVIRONMENT MANAGEMENT AUTHORITY (REMA)

REMA

Kigali, on 23 AUG 2022

N°...2169.........../DG/2022

Dean, School of Science
College of Science and Technology (CST)
University of Rwanda
KIGALI

Dear Sir,

Re: Response to your request for the research permit for Mr. Nathan AKIMANA to collect data in Nyandungu Eco-Park.

Reference is made to your letter dated 16th August 2022 requesting to permit your student to conduct a research at Nyandungu Eco-Park.

I would like to inform you that, **Mr. Nathan AKIMANA,** final year Biodiversity Conservation and Natural Resources Management student at the Department of Biology, School of Science, College of Science and Technology, University of Rwanda, is permitted to visit Nyandungu Eco-Park with the purpose of collecting data related to Fauna (indigenous and exotic plant species).

Dear Dean, note that prior to the publication of any findings from the research using the data collected from Nyandungu Eco-Park, a draft of thesis or manuscript and raw data collected have to be shared with the Rwanda Environment Management Authority for review.

For more details and guidance before entering the Park, students should contact Mr. Eric CYUBAHIRO on Tel: 0785177892 or by email: ecyubahiro@rema.gov.rw.

Sincerely,

Juliet KABERA

Director General

Cc:

- Head of the Department of Biology, UR-CST
  KIGALI

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