EFFECTS OF ANTHROPOGENIC ACTIVITIES ON TREE SPECIES DIVERSITY IN GISHWATI FOREST RESERVE, WESTERN, RWANDA

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Master of Science in Environmental management and Development

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By

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Bsc-Educ Hons (KIE)

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DECLARATION

"This dissertation is my original work and has not been presented for a Degree or any other academic award in any University or Institution of Learning".

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19. 09. 10

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APPROVAL

This dissertation entitled " Effects of anthropogenic activities on tree species diversity in Gishwati Forest Reserve, Western, Rwanda" prepared and submitted by ISHIMO Yvette in partial of the requirements for the Degree of Master of Science in Environmental management and development has been examined and approved on oral examination with a grade of PASSED

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Professor Remigius Bukenya-Ziraba

25/9/10
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DEDICATION

To my parent Rubangura Antoine and Nzamugura Jeanne d'Arc

My siblings Ishimwe Yvonne, Igena Dianne,Igabe Divine

Uwacu Yves Moise and Ineza Antoinette

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ABSTRACT

The study in Gishwati forest Reserve aimed at determining the effect of anthropogenic activities on tree species diversity. Three areas within the forest were described as Disturbed Forest (DF), Natural forest (NF) and secondary forest (SF) in consideration of level of human disturbance. Data collection was done using plot sampling based on enumerating tree species (with a diameter at breast height ≥10 cm) within the forest, and observations to improve on validity and reliability of the measurement. Four transects, ranging from 2 to 3.8 km in length and cutting through the disturbed and undisturbed portions of the study were established.

The distribution of species within the sample plots was determined using percentage frequency, relative density and species abundance. Shannon-Wiener diversity index (H') and Pielou's evenness index (E) were used to characterize species diversity in the sampling area. To determine if there was significant difference in tree species diversity between the disturbed and undisturbed areas of the Forest reserve, one-way Analysis of Variance (one-way ANOVA) test using SPSS package, version 16.0 was used to find if the means are different between different areas of the forest.

Analysis of data collected from the 60 sample plots in the study area, revealed that 753 individuals trees were in existence: 44 species, 43 genera and 27 families. There was a difference in number of tree species and individual trees. The results showed 31 species with 235 tree individuals in disturbed forest, 40 species with 291 tree individuals in natural forest and 30 species with 227 tree individuals in secondary forest. The results revealed also that the differences in tree canopy density and tree diversity and DBH distribution are highly significant in three area of the forest.

The results of the Shannon index (H') indicated that the highest community diversity was discovered in Natural forest reserve defined as undisturbed part of the forest (3.45). This is followed by secondary part of the forest (2.75) while the last value was obtained for the disturbed part of Forest Reserve (2.7). The species diversity values obtained for the three sites were different. This showed that the anthropogenic activities have an impact on tree species diversity. Species evenness (E) results followed the same pattern as H'. The highest value 0.936(Evenness) was obtained for natural part of the Forest Reserve while 0.809 and 0.788 were obtained for secondary part of the forest and disturbed part of forest reserve respectively. Tree diversity decreased with increase of disturbances. Anthropogenic disturbances have an impact on forest structure, tree distribution and diversity.

The management strategies for forest rehabilitation and tree diversity conservation should be applied in the forest reserve the restoration of tree species which are rare or that have disappeared in the study area and forest regeneration. Other approaches such as involving local communities in forest biodiversity conservation and protecting people's livelihoods is the most appropriate strategy for sustainable management of tree diversity.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Rwanda is one of the smallest countries in Africa, and, until the last 20 years, it was little known by the outside world (Weber, 1987). Its high soil fertility, due to rich volcanic soils, has led to the highest population density on the African continent, with up to 500–700 people per square kilometer (Weber, 1987). According to Sutherland (2000) conservation problems largely result from increasing human population, new technologies and our increasing expectation. In Rwanda, over 90% of the population relies on subsistence agriculture to meet its needs, with a concomitant need for land, which puts great pressure on the country's remaining natural ecosystems, whether forested, savanna, or wetland.

Loss of biological diversity is currently a problem raising much concern globally and at national level. This concern according to Wilson (1994) stems from the accumulation of substantial knowledge on the extent of deforestation, species extinction and tropical biology. The overall decline in the abundance of wildlife globally; the rate of habitat loss is alarming, especially for tropical forests, followed by others ecosystems such as dry land and wetland.

For a period of about 40 years, the area under natural forest in Rwanda underwent a decrease of about 65% between 1960 and 2002 (Twagiramungu, 2006). The search for arable lands, extensive farming, illegal felling of forests for firewood, production of wood for charcoal and poles for building in urban areas, as well as land mismanagement have drastically contributed to the reduction of the surface area of forests. Despite this pressure, two national parks and several forest reserves had been established by the mid-1950s for either complete protection or sustainable management (Weber, 1987) and one of the forests is Gishwati forest reserve.

Gishwati is an Albertine Rift Afro-mountain forest and for decades constituted an important area of biodiversity. It constituted approximately 280 square kilometers in the mid-1970s and it used to cover large areas of the highland range of the Congo-Nile Divide in the North-west of Rwanda before the deforestation started in the middle of the 1990s. It contained populations of chimpanzees (*Pan troglodytes*) and golden monkeys (*Cercopithecus mitis kandti*) as well as blue monkeys (*Cercopithecus doggeti*), although the forest was fairly degraded by many years of cattle keeping within the forest (Weber, 1987).

The World Bank supported an integrated forestry and livestock project that converted 100 km^2 of forest pasture and other 100 km^2 of forest to pine plantations in the early 1980s. Thirty square kilometers were designated as a military zone in the North of the forest, leaving only 50 square kilometers of natural forest. In fact Gishwati Forest has never been a priority for forest conservation. During and following the war, the northern part of Gishwati was used to host camps for displaced people. By late 1997 the total number of families settled in Gishwati was estimated at 10,184. During 1997 and 1998, the forest was also used as a hide out by many of the Interahamwe militia. Consequently, a considerable number of military operations took place in the forest, which caused further degradation. The forest was converted to settlement, agricultural land as well as pasture. After the degradation, there is little of the original forest remaining in Gishwati.

Therefore, rapid and special intervention is needed to address the conservation problems and to reduce the pressure on endemic biodiversity. The present study focused on analyzing distribution and abundance pattern of tree species and tree diversity in both disturbed area and undisturbed area of Gishwati Forest reserve in order to provide recommendation for appropriate conservation strategies.

1.2 Problem statement

Tropical forests often are referred to as one of the most species-diverse terrestrial ecosystems (Kumar et al., 2006). Their immense biodiversity generates a variety of natural resources which help sustain the livelihood of local communities. However, many tropical forests are under great anthropogenic pressure and require management intervention to maintain the overall biodiversity, productivity and sustainability (Kumar et al., 2006)

Anthropogenic pressure in Gishwati Forest reserve has been due to the establishment of pastures and the development of pasture lands and correlated activities done by cutting down the forest. It was done in such a way that shrubs were eliminated, followed by tree cutting and bamboo elimination. The development of Irish potatoes agriculture and infrastructure such as roads and buildings led to loss of an important part of this forest. Then the fastest degradation took place from 1995 when a number of returnees from the eastern part of the Democratic Republic of Congo occupied one part of the forest to survive.

For Gishwati Forest reserve to recover there is a need for reforestation, forest regeneration as well as forest conservation. However in her study, Nyiratuza (2007) found that people adjacent to Gishwati Forest Reserve still use the forest in different ways for different purposes. Some go to forest to collect firewood, building materials, handcraft materials, honey, bush meat and medicinal plants. Others go to harvest natural vegetables from the reserve, to graze animals inside the reserve, to plant crops inside, and to collect water from the reserve. All these activities conducted in the forest are illegal since 2004 when the Ministry of Lands, Resettlement and Environment decided to protect this reserve.

There is a conflict between the surrounding community through the need of forest use and conservation of the Gishwati forest. Thus understanding species diversity and distribution patterns is important for helping managers evaluate the complexity and resources of this forest.

1.3 Purpose of the study

The purpose of this study was to examine the effect of anthropogenic activities on the diversity and distribution of tree species in Gishwati Forest reserve.

1.4 Research objectives

The research was intended to achieve the following objectives:

1. To assess the diversity and distribution of tree species in Gishwati forest
2. To determine if there is significant difference in tree species diversity between the disturbed and undisturbed areas of Gishwati Forest reserve.
3. To determine possible intervention strategies for species diversity conservation of Gishwati forest reserve

1.5 Research questions

The following questions were explored in this research:

1. What is the diversity and distribution of the tree species in Gishwati forest reserve?
2. What is the difference in tree species diversity between the disturbed and undisturbed areas of Gishwati forest reserve?
3. What are the possible intervention strategies for tree species diversity conservation of Gishwati forest reserve?

1.6 Scope of the study

The study was conducted in Gishwati forest reserve located in Rutsiro District, Western province of the country. Gishwati forest reserve is selected because it is the most affected by degradation, where 98% of the original forest has been removed by various activities.

1.7 Significance of the study

The study is expected to benefit NGOs especially the Great Ape Trust the first international conservation NGO to focus on Gishwati Forest Reserve in their project "the reforestation of forest and biodiversity in Gishwati and improved livelihood of the people in the region." The information collected will also serve as a reference by students and researchers who may wish to carry out research in all aspects of forest reserves conservation and data collected will also yield crucial inventory information fundamental for the conservation of the forest reserve. It will also be of great importance to relevant stakeholders and other organization with initiatives to conserve the forest reserve.

CHAPTER TWO

LITERATURE REVIEW

2.1 Gishwati forest reserve degradation

Changes in the forest functions result from pressures on such functions, such as human interventions, natural processes and events, or both. Generally human interventions include exploitation and destruction of resources or disposal of waste materials. The relationship between regeneration processes and pressures determines to what extent such processes lead to degradation of the environmental functions. Therefore, reproduction and regeneration processes influence the capacities to maintain stability, and include regulation processes such as reproduction rates of animals, re-growth and succession of plants, soil formation, purification and decomposition and recharge of water storage.

According to Keller and Botkin (2006) there is basically three degradation processes of any environmental functions; these are:

(i)Depletion: Taking out (utilizing, exploiting) environmental resources (e.g. plants, nutrients, animals, etc.) in excess of regeneration rates;

(ii)Pollution: Putting in quantities of damaging elements in excess of the rate of decomposition, break down and purification processes and;

(iii) Disruption and manipulation: Changing or destroying the natural conditions (e.g. construction of roads, introduction of exotic species or varieties by genetic engineering).

The degradation of Gishwati forest happened gradually from 1965 and culminated in the period after genocide which took place in 1994. The encroachment of Gishwati started in 1965 when tea estates and factories were established by the government. Tea being a rain fed crop, Gishwati was identified as a suitable site for tea plantation, and thus three tea factories were established.

The second factor that contributed to Gishwati forest loss is the establishment of GBK project in 1978 seen as disruption and manipulation. When conceived, this project was meant to carry out planting of *Eucalyptus* in order to curb the high demand in firewood for Kigali and Butare towns which then had 300,000 inhabitants and 60,000 inhabitants in the same year respectively (Munyansanga, 2003). Few years later, the project extended its activities in Gisenyi province and especially in Gishwati area with not only the mission of planting *Eucalyptus* and pines but also livestock production.

In other words it extended its activities in Gishwati area as an agro pastoral project with the following objectives: (i) to transform bamboo zones and zones of secondary forest of Gishwati into Pine and Cypress plantations and (ii) to transform the bamboo zones into improved pasture lands. The implementation of this project however, consisted in improving agriculture whereby communities were assisted in soil erosion protection and soil productivity by providing population with improved seeds and fertilizers. The project also intervened in livestock improvement by the establishment of pasture lands. In addition to the above factors infrastructure development inside the forest also contributed to the loss of Gishwati in that 16 hectares were removed for roads and buildings construction. Another government project which contributed to Gishwati loss is the Irish potatoes development project launched in 1978 by the Ministry of Agriculture and Livestock Development (MINAGRI, 2003), the project had a number of objectives including (i) the selection and introduction of new irish potato species from abroad; (ii) improvement existing Irish potato species and their dissemination into local communities; (iii) improvement of the stocking technique of irish potatoes. To achieve these objectives, an area of 200 ha of Gishwati natural forest was destroyed in 15 years only. The last phase and the fastest phase of Gishwati forest loss was done by returnees from DRC during the years that followed 1994 when the genocide took place in Rwanda. The destruction of this forest by these people was motivated by a number of reasons including: lack of land for agriculture; need for settlement; basic needs such as firewood, construction and timber production (Munyansanga, 2003). Munyansanga (2003) further states that although the destruction of this forest was mainly done by returnees, there were a significant number of people who had stayed in Gishwati area for long who also did participate in the destruction of Gishwati for the same motive.

2.2 Gishwati forest reserve Biodiversity

Gishwati forest degradation has been going on for thousands of years chiefly as a result of clearing land for commercial and industrial development; intensive collection of firewood; clearing of land for growing crops and to develop pasture for grazing animals leading to a serious loss of biodiversity. Before the destruction of Gishwati forest, the forest was characterized by a diverse number of plant species. All the slopes were covered by a luxuriant forest with an exceptional floristic richness (Munyansanga, 2003)

The species of big trees and high value were mainly *Podocarpus milanjianus, Newtonia buchananii, Polysias fulva, Macaranga pavifolium, Chrysophyllum gorungozanum, Neoboutonia macrocalyx, Hagenia abyssinica, Symphonia globulifera, Carapa grandiflora* and *Entandrophragma excelsum*. There are other species which were poorly represented such as *Dracaena afromontana, Croton macrostachys, Macaranga mildbraedii* (Prioul & Sirven, 1984). At the bottom of hills there were some species of trees such as *Fagara sp, Lobelia giberosa, Croton macrostachys* and the *Ortiz* (natural grass) while on the top of the hills there were species such as *Polysias fulva* and some species of ferns.

Blondel (2004) found recently 54 species of trees and shrubs. He also reported that the best species for charcoal disappeared. The most abundant species found included *Symphonia globulifera* (because it is said to be useless to produce charcoal) and *Myrianthus holstii*. Some species which used to be very common in the original forest such as *Carapa grandiflora* (the tree which gave its name to Gishwati forest), *Syzygium guineense, Ilex mitis, Chrysophylum gorungosanum, Strombosia scheffleri*, etc., were found to be still present but in low densities.

Three species represent most of the young seedlings and saplings in a way which depends on the topographic position. On the slopes of the hills, *Makaranga kilimandscharica* makes most of the regeneration and sometimes forms thickets of up to a hundred meters in diameter. On the dumper and more fertile soils at the bottom of the slopes, in valley bottoms and on gentle slopes, the seedlings and saplings of *Neoboutonia macrocalyx* and *Dombeya goetzenii* are very abundant and can also form thickets.

Apart from botanical composition, Blondel (2004) also surveyed animals remaining in Gishwati Forest Reserve. He found four types of primates: Chimpanzees *(Pan troglodytes schweinfurthi*), Mountain monkeys (*Cercopithecus l'hoesti*), Golden monkeys (*Cercopithecus mitis kandti*), and Blue monkeys (*Cercopithecus mitis doggetti*). He also observed a jackal but no signs of ungulates have been found. He also observed 84 species of birds.

2.3 Anthropogenic pressure on forest biodiversity

Human activities have a great effect of the species diversity of a region. When humans exploit an area, they influence species diversity, they convert natural ecosystem to human-manage agriculture, forest, aquaculture and urban ecosystem. They harvest certain species for their use. They specially eliminate species that compete with more desirable species. They introduce species that are not native to the area (Bradley and Eldon, 2006).

Four major human activities threaten to reduce biodiversity. Habitat loss occurs when human activities result in the conversion of natural ecosystem to human dominated systems (Wilson, 1994). The results include elimination or reduction in the number of species that were part of the original ecosystem.

According to Bradley and Eldon (2006) over exploitation occurs when humans harvest organisms faster than the organisms are able to reproduce. Over exploitation has driven some organisms to extinction and threatened many others. Introduction of exotic species can also have a significant effect on biodiversity by competing with native species and driving them to extinction.

The Convention on Biological Diversity (CBD) defines biodiversity as the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems (McNeely 1990; Heywood and Watson 1995). Diversity can also be observed within ecosystem at species and genetic levels. In this context, diversity refers to a number of times and their relative frequency. Madhu (2006) explains how conserving biological diversity within existing protected areas is becoming progressively more difficult. Protected areas are becoming increasingly ecologically isolated as a result of agriculture development, deforestation, and human settlement and grazing.

Forests are biologically diverse systems, representing some of the richest biological areas on earth. Offering a variety of habitats for plants, animals and micro-organisms, forest biodiversity is increasingly becoming threatened as a result of deforestation, fragmentation, climate change and other factors. The loss of tropical forest fauna, for example, is reaching critical levels (Sutherland, 2000). Forestry operations are often closely linked to commercial bush meat hunting through logging and roads construction. The "empty-forest syndrome" and biodiversity loss caused by habitat degradation and the over-exploitation of mammals, birds, reptiles, and amphibians in many tropical and sub-tropical countries has become a global threat. The degradation of forest ecosystems makes national and local economies weaker and more vulnerable.

It is pointed out by McNeely (1990) that mechanisms that cause deforestation, fragmentation and degradation are varied and can be direct or indirect. However, the most important factors associated with the decline of forest biological diversity are of human origin.

The conversion of forests to agricultural land, overgrazing, unmitigated shifting cultivation, unsustainable forest management, introduction of invasive alien plant and animal species, infrastructure development (e.g. road building, hydro-electrical development, urban sprawl), mining and oil exploitation, anthropogenic forest fires, pollution, and climate change are all having negative impacts on forest biological diversity(McNeely,1990).

Forests degradation is leading to loss in biological diversity loss. This degradation lowers the resilience of forest ecosystems and makes it more difficult for them to cope with changing environmental conditions

At the ecosystem level, a landscape consisting of many different ecosystems has more diversity than a landscape with only one ecosystem. The argument follows that when a landscape with tropical forests, savannah woodlands and mangrove ecosystems is converted into agricultural land its ecosystem diversity is reduced. Proponents of agro diversity, as discussed here under, challenge this notion. At the species level, species diversity can be reduced, for example by overgrazing rangelands which formerly had a high number of annual and perennial grass and shrub species, leaving behind only a few unpalatable species.

In interpreting the concept of biodiversity, Heywood and Watson (1995) put more emphasis on the fact that biodiversity refers to the degree of variety in nature i.e. it is not nature itself. In addition to the term 'biodiversity' the term' biological resources' is often used. Biodiversity and biological resources are identical at local level because most habitat modifications or reductions entail an erosion of biodiversity. McNeely (1990) indicates that in discussing biodiversity a cultural dimension should be considered. It is argued for example that conservation of biodiversity should go hand in hand with conservation of cultural diversity.

The socio-cultural dimension is further emphasized by Richards (1992) who argues against conservationists who consider themselves as "saves of the forts" without taking into account the local people's perceptions of the forests and forest resources. The cultural shaping of biodiversity has very much been emphasized by proponents of agro diversity and the role of local communities in maintaining biodiversity. According to this school-of-thought, transformations of natural ecosystems by rural communities often result in a new form of biodiversity, referred to as agricultural diversity or agro biodiversity (McNeely 1990) often not appreciated in the conservation arena.

Similarly, Richards (1996) observe with concern, that there can be too much speculative concern with the unknown portions of biodiversity, making the concept of biodiversity odd from the point of view of quantification. The importance of maintaining biodiversity cuts across a number of writings. The normal functioning of the biosphere in which human beings live depends largely on the continued existence of different plants and animals in different ecosystems. The reasoning is extended further to include future discoveries of medicine/drugs, which depend on the same genetic resources. Biodiversity can be considered as an indication of environmental quality. There are also ethical, aesthetic and cultural reasons for conserving biodiversity. All the reasons given are based on how society values biodiversity.

Biodiversity conservation objectives vary according to who is the intended beneficiary and scale of analysis. Priorities tend to differ at global and national levels, and at developed/developing country and local people's level. Wilson (1994) points out that the uneven distribution of conservation benefits is a disincentive to effective conservation and ineffective positive interventions (e.g. poor enforcement of conservation laws). Unintentional negative interventions (e.g. taxation and poor credit facilities for local people) contribute to loss of biodiversity.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The study area

The study was conducted in Gishwati Forest Reserve which is located in Rutsiro District, Rwanda (Fig.3.1). The district has 14 sectors but only four of them are adjacent to the forest. Those are Kigeyo, Ruhango, Mushonyi, and Nyabirasi sectors.

Gishwati Forest Reserve lies in the Albertine Rift, a landscape of high species endemism and diversity (Wildlife Conservation Society, 2004). Gishwati region is characterized by a mountain climate which is cool and humid. Temperatures are relatively stable and precipitation is moderate throughout the year.

The remaining forest is a tiny part of about 9 km^2 in the South-West. It has been demarcated by PAFOR, a reforestation project funded by African Development Bank and it works to replant trees in this new reserve, located in Rutsiro District. Its maximum dimensions are 3.6 km (North-South) and 3.9 km (West-East). The Western edge follows the main road Rubavu -Karongi (or ex Kibuye-Gisenyi). The Western part is also the lowest one around 2100 m, in the valley of the river Pfunda. From there, the land rises up to altitude of about 2550 m at the Eastern end (Blondel, 2004).

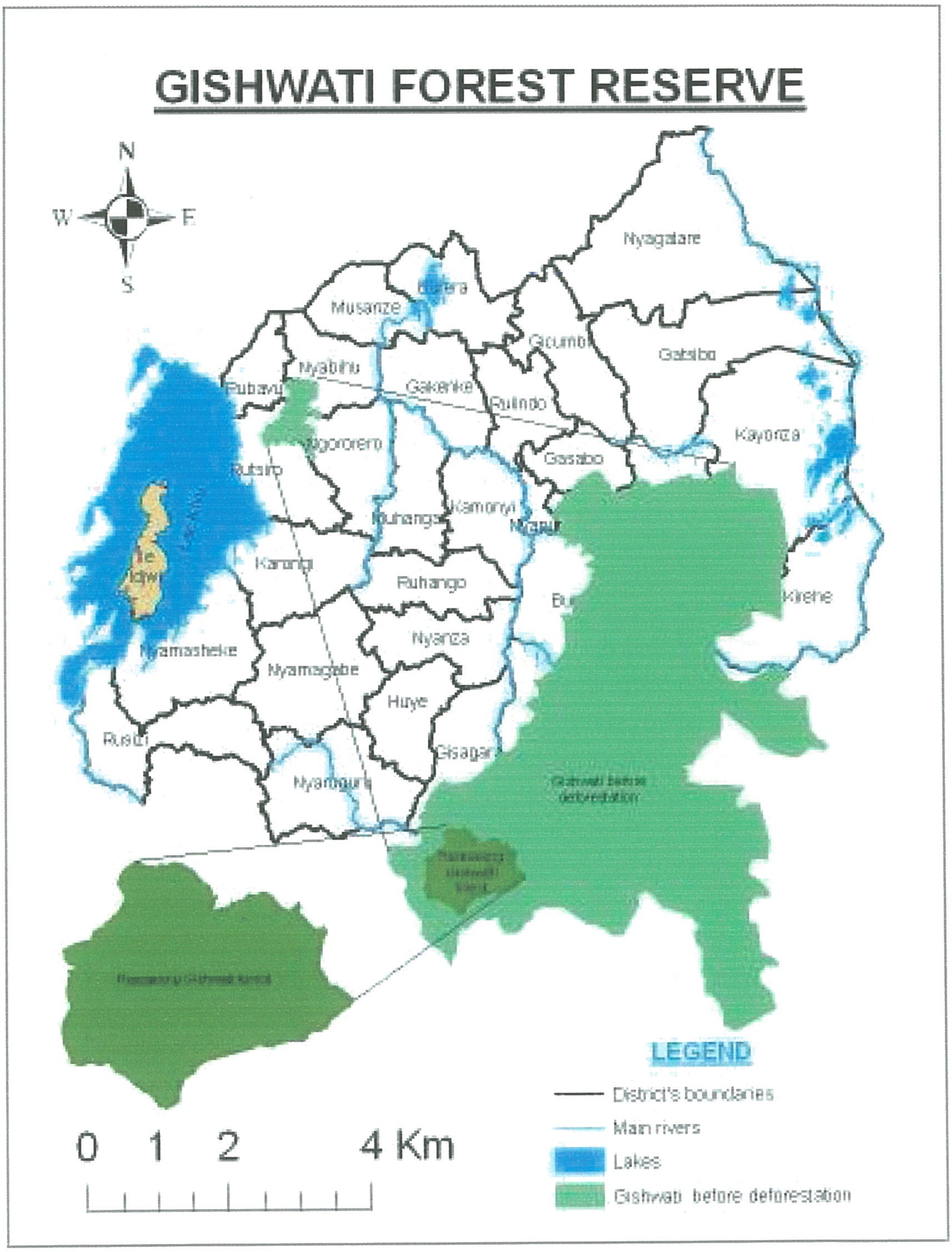

Fig. 3 1: Location of Gishwati forest Reserve area

3.2 Research design

The study involved the use of a botanical inventory. According to White and Edwards (2000) botanical inventory is a study that aims to record the diversity of plant species found in an area; distributions of favored habitats of each species and estimates of abundance of each species in the area of interest.

An inventory is the necessary first step in any detailed vegetation study. Data collection was done using plot sampling based on enumerating tree species within the forest, and observations to improve on validity and reliability of the measurement.

3.3 Botanical survey method

Four transects, ranging from 2 to 3.8 km in length and cutting through the disturbed and undisturbed portions of the study were selected.

A nested quadrat method (Stohlgren et al., 1995) was used in sampling trees and shrub species in the study area. Sixty plots (quadrat) were established in both disturbed and undisturbed areas. Trees were sampled in 10 x 10 meter and shrubs in 5 x 5 meter quadrat respectively.

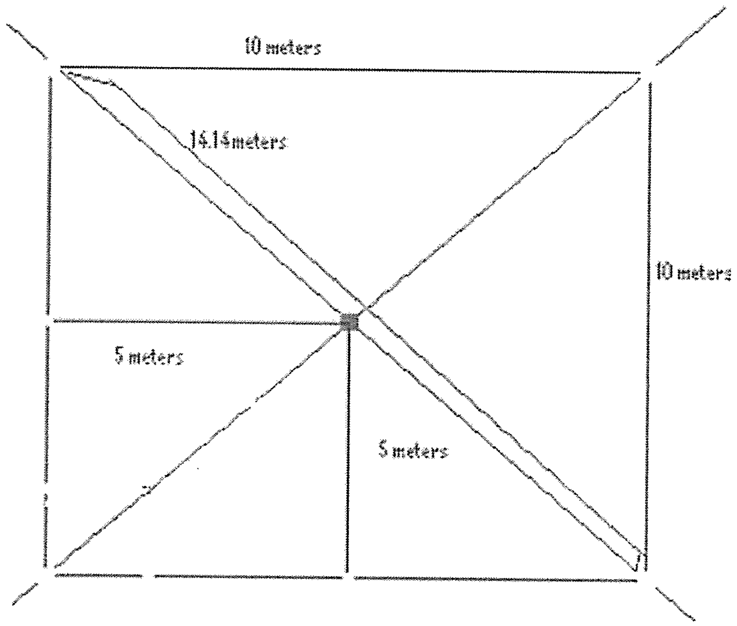

Fig. 3 2: Typical plots design

The orientation and disposition of the plots in respect to transects is shown in the figure below:

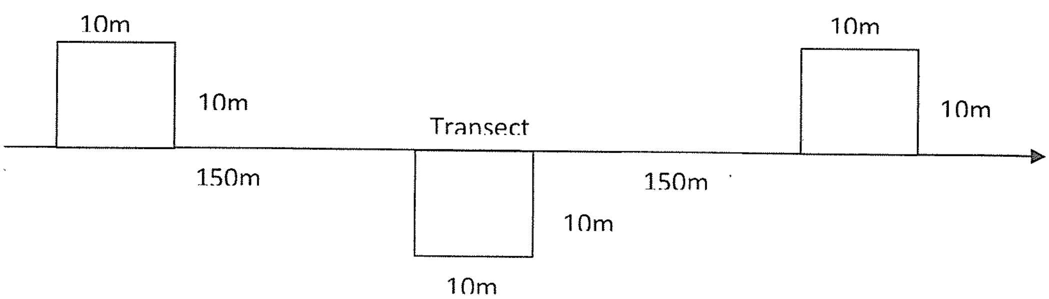

Fig. 3 3: Plots disposition in respect to transect

3.4 Estimation of diameter at breast height and Canopy cover

In all the sampling, plots all trees of ≥ 10 cm diameter at breast height (dbh; tree stage), were measured and counted. Canopy cover estimated by direct vertical observation was used to estimate the amount of light penetrating through to different layers of the forest in each plot.

3.5 Survey of former users of the forest

A total of 32 heads of former forest users from four sectors around Gishwati Forest Reserve were interviewed using a structured questionnaire. This survey revealed socio-economic aspects related to the forest use. The focus of this short survey socio-economic survey

3.6 Identification of tree species

Voucher specimens of most trees species in this study were collected from the areas/plots visited. These were collected in duplicate to allow for further identification of those plants that could not be positively identified and to confirm the identification of those that were identified in the field in assistance of botanist from Gishwati Area conservation program.

3.7 Data analysis

3.7.1. Tree species distribution

The distribution of species within the sample plots was determined using percentage frequency, relative density and species abundance (Martin, 1995). Percentage frequency is the chance of finding a species within a sample area in any one search and is calculated as follows:

$$\text{Percentage frequency} = \left(\frac{\text{Number of plots in which a species occurs}}{\text{Total Number of all plots}}\right) \times 100$$

The density of species is the number of individuals of that species per unit area, while relative density is a measure of how one species is represented in relation to all other species (Martin, 1995) and it is calculated as follows:

$$\text{Relative density} = \left(\frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \right) \times 100$$

The mean density of a species within occupied plots (i.e. sample plots in which the species occurs) is defined as their abundance and is calculated as follows:

$$\text{Abundance} = \left(\frac{\text{Total number of individuals}}{\text{Number of occupied plots}} \right)$$

3.7.2. Tree species diversity analysis

Species diversity is a measure of the number of different species present in an area. Some localities naturally have high species diversity while others have low species diversity. One way is simply to count the number of different kind of species in an area. Another way to look at species diversity is to take into account the number of different taxonomy categories of the species present. (Bradley and Eldon: 2006)

In order to have a deeper intuition of the tree community structure in the study area, Shannon-Wiener diversity index (*H'*) and Pielou's evenness index (*E*) were used to characterize species diversity in the sampling area (Feinsinger, 2001; Cheng,2004). The indices were derived by the following formulae:

Shannon-Wiener diversity index (*H'*):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where *H'* is the Shannon-Wiener diversity index, ln is natural log, p_i is the proportion of individuals of each species belonging to the i^{th} species of the total number of individuals and is estimated as *ni/N*, where N is the total number of individuals in a sample.

Pielou's evenness index (*E*) is given as: $E = \frac{H'}{H'_{max}}$

Where *E* is the Pielou's evenness index, *H* is the Shannon-Wiener diversity index and H_{max} is the maximum value of *H'*, equal to: $H_{max} = -\sum_{i=1}^{S} \frac{1}{S} \ln \frac{1}{S} = \ln S$

Where *S* is the species richness

3.7.3 Statistical analysis

To determine if there was significant difference in tree species diversity between the disturbed and undisturbed areas of the Forest reserve, one-way Analysis of Variance (one-way ANOVA) test in SPSS package, version 16.0 were used to find if the means are different between different areas of the forest.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Tree species composition and species richness

Within the total area sampled, 753 individual trees comprising of 44 species in 41 genara and 29 families were recorded. 235; 291 and 227 individuals were recorded in disturbed area (DA), natural part of the forest (NF) and second forest respectively (SF). Family Euphorbiaceae was the most diverse family represented by five species. It was followed by Meliaceae and Rubiaceae each represented by three species. Acanthaceae, Asteraceae, Clusiaceae, Mimosaceae, Moraceae and Myrrtaceae were represented by two species each. Families Alangiaceae, Apocynaceae, Aquifoliaceae, Araliaceae, Monimiaceae, Betulaceae, Chrysobalanaceae, Cytheaceae, Dracaenaceae, Lamiaceae, Melianthaceae, Myrsinaceae Olacaceae, Pinaceae, Podocarpaceae, Rhizophoraceae, Rutaceae, Sapotaceae, Solanacea and Sterculiaceae were represented by one species each (Table 4.1).

Table 4. 1. Tree species composition

No	Scientific name	Genus	Vernacular name (in Kinyarwanda)	Family Name
1	*Acacia mearnsii*	*Acacia*	Barakatsi	Mimosaceae
2	*Alangium chinense*	*Alangium*	Umupfuka, Intogota	Alangiaceae
3	*Albizia gummifera*	*Albizia*	Umusebeya	Mimosaceae
4	*Alnus sp.*	*Alnus*	Alinusi	Betulaceae
5	*Bersama abyssinica*	*Bersama*	Umukaka	Melianthaceae
6	*Bridelia brideliifolia*	*Bridelia*	Umugimbu	Euphorbiaceae
7	*Carapa grandiflora*	*Carapa*	Umushwati	Meliaceae
8	*Cassipourea*	*Cassipourea*	Ingongo	Rhizophoraceae

	ruwenzorensis			
9	*Chrysophyllum gorungosanum*	*Chrysophyllu m*	Umutoyi	Sapotaceae
10	*Clerodendron bukobensis*	*Clerodendron*	Umukuzanyana, Umukondogoro	Lamiaceae
11	*Croton macrostachyus*	*Croton*	Umurangara	Euphorbiaceae
12	*Croton megalocarpus*	*Croton*	Umunege	Euphorbiaceae
13	*Cyathea mannianna*	*Cyathea*	Igishigishigi	Cytheaceae
14	*Discopodium*	*Discopodium*	Ikijojo	Solanaceae
15	*Dombeya goetzenii*	*Dombeya*	Umukore	Sterculiaceae
16	*Dracaena afromontana*	*Dracaena*	Umuhati	Dracaenaceae
17	*Entandrophragma excelsum*	*Entandrophra gma*	Umuyove	Meliaceae
18	*Eucalyptus sp.*	*Eucalyptus*	Inturusi	Myrtaceae
19	*Ficus thonningii*	*Ficus*	Umuvumu	Moraceae
20	*Galiniera saxifraga*	*Galiniera*	Umubonobono, Ikiryoheramuhoro	Rubiaceae
21	*Harungana montana*	*Harungana*	Umushayishayi	Clusiaceae
22	*Ilex mitis*	*Ilex*	Umuhisi	Aquifoliaceae
23	*Lepidotrichilia volkensii*	*Lepidotrichilia*	Imbayu	Meliaceae
24	*Macaranga kilimandscharica*	*Macaranga*	Umurara or umusekera	Euphorbiaceae
25	*Mimulopsis excellens*	*Mimulopsis*	Igihwapfu	Acanthaceae
26	*Mimulopsis solmsii*	*Mimulopsis*	Umunayu	Acanthaceae
27	*Maesa lanceolata*	*Maesa*	Umuhanga	Myrsinaceae
28	*Myrianthus holistii*	*Myrianthus*	Umwufe	Moraceae

29	*Neobutonia macrocaryx*	*Neobutonia*	Umwanya	Euphorbiaceae
30	*Oricia renieri*	*Oricia*	Umuno	Rutaceae
31	*Parinari exelsa)*	*Parinari*	Umunazi (isama)	Chrysobalanaceae
32	*Pinus patura*	*Pinus*	pinusi	Pinaceae
33	*Podocarpus falcatus*	*Podocarpus*	Umufu	Podocarpaceae
34	*Polyscias fulva*	*Polyscias*	Umwungo	Araliaceae
35	*Prunus africana*	*Prunus*	Umwumba, umuvumba	Rosaceae
36	*Psychotria bugoyensis*	*Psychotria*	Ikibonobono, Umugingwe	Rubiaceae
37	*Rytiginia bugoyensis*	*Rytiginia*	Umushabarara	Rubiaceae
38	*Strombosia scheffleri*	*Strombosia*	Umuhika	Olacaceae
39	*Symphonia Globulifera*	*Symphonia*	Umushishi	Clusiaceae
40	*Syzygium guinense*	*Syzygium*	Umugote	Myrtaceae
41	*Tabernaemontana stapfiana*	*Tabernaemon tana*	Umuroje, Umubaribari	Apocynaceae
42	*Vernonia auriculifera*	*Vernonia*	Igaragara or umugaragara	Asteraceae
43	*Vernonia kirungae*	*Vernonia*	Igiheriheri, Ikamambogo	Asteraceae
44	*Xymalos monospora*	*Xymalos*	Umuhotora, Ikirazabuzima	Monimiaceae

4.2 Canopy cover estimation

Canopy cover gives a measure of the amount of light penetrating through to different layers of the forest (White and Edwards, 2000). Many methods have been used to estimate canopy cover. Some researchers have used light meters (or have used cameras to record the exposure required at a certain film and shutter speed as a measure of light availability). Others have used photographs taken vertically, with either a standard or fish-eye lens, and estimate the proportion of their pictures are covered by sky.

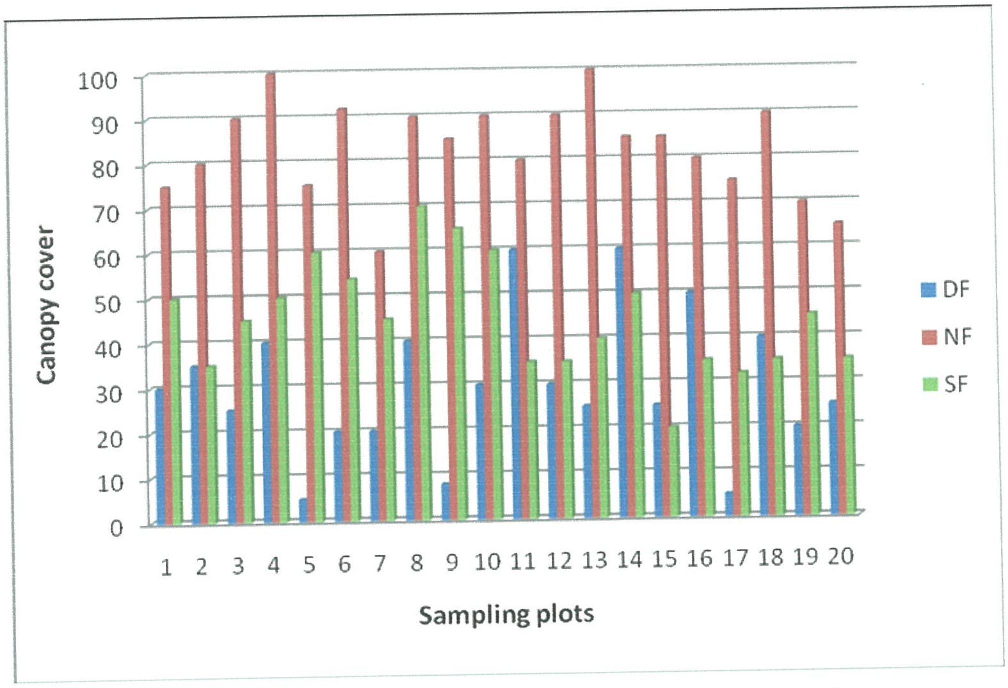

Fig. 4. 1: Canopy cover estimation for each visited plot

The figure 4.1 shows that in the 60 plots visited, the canopy cover was high in the undisturbed part of Gishwati forest reserve and very low in disturbed area. The average value of the canopy cover was 29.65% in the disturbed area, 82.85% in undisturbed area and 44.8% in the secondary forest zone. Undisturbed forests have high canopy cover and there is only sparse ground vegetation in their gloomy under-storey.

Secondary or disturbed forests tend to have incomplete canopy cover and dense ground vegetation (White & Edwards, 2000).

4.3 Tree species distribution in Gishwati Forest reserve

Tree species distribution was different in the disturbed and undisturbed forest areas. There were species recorded in the disturbed area and not in the undisturbed area. Many of these were not native tree species. The exotic species identified in the study area were *Pinus patula* (5%), *Acacia mearnsii* (11.6%), *Eucalyptus sp.* (5%), and *Alnus sp.*(5%).

The percentage frequence of exotic species is high in disturbed area where as in the undisturbed is null. Other tree species recorded in the undisturbed area only include *Bridelia brideliifolia, Carapa grandiflora, Croton megalocarpus, Cyathea mannianna, Croton megalocarpus, Chrysophyllum gorungosanum, Ficus thonningii, Mimulopsis excellens, Prunus Africana, Oricia renieri* and *Psychotria bugoyensis.*

Except the exotic species, other most of species with high abundance belong to the natural forest where today the human impact activities are not allowed. These trees are *Croton macrostachyus; Cyathea mannianna; Dombeya goetzenii; Mimulopsis excellens* etc

Table 4. 2. Tree species distribution

	Percentage frequency				Relative density			Abundance		
Species name	DA	NF	SF	All parts of the forest	DA	NF	SF	DA	NF	SF
Acacia mearnsii	20	0	15	11.667	0.1234	0.0000	0.0441	7.25	0	3.333
Alangium chinense	5	15	5	8.333	0.0085	0.0172	0.0044	2	1.667	1
Albizia gummifera	0	15	10	8.333	0.0000	0.0206	0.0088	0	2	1
Alnus sp.	15	0	0	5	0.1106	0.0000	0.0000	8.667	0	0
Bersama abyssinica	10	15	10	11.667	0.0085	0.0241	0.0264	1	2.333	3
Bridelia brideliifolia	0	10	0	3.333	0.0000	0.0069	0.0000	0	1	0
Carapa grandiflora	0	25	5	10	0.0000	0.0447	0.0044	0	2.6	1
Cassipourea ruwenzorensis	0	20	10	10	0.0000	0.0241	0.0088	0	1.75	1
Chrysophyllum gorungosanum	0	25	0	8.333	0.0000	0.0241	0.0000	0	1.4	0
Clerodendron bukobensis	10	10	5	8.333	0.0170	0.0309	0.0352	2	4.5	8

Croton macrostachys	5	15	15	11.667	0.0043	0.0309	0.0176	1	3	1.333
Croton megalocarpus	0	20	0	6.667	0.0000	0.0378	0.0000	0	2.75	0
Cyathea mannianna	0	15	0	5	0.0000	0.0344	0.0000	0	3.333	0
Discopodium	10	5	10	8.333	0.0255	0.0103	0.0485	3	3	5.5
Dombeya goetzenii	5	15	45	21.667	0.0128	0.0309	0.1366	3	3	3.444
Dracaena afromontana	10	10	10	10	0.0085	0.0103	0.0088	1	1.5	1
Entandrophragma excelsum	10	5	5	6.667	0.0170	0.0034	0.0088	2	1	2
Eucalyptus sp.	0	0	15	5	0.0000	0.0000	0.0132	0	0	1
Ficus thonningii	0	10	0	3.333	0.0000	0.0069	0.0000	0	1	0
Galiniera saxifraga	10	10	5	8.333	0.0085	0.0103	0.0088	1	1.5	2
Harungana Montana	5	20	5	10	0.0128	0.0584	0.0044	3	4.25	1
Ilex mitis	5	5	5	5	0.0043	0.0034	0.0044	1	1	1
Lepidotrichilia volkensii	5	10	0	5	0.0213	0.0103	0.0000	5	1.5	0
Macaranga kilimandscharica	35	40	25	33.333	0.1277	0.0790	0.0749	4.286	2.875	3.4
Maesa lanceolata	15	20	30	21.667	0.0170	0.0206	0.0396	1.333	1.5	1.5

Mimulopsis excellens	0	5	0	1.667	0.0000	0.0103	0.0000	0	3	0
Mimulopsis solmsii	5	5	0	3.333	0.0043	0.0137	0.0000	1	4	0
Myrianthus holistii	5	30	0	11.667	0.0085	0.0378	0.0000	2	1.833	0
Neobutonia macrocaryx	15	5	20	13.333	0.0128	0.0069	0.0352	1	2	2
Oricia renieri	0	10	0	3.333	0.0000	0.0103	0.0000	0	1.5	0
Parinari exelsa)	5	15	5	8.333	0.0043	0.0275	0.0044	1	2.667	1
Pinus patura	5	0	5	3.333	0.0043	0.0000	0.0617	1	0	14
Podocarpus falcatus	5	5	0	3.333	0.0043	0.0103	0.0000	1	3	0
Polyscias fulva	5	10	5	6.667	0.0085	0.0172	0.0044	2	2.5	1
Prunus africana	0	5	0	1.667	0.0000	0.0103	0.0000	0	3	0
Psychotria bugoyensis	0	10	0	3.333	0.0000	0.0069	0.0000	0	1	0
Rytiginia bugoyensis	5	15	15	11.667	0.0340	0.0412	0.0485	8	4	3.667
Strombosia scheffleri	10	50	5	21.667	0.0085	0.0550	0.0044	1	1.6	1
Symphonia Globulifera	25	35	15	25	0.0596	0.0378	0.0132	2.8	1.571	1
Syzygium guinense	10	20	5	11.667	0.0085	0.0309	0.0044	1	2.25	1
Tabernaemontana stapfiana	5	10	5	6.667	0.0043	0.0103	0.0176	1	1.5	4

Vernonia auriculifera	20	25	20	21.667	0.1064	0.0550	0.1762	6.25	3.2	10
Vernonia kirungae	40	15	20	25	0.1872	0.0378	0.0969	5.5	3.667	5.5
Xymalos monospora	15	30	5	16.667	0.0170	0.0412	0.0352	1.333	2	8
					1.0000	1.0000	1.0000			

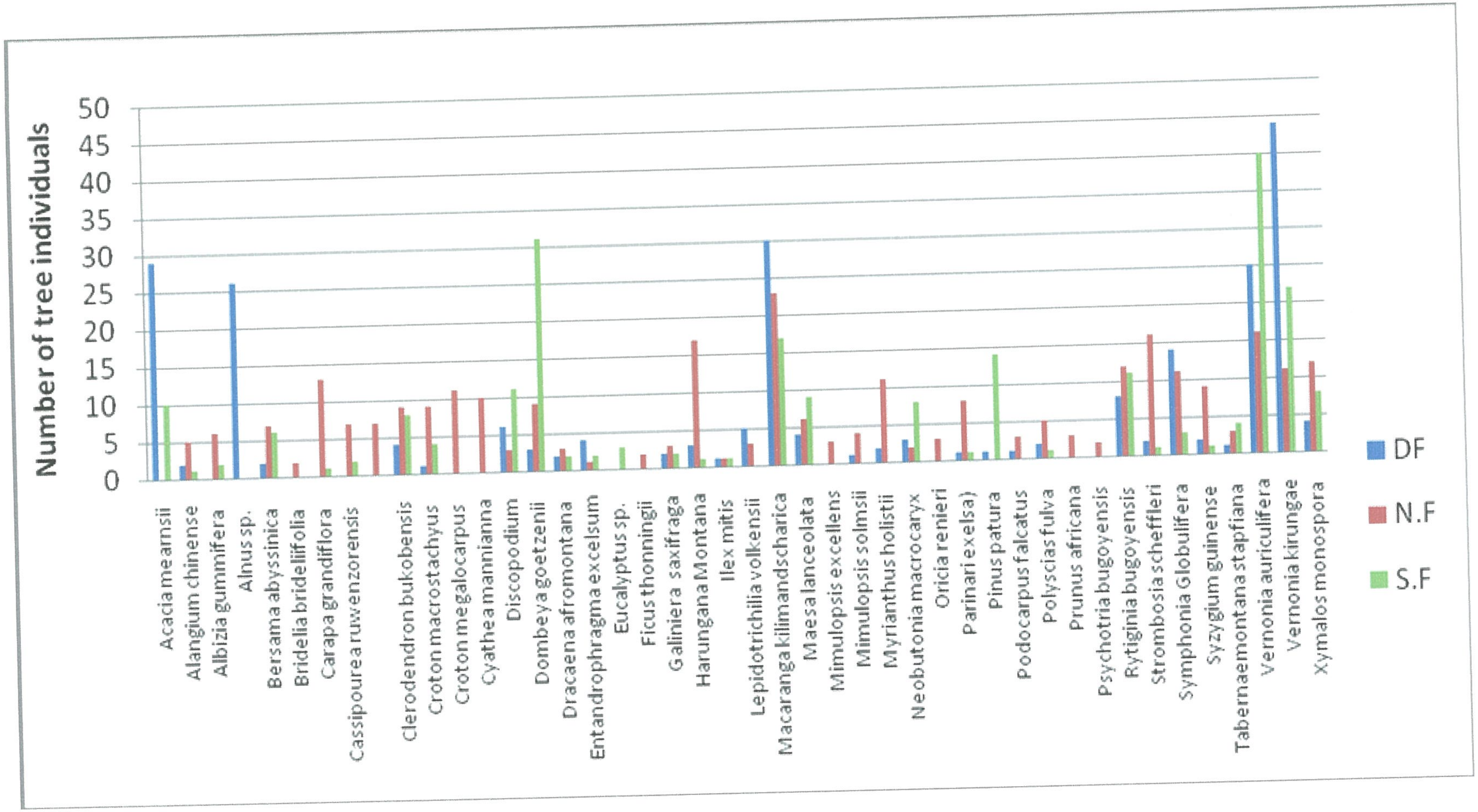

Fig.4. 2: Presence or absence of tree species in the three areas within the forest

Some species became rare or disappeared from the study area. As explained by the local people, the species such as *Faureo saligna, Entadrophragma excelsum, Podocarpus spp. Ocotea usambalensis* and *Trema orientalis* were selected for illegal logging because they provided the good materials for furniture and charcoal.

The results showed that only the exotic species were prevalent in disturbed part (Secondary forest and disturbed forest) not in undisturbed area (Natural forest) are exotic species: *Acacia mearnsii, Alnus sp., Eucalyptus sp. and Pinus patula.* However species such as *Bridelia bridelifia, Chrysophylum gorunosanum, Croton megalocarpus, Cyathea mannianna, Ficus thonningii, Mimulopsis excellenses, Oricia enieri, prunus Africana* are prevalent in natural forest and neither in secondary forest nor in disturbed forest.

The recurrent human interventions for collection of fuel wood and minor forest products and the practices of grazing and trampling may change the habitat for many species (Sagar, Raghubanshi et al, 2003). And high intensity of human disturbances adversely affected tree species abundance, diversity and regeneration (Eilu and Obua, 2005)

4.5 DBH class distribution

In each plot, dbh for trees with more than 10 cm in diameter were recorded (Figure 4.3). *Symphonia Globulifera* was the most dominant tree species in the dbh classes of over 40 cm diameters.

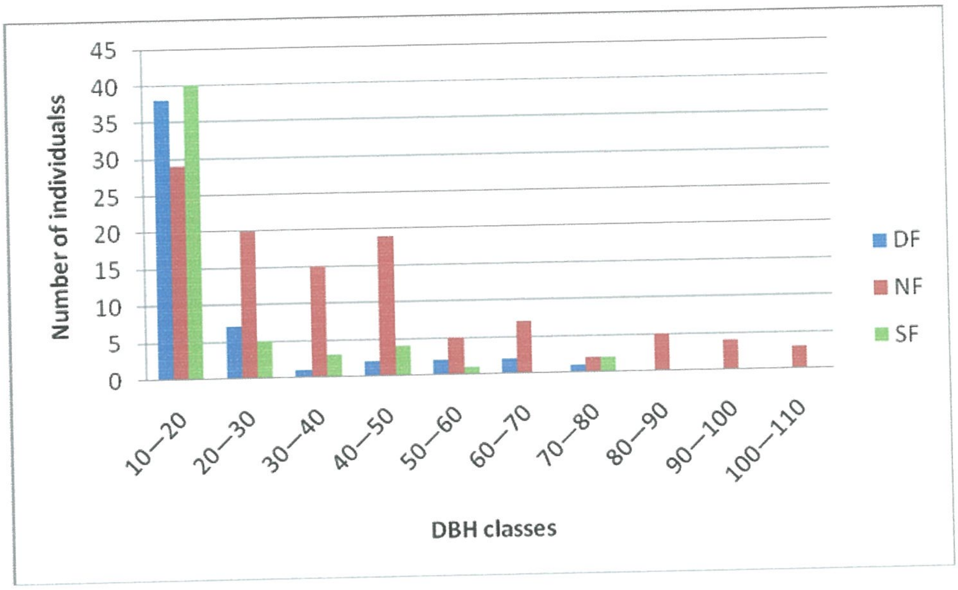

Fig. 4. 3: DBH classes' distribution in three part of the forest

4.6 Anthropogenic impacts on the tree species diversity

In the present study, a comparison of species diversity using different indices between the different plots surveyed was done. To achieve this, 20 plots in the three zones of the forest (Natural forest: NF, Secondary forest: SF and Disturbed forest: DF) were sampled. . An analysis was carried out to find if the tree structure of Gishwati forest reserve has been influenced by different human activities like logging, harvesting tree, cattle grazing and cultivation.

Table 4. 3. Shannon Index and Eveness Calculation

Species name	Common Name (Vernacular name In Kinyarwanda)	Disturbed Area			Natural Forest			Secondary Forest		
		P	LnP	PlnP	P	LnP	PLnP	P	LnP	PLnP
Acacia mearnsii	Barakatsi	0.123	-2.092	-0.258				0.044	-3.078	-0.136
Alangium chinense	Umupfuka, Intogota	0.009	-4.766	-0.041	0.017	-4.064	-0.070	0.004	-5.421	-0.024
Albizia gummifera	Umusebeya				0.021	-3.882	-0.080	0.009	-4.723	-0.042
Alnus sp.	Alinusi	0.111	-2.201	-0.244						
Bersama abyssinica	Umukaka	0.009	-4.766	-0.041	0.024	-3.727	-0.090	0.026	-3.607	-0.095
Bridelia brideliifolia	Umugimbu				0.007	-4.980	-0.034			0.000
Carapa grandiflora	Umushwati				0.045	-3.108	-0.139	0.004	-5.421	-0.024
Cassipourea ruwenzorensis	Ingongo				0.024	-3.727	-0.090	0.009	-4.723	-0.042
Chrysophyllum gorungosanum	Umutoyi				0.024	-3.727	-0.090			
Clerodendron bukobensis	Umukuzanyana, Umukondogoro	0.017	-4.073	-0.069	0.031	-3.476	-0.108	0.035	-3.310	-0.117
Croton macrostachyus	Umurangara	0.004	-5.460	-0.023	0.031	-3.476	-0.108	0.018	-4.021	-0.071
Croton megalocarpus	Umunege				0.038	-3.275	-0.124			
Cyathea mannianna	Igishigishigi				0.034	-3.371	-0.116			
Discopodium	Ikijojo	0.026	-3.668	-0.094	0.010	-4.575	-0.047	0.048	-2.979	-0.144
Dombeya goetzenii	Umukore	0.013	-4.361	-0.056	0.031	-3.476	-0.108	0.137	-1.854	-0.253
Dracaena afromontana	Umuhati	0.009	-4.766	-0.041	0.010	-4.575	-0.047	0.009	-4.723	-0.042

Entandrophragma excelsum	Umuyove	0.017	-4.073	-0.069	0.003	-5.673	-0.019	0.009	-4.723	-0.042
Eucalyptus sp.	Inturusi							0.013	-4.313	-0.057
Ficus thonningii	Umuvumu				0.007	-4.980	-0.034			
Galiniera saxifraga	Umubonobono, Ikiryoheramuhoro	0.009	-4.766	-0.041	0.010	-4.575	-0.047	0.009	-4.723	-0.042
Harungana Montana	Umushayishayi	0.013	-4.361	-0.056	0.058	-2.840	-0.166	0.004	-5.421	-0.024
Ilex mitis	Umunywande/Umuhisi	0.004	-5.460	-0.023	0.003	-5.673	-0.019	0.004	-5.421	-0.024
Lepidotrichilia volkensii	Imbayu	0.021	-3.850	-0.082	0.010	-4.575	-0.047			
Macaranga kilimandscharica	Umurara or umusekera	0.128	-2.058	-0.263	0.079	-2.538	-0.201	0.075	-2.517	-0.188
Maesa lanceolata	Igihwapfu	0.017	-4.073	-0.069	0.021	-3.882	-0.080	0.040	-3.188	-0.126
Mimulopsis excellens	Umunayu				0.010	-4.575	-0.047			
Mimulopsis solmsii	Umuhanga	0.004	-5.460	-0.023	0.014	-4.287	-0.059			
Myrianthus holistii	Umwufe	0.009	-4.766	-0.041	0.038	-3.275	-0.124			
Neobutonia macrocaryx	Umwanya	0.013	-4.361	-0.056	0.007	-4.980	-0.034	0.035	-3.310	-0.117
Oricia renieri	Umuno				0.010	-4.575	-0.047			
Parinari exelsa)	Umunazi (inkungu,isama)	0.004	-5.460	-0.023	0.027	-3.594	-0.099	0.004	-5.421	-0.024
Pinus patura	pinusi	0.004	-5.460	-0.023				0.062	-2.724	-0.168
Podocarpus falcatus	Umufu	0.004	-5.460	-0.023	0.010	-4.575	-0.047			
Polyscias fulva	Umwungo	0.009	-4.766	-0.041	0.017	-4.064	-0.070	0.004	-5.421	-0.024
Prunus africana	Umwumba, umuvumba				0.010	-4.575	-0.047			
Psychotria bugoyensis	Ikibonobono, Umugingwe				0.007	-4.980	-0.034			
Rytiginia bugoyensis	Umushabarara	0.034	-3.380	-0.115	0.041	-3.188	-0.131	0.048	-2.979	-0.144

Strombosia scheffleri	Umuhika	0.009	-4.766	-0.041	0.055	-2.901	-0.159	0.004	-5.421	-0.024
Symphonia Globulifera	Umushishi	0.060	-2.821	-0.168	0.038	-3.275	-0.124	0.013	-4.313	-0.057
Syzygium guinense	Umugote	0.009	-4.766	-0.041	0.031	-3.476	-0.108	0.004	-5.421	-0.024
Tabernaemontana stapfiana	Umuroje, Umubaribari	0.004	-5.460	-0.023	0.010	-4.575	-0.047	0.018	-4.021	-0.071
Vernonia auriculifera	Igaragara or umugaragara	0.106	-2.241	-0.238	0.055	-2.901	-0.159	0.176	-1.560	-0.275
Vernonia kirungae	Igiheriheri, Ikamambogo	0.187	-1.675	-0.314	0.038	-3.275	-0.124	0.097	-2.237	-0.217
Xymalos monospora	Umuhotora, Ikirazabuzima	0.017	-4.073	-0.069	0.041	-3.188	-0.131	0.035	-3.310	-0.117
				-2.707			-3.455			**-2.752**
Nunber of Species		31			40			30		
Shannon index value				**2.707**			**3.455**			**2.752**
Eveness(Equitability) value				0.7882			0.93666			0.809191

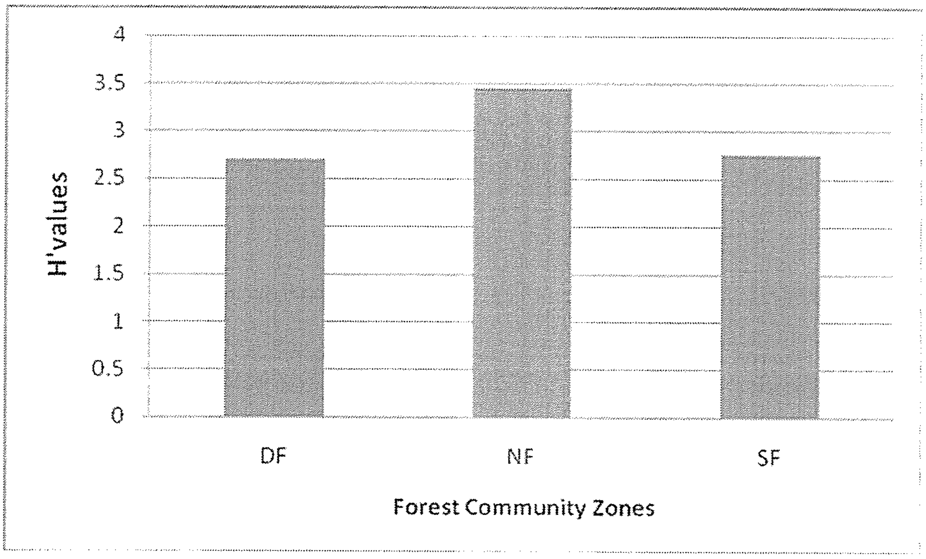

Fig.4. 4: Shannon Wiener index values for the three forest zones

DA= Disturbed forest

NF= Natural forest

SF= Secondary forest

Figure 4.4 presents the analysis values of Shannon Wiener index the three zones of the forest. Low diversity was recorded in the disturbed forest. The higher the disturbance and the younger a forest site is, the less divers is the habitat. The undisturbed or less disturbed part of the forest had the highest diversity measures.

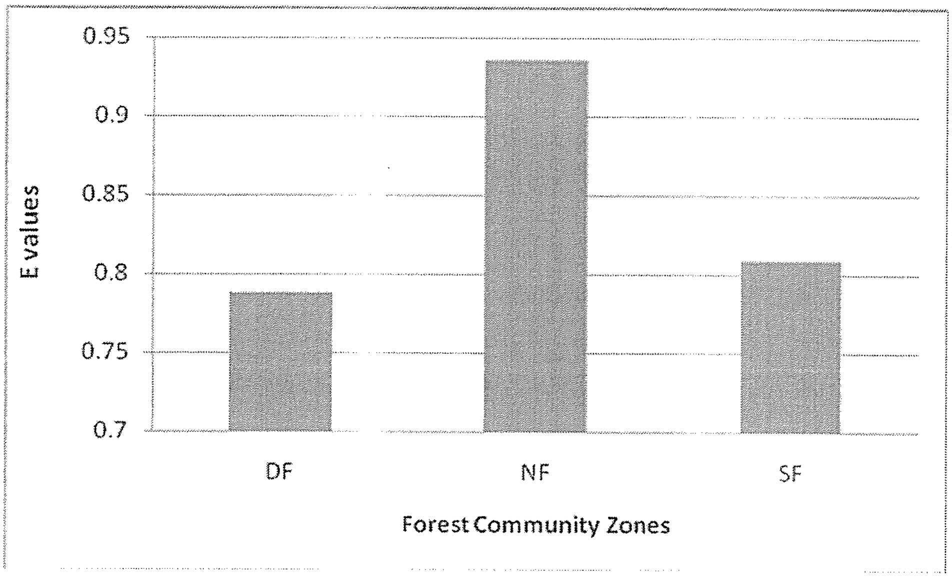

Fig. 4. 5: Evenness index values for the three forest zones

DA= Disturbed forest

NF= Natural forest

SF= Secondary forest

Figure4.5 indicates a higher evenness in the undisturbed areas than in the disturbed areas (Secondary forest and disturbed forest).

Table 4. 4. Tree species diversity and distribution in Gishwati forest reserve

Area	No of species	No of individual trees	H'	E
Disturbed forest	31	235	2.707	0.788
Natural forest	40	291	3.455	0.936
Secondary forest	30	227	2.752	0.809

H'= Shannon Wiener index

E= Evenness

The reduction in number of tree species and individuals' trees and tree species diversity revealed that the ecosystem has been disturbed by various activities of human beings. The results of the Shannon index (H') indicated that the highest community diversity was discovered in Primary part of the forest reserve defined as undisturbed (3.45). This is followed by secondary part of the forest (2.75) while the last value was obtained for the disturbed part of Forest Reserve (2.7). The species diversity values obtained for the three sites were different.

The highest value 0.936(Evenness) was obtained for natural part of the Forest Reserve while 0.809 and 0.788 were obtained for secondary part of the forest and disturbed part of forest reserve respectively.

Diversity and evenness increased in the order Natural forest followed by secondary forest followed by disturbed forest (Table 4.4). Natural forest has greater number of species (40) but the individual in the community are distributed more evenly among the species.

In secondary forest there are five different species that were not prevalent in the disturbed forest although the two sections of the forest had approximately equal number of species. Different levels of disturbance have different effect on diversity. Some species are rare and others are common(for example *Acacia maernsii* 12.3% *Macaranga kilmandscharica* 12.8% in disturbed forest)

Table 4. 5. Analysis of variance of Shannon index in three part of the forest

	SS	DF	MS	F	p
Between groups	8.153	2	4.076	69.084	0.000
Within groups	3.363	57	0.059		
Total	11.516	59			

SS= Sum of squares

DF= Degree of freedom

MS= Mean square

F= Fischer

P= Significance

There was significant difference between the three part of Gishwati forest reserve in terms of Shannon Wiener index. ($F_{2, 59}$= 69.084, P<0.001), Table 4.5, this explained by the fact that the higher community diversity was discovered in primary part of forest than other part

Table 4. 6. Analysis of variance of Evenness index in three part of the forest

	SS	DF	MS	F	p
Between groups	0.569	2	0.285	69.083	0.000
Within groups	0.235	57	0.004		
Total	0.804	59			

SS= Sum of squares

DF= Degree of freedom

MS= Mean square

F=Fischer

P= Sgnificance

There was significant difference between the three part of Gishwati forest reserve in terms of Evenness index. ($F_{2, 59}$= 69, 083, P<0.001) (Table: 4.6)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The forest zones in Gishwati forest reserve investigated during the present study include NF(natural forest), SF(secondary forest), and DF(Disturbed forest) in which NF had the highest tree species richness, canopy cover, DBH and tree diversity. Secondary Forest and Disturbed Forest did not significantly differ in tree species frequency class distributions, although SF had a higher proportion of species than in DF.

The study shows that forest disturbance in Gishwati forest reserve has incurred severe losses in terms of tree species diversity in the study area. Logging, cultivation, tree harvesting and cattle grazing are the most common anthropogenic activities carried out in the forest. The research results also showed that the tree species diversity indices (Shannon-Wiener's H' and Evenness) decrease with the level of disturbance. This was demonstrated by the variations in the diversity index values in the three distinct zones of the forest reserve

5.2 Recommendations

The rarer tree species with poor representation in our samples need proper attention from plant biologists to determine their conservation status and key functions. Mapping concentration areas of these species and further studies on their key ecological and cultural functions would help identify locations for conservation actions and determine which wildlife species may depend on them in Gishwati Forest reserve.

Forest managers can use such information on rare and common tree species alike to help manage wildlife habitat as well as provide cultural resource values of these trees.

The quantitative characters related with percentage frequency, relative density, abundance and diversity of the observed trees could well act as indicators of changes and susceptibility to anthropogenic stressors among various vegetation categories and their formations, which could be further interpreted as distinct wildlife habitats.

The number of observed tree species and species richness, diversity and evenness all varied significantly among the three forest vegetation types. In order to improve species composition for biodiversity conservation in Gishwati forest, the following recommendations are made:

- There is need to carry out reforestation of all degraded areas in natural forest so as to increase the number of tree diversity;
- There would a need to undertake vegetation mapping showing the current levels of the forest degradation. These would be useful tools when doing rehabilitation planning of the forest.
- Seedlings of species which are rare or disappeared could be imported to facilitate the restoration of native trees in the study area;
- In order to reduce the accessibility to the natural forest, the buffer zone must be increased by planting exotic species around the forest and closing all paths into the forest thereby protecting the biodiversity;
- Involving local communities in forest biodiversity conservation and protecting people's livelihoods is the most appropriate strategy for sustainable management of tree diversity.

- It would be important to mobilize the community to establish community conservation groups which would involve establishment of home gardens and group tree planting nurseries especially of the rare and threatened tree species.
- Permanent sample plots for tree species monitoring in the study area are important and should be increased to ensure consistence in biodiversity surveys results.

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APPENDICES

Appendix 1. Data collection sheet

DATA COLLECTION SHEET (RESEARCH IN GISHWATI FOREST RESERVE)

<table>
<tr><td colspan="2">Researcher Name :</td><td>Transect No</td><td colspan="2" rowspan="2"><u>Altitude :</u></td></tr>
<tr><td colspan="2">Date :</td><td>Plot No</td></tr>
<tr><td colspan="2">Ecosystem :</td><td colspan="3">Canopy cover estimation (%) :</td></tr>
<tr><td>Familly</td><td>Species</td><td>DBH</td><td>Strate</td><td>N° of individus</td></tr>
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Appendix 2. Plates

Plate1: Disturbed area in Gishwati

Plate 2: Gishwati forest reserve

Plate 3: Author during data collection

Plate5: Specimen: *Chrysophyllum g.*

Plate 5 : *Myrianthus holistii*

Plate 6: *Symphonia globulifera*