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Regeneration of indigenous species in Nyungwe buffer zone for biodiversity conservation and local people's livelihood in Rwanda

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Abstract

Nyungwe National Park is surrounded by densely populated areas and the community has for a long time been in search for agricultural space and forest products. This has contributed to the reduction of its size. A buffer zone was established with exotic species in order to stop the abuse of the reserve. This study was conducted in the eastern part of the Nyungwe National Park. The research question was to perceive if indigenous species regenerate in the buffer zone and which exotic species best facilitates the regeneration under its canopy. We wanted also to know the role played by the regenerating species in the improvement of people's livelihood. The findings showed that the regeneration of indigenous species in the buffer zone represents 10% of the tree species found in Nyungwe National Park. Species richness and abundance was highest for *Cupressus lusitanica* stands. *Eucalyptus* has been preferred before other exotic species in spite of its ecological drawbacks. Local people interact with buffer zone; they get few non-timber forest products from there, but honey collection is much appreciated. The buffer zone is playing a role as barrier to abuse of the core zone and is conciliating the interests of conservation and needs of the local community. The awareness about the conservation of biodiversity conservation is raised. A need for a new orientation of management of the buffer zone and the improvement of conservation values of the park has been expressed.

Key words: *Beekeeping, Biodiversity, Buffer zone, Exotic species, Indigenous species, Nyungwe National Park, Regeneration, Surrounding community.*

Contents

Introduction

Context

The purpose of gazetting protected areas is to guarantee the conservation of their ecosystems. The buffer zone is a combination area of both biological resource conservation and human use purposes.

The establishment of protected areas has been a major worldwide conservation strategy (e.g. Budhathoki 2004). However, in many parks biodiversity is threatened by surrounding human populations looking for their subsistence needs (DFID 2002). It is widely recognised that protected areas affect the livelihoods of local people (Lynagh and Urich 2002, Tisdell and Zhu 1998, Wild and Mutebi 1997, Nepal and Weber 1994, 1995, Kothari *et al*. 1995, Skonhoft 1995, Brandon and Wells 1992). On the other hand, over time it has become evident that successful protection is unavoidably linked with the satisfaction of local needs (Shyamsundar and Kramer 1995). The success of conservation will be assured by the establishment of a buffer zone which can resolve the conflict park-people and meet the needs of local people (Nayak 2003, Straeda and Treue 2006).

The survival of forest is a key for the continuity of plants and animals in the park. People around the park are usually the first to affect the biodiversity once their needs are not satisfied. In order to reduce the frequent encroachments into the park, buffer zones are made with either indigenous or introduced species. In both cases, they should improve the local community's livelihood.

Exotic plant species in the buffer zone could affect the dispersal of indigenous species but also contribute to the satisfying of the needs of local communities. Buffer zones should be managed in such a way that people and components of biodiversity are interacting and benefiting from each other. Regeneration of indigenous species in plantations is one alternative to compensate and bring closer the plants that people are usually using, while the core zone is protected.

The current study investigated the regeneration of indigenous species in Nyungwe Buffer Zone and their contribution to Biodiversity Conservation and local people's livelihood in Rwanda.

Background information on Rwanda

Brief description of Rwanda

Rwanda is a small country covering 26 338 km^2 and densely populated (346 inhabitants/km^2; ACDI 2007). The topography is characterized by vast hills, mountains and interspersed valleys ranging from 900 m a.s.l. in the southwest (Bugarama) to 4 500 m a.s.l. in the northwest (Volcanoes Range) (USAID 2004); hence, the nickname of Rwanda as "*Pays des mille collines*" (country of a thousand hills). Rwanda enjoys an equatorial temperate climate type AW3 according to the KÖPPEN classification (Musabe 2002).

The country is divided between the Congo basin and the Nile basin. The Nile basin occupies the greatest part of Rwanda. Most rivers originate from the slopes of the Congo-Nile ridge. The Nile River Basin covers 67 percent of the land and drains 90 per cent of the national waters through two major water courses: the Nyabarongo, which originates in Nyungwe Forest, and the Akagera River (MINITERE 2004).

Biodiversity status

In Rwanda, protected areas cover 3 270 km^2, which is 12% of the area (MINAGRI 2003). The three main conservation areas are the Volcanoes National Park (VNP) the Nyungwe National Park (NNP) and the Akagera National Park (ANP) (USAID 2003). Table 1 shows the status of protected areas and reserves in Rwanda.

Tab. 1. Parks and Nature Reserves of Rwanda

Name & status	IUCN Category	Size (ha)	Altitude range (m)	Location	Date of creation
Akagera NP	II	250000	1250 - 1825	1°45'00S – 30°38'00E	1934
Volcanoes NP	II	14000	2400 - 4507	1°28'41S – 29°30'43E	1929
Nyungwe NP*	IV	101900	1600-2950	2°30'00S -29°14'00E	1933
Gishwati Forest Reserve	IV	6100	(1500)2000-(2990)3000	1°47'00S - 29°23'00E	1933
Mukura Forest Reserve	IV	2000	2500	1°59'00S -29°31'00E	1933

Source: IUCN 1994

*Nyungwe NP includes former Nyungwe forest reserve, Cyamudongo and Gisakura forests.

In these parks, it has been estimated that there are about 2 150 species of plants, and the assumption is that the degree of endemism is quite high (USAID 2003). Rwanda has 151 different types of mammal species, 11 of which are currently threatened. There are about 670 different species of birds out of which four species are threatened of extinction. The country is particularly well known for its 14 to 16 species of primates, including the mountain gorilla found in VNP. The endangered chimpanzee in Nyungwe and the golden monkey are endemic at a certain altitude (USAID 2004). Fig. 2 shows the three major National Parks.

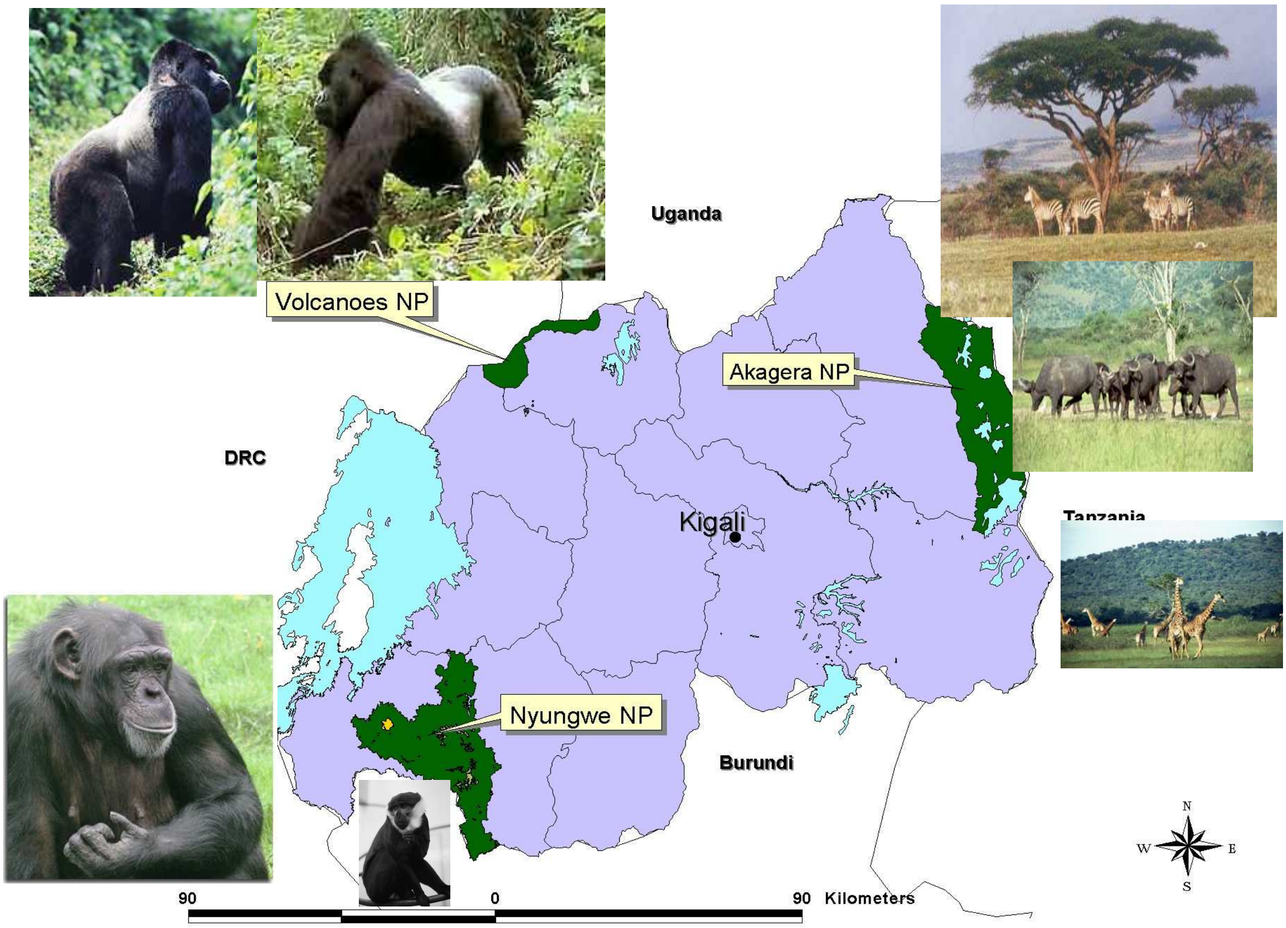


Fig. 1. Rwanda, Protected areas.

Threats to biodiversity

In Rwanda, like elsewhere in the world, though rich and diversified, biological diversity is seriously threatened. Many ecosystems are undergoing rapid environmental degradation and change following accelerated deforestation, soil erosion, landslides, loss of habitat and genetic erosion. These habitats have been altered by man's activities including reforestation and cultivated areas (MINITERE 2003) and natural factors. The total area under forest cover was reduced by 70 % between 1958 and 1996 (USAID 2004). The losses in protected areas are both caused by traditional use and a reflection of the economic situation (Fig. 2). Nyungwe area is being restored since it was declared as a National Park, and encroachment is reduced.

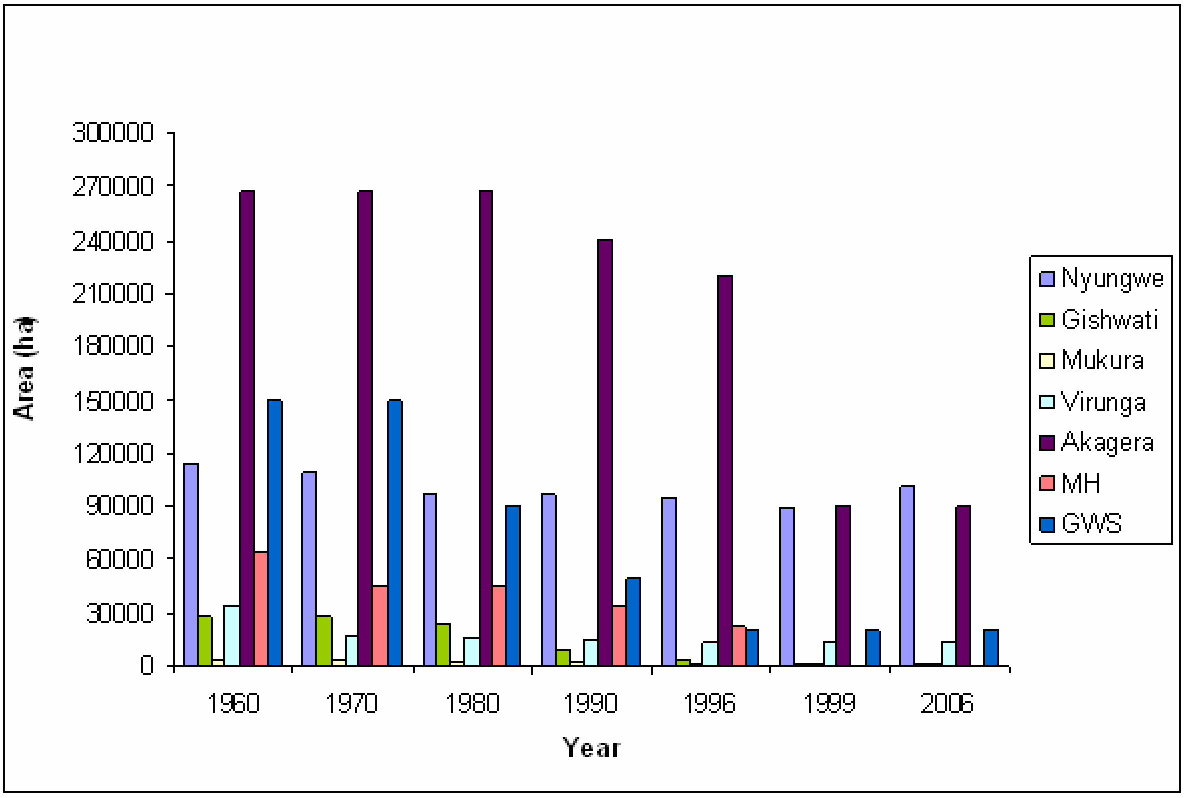


Fig.2. Reduction of natural forests in Rwanda from 1960 to 2006 (Gapusi 1999, ORTPN 2005, GOR 2005).
MH: Mutara Hunting Reserve, GWS: Gallery and wooded savannas

The major cause of reduction and degradation of natural ecosystems in Rwanda is the human pressure resulting from population growth (MINISANTE/ONAPO 2003; Rutagarama 2003), which has led to increased demand for new land for cultivation, which could be found within the park (Plumptre *et al.* 2004). This, together with the soil infertility, has led to smaller farm size (Weber 1989). Fire and construction wood, grazing as well as wildlife poaching, introduction of exotic species in combination with poverty and the lack of alternative income-generating opportunities, led people to harm the forest ecosystem and undermine biodiversity (USAID/Rwanda 2004).

Biodiversity loss in Rwanda is severe mainly due to the progressive reduction of national parks and large-scale habitat destruction (World Bank 2004). Population pressure has led to the depletion of arable land; the surface area per capita has fallen from 47 acres in 1970 to 13 acres in 2000, when in Sub-Saharan Africa the average was estimated at 26 acres in the same year (MINITERE 2003). Nyungwe has been fragmented by agriculture (Kanyamibwa 1998) and has lost more than 1 000 ha, while the Akagera National Park has lost more than 50 % of its area (USAID 2004) and approximately 90% of its megafauna (MINITERE 2003).

Environmental threats are mainly the soil erosion, floods, drought and the proliferation of invasive species (Figs.3 and 4) and pests or diseases.

Figs. 3 and 4. The invasion of NNP by Sericostachys scandens.

The proliferation of certain competitive species inhibits the regeneration of wood and grass species. This is one of the factors that speed up the formation of open areas. Such is the case with the climber *Sericostachys scandens* in the forest of Nyungwe which inhibits tree species regeneration and creates the open areas in the forest.

The reduction of natural ecosystems is always accompanied by the loss of biodiversity. Research has shown that about 115 plant species are threatened with extinction in Rwanda (Gapusi *et al.* 1997; MINITERE 2003). Three plant and 13 animal species are IUCN red listed (critically endangered, endangered and vulnerable) and primates are threatened by habitat destruction and poaching (FAO 2002; World Bank 2004).

Problem statement

The conservation of biodiversity in Rwanda is an important issue due to the strong dependence of Rwandese people on plants and the continuous loss of habitats. Plant extinctions will inevitably jeopardise the life of the community. For a long time, some rich ecosystems have been formally protected, but others are being progressively destroyed due to increased demand of their products by the surrounding human population.

The problems of land tenure, non-respect of sustainable land use, habitat loss and human demographic growth are the greatest challenges which Rwanda is facing as it strives for food security and biological diversity conservation. The pressure on natural forests and reserves resulting from people's search for agricultural and pastoral land and forest products has reached alarming levels. Despite these preoccupations, Rwanda views conservation of its montane forests as a priority concern (GOR *et al.* 2006).

In fact, between 1958 and 1990 the forest reserve was reduced in size from 1 141 to 970 km2 through encroachment by local farmers (Weber 1989). This represents a loss of 15% of the total area. The forest has been used for a wide range of activities including honey collection, woodcutting, poaching of animals, and small-scale agriculture. Shifting cultivation, gold mining and hunting over the last century have led to extinction of large mammals, forest fragmentation and changes of the hydrological basin that provides irrigation water to the surrounding human population and most parts of the country (Barakabuye 2001).

The first measures towards protection of natural forests were taken before the 1930's. In 1967 the Swiss Technical Assistance Programme initiated a Forest Pilot Project (PPF) along the northern edge of Nyungwe Reserve where they established buffer plantations of pine trees and constructed sawmills (Barakabuye 2001). In 1984 a buffer zone of pine trees (*Pinus patula*) was created around Nyungwe with the aim of establishing a boundary for the reserve and to provide employment and income to the people living around it (Masozera & Alavalapati 2004). Other measures concerning the protection and conservation of the forest of Cyamudongo (a forest island of Nyungwe) were promulgated in 1985 and a buffer zone of 25 km2 made up of exotic species like *Pinus* and *Cupressus* was established along the northern and southern part of the forest.

After the Genocide, between 1995 and 1998, the local communities accentuated their pressures on the natural resources. At that time, poaching was very significant in the forest. It appeared that the measures taken were not sufficient. Therefore, some studies were done and it was suggested to gazette Nyungwe as a National Park for its successful conservation (Gapusi 1999). Subsequently, in 2005, Nyungwe became a National Park. Since then the local population is no more allowed to collect any kind of forest products from the park. The only alternative to get non-timber products is the buffer zone. As this is made up of plantations of exotic species, there is a need for information on indigenous species in the buffer zone that could be useful for sustainable management and future use. Therefore, the current study undertook to evaluate the regeneration of indigenous species in the buffer zone and the surrounding communities' perceptions on the buffer zone and its use.

The research questions for this study are:

(1) Which exotic species is most favourable for regeneration of indigenous species in the buffer zone?

(2) Is the amount of indigenous species regenerating within the buffer zone different from the forest and how does it vary?

(3) To what extent can the indigenous species which regenerate in the buffer zone contribute to meeting the needs of the local communities?

(4) What is the role of the buffer zone from local people's perspectives?

Objectives and hypotheses

The objectives of this study are

(1) to evaluate the regeneration of indigenous species in the buffer zone

(2) to identify the suitable exotic species in plantation for regeneration of indigenous species

(3) to identify sustainable strategies for the buffer zone management

(4) to assess the abundance of medicinal plants among the regenerating indigenous species in the buffer zone

(5) to assess the role of the buffer zone in the livelihood of local communities.

The hypotheses to be tested are:

H0: The abundance of regeneration of indigenous species in the buffer zone does not differ among exotic species plantations;

H1: The abundance of regeneration of indigenous species in the buffer zone differs from one exotic species plantations to another and from natural forest;

H0: There are no medicinal plants among the indigenous species regenerating in the buffer zone;

H1: At least 10 % of the indigenous species found in the buffer zone are medicinal plants.

H0: The buffer zone does not benefit to local people's livelihood

H1: The buffer zone has an important role for the livelihood of the local people

Description of the study area

Nyungwe National Park

The NNP and the VNP reflect the real image of Afromontane forest along the Nile-Congo Crest in Rwanda. These ecosystems of mountain forest are part of the Albertine Rift Afromontane forests and constitute an important habitat of biodiversity. The NNP is the largest conservation area in the country and the largest section of Afromontane forest remaining in Africa with one of the highest biodiversity levels (USAID 2003; Weber 1989; Vedder *et al.* 1992).

Location and size

Nyungwe is widely recognized as being of global as well as national significance. NNP is situated in the majestic hills of southwestern Rwanda (Musabe 2002). It is located between the latitude 2°15' and 2°55'South and longitude 29°00' and 29°30'East (Plumptre *et al.* 2002) and lies within the Albertine Rift Valley on the Congo-Nile ridge between 1 600 m and 2 950 m. The forest is contiguous with the Kibira National Park in Burundi (Budowski 1975) forming one of the largest blocks of lower montane forest in Africa (Weber, 1989; Dowsett, 1990; Vedder, 2002). The Rwandan part covers five districts and is divided into eleven administrative sectors (Fig. 5).

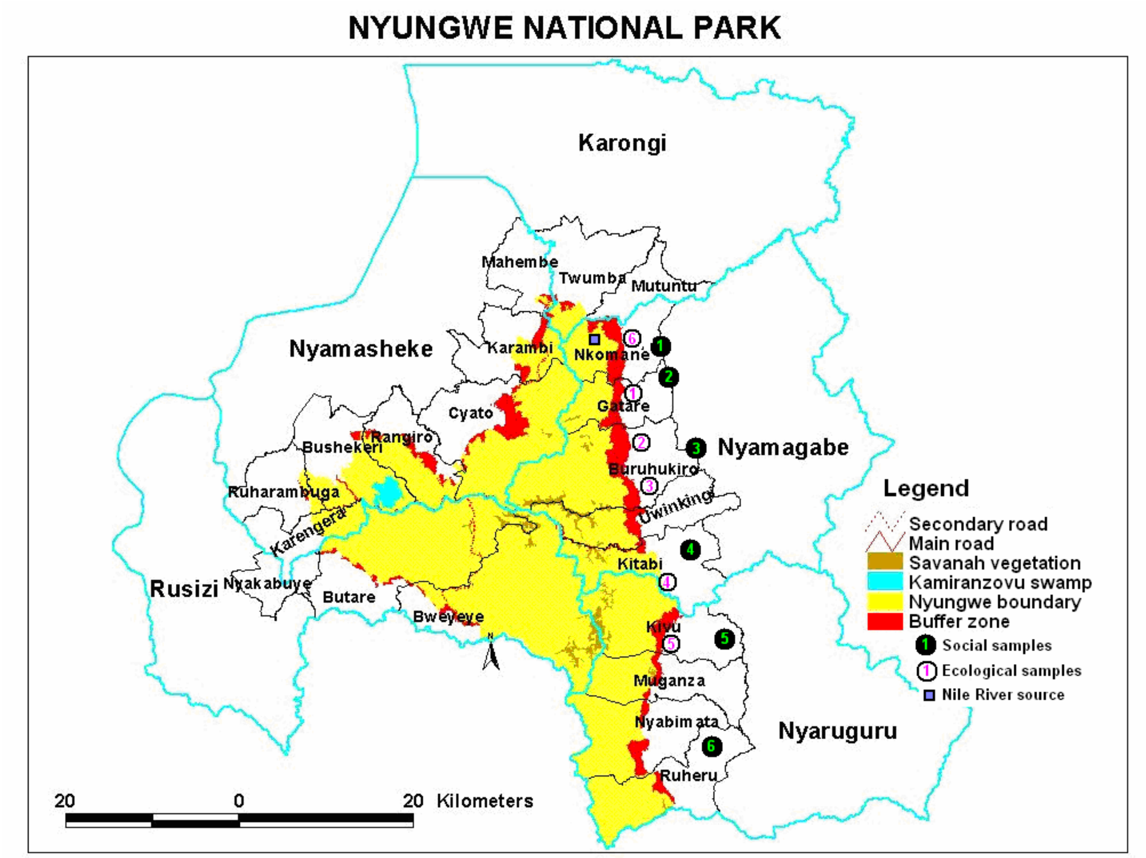


Fig. 5. Administrative map of NNP (ORTPN 2005), updated.

When it was designated as a forest reserve, its total area was 1 300 km^2 (Nyandwi 2003) and was covering the area included between the territory of Shangugu, Kibuye and Nyanza (Gapusi 1999). Since then, Nyungwe Forest cover has steadily shrunk though the extent of decline is not agreed upon. Gapusi (1999) reported the area as 892 km^2 by 1996 and Masozera (2004) as 1 067 km^2 by 2004. However, USAID/Rwanda (2004) estimated that the area of NNP was 1 019 km^2 according to recent demarcation of NNP using the delineate satellite images and the ground GPS mapping. The Law n° 22/2005 of the 21st November 2005 establishing the NNP including Cyamudongo and Gisakura Natural Forests reported that the total area of the park was 101 957.67 ha (GOR, 2005). Whatever the case, the NNP remains one of the largest blocks of lower Montane forests in Africa (Weber 1989).

Climate and soils

The annual precipitation in NNP ranges between 1600 mm and 2200 mm (Offutt 1990). The climate is generally cool, with an average minimum temperature of 10.9^{0}C and an average maximum temperature of 19.6^{0}C (Sun *et al.* 1996). The temperatures rarely fall below 0^{0}C in high altitude zones of the forest (Budowski 1976) and reach 30^{0}C with an average of 15.5^{0}C during the daytime.

The bedrock of Nyungwe Forest is mainly composed of very old Precambrian rocks differentiated in three geological parts (Storz 1983). In the eastern part of the forest, the substratum is derived from granites and granitic rock usually poor in nutrients (Sorg 1978). In the western part of the forest schist, quartzite and dolerite are the main parent rocks deriving to more fertile soils (Sorg 1978).
Around Nyungwe, agriculture encounters significant problems because the soil which was previously protected by the forest becomes poor and fragile over time (Plumptre *et al.* 2004)

Biodiversity richness

Nyungwe Forest shelters a complex mosaic of types of vegetation (Sun *et al.* 1996). Beside the Montane forests, there are various and unique vegetation types in NNP including savanna grassland, high altitude wetland, bamboo and acacia woodland, which are all habitat to unique wildlife species (ORTPN 2005). Floristically, NNP is regarded as the richest forest remaining in Rwanda with more than 265 plant tree species belonging to 45 families (Dowsett 1990, Plumptre *et al.* 2002) and including at least 24 species that are believed to be endemic to the Albertine Rift.

On the basis of altitude ranges, four vegetation strata are identified and recognised by dominant tree species, as described by Sorg (1978), Gapusi (1999) and Ndayambaje (2002). Between 1 600 m and 2 000 m a.s.l. (17% of the total area), dominant tree species reach 35 to 40 m in height and include *Parinari excelsa, Newtonia buchananii, Symphonia globulifera, Entandrophragma excelsum* and *Albizia gummifera*. Orchids and ferns are abundant as well. From 2 000 to 2 300 m a.s.l. (21% of the forest), dominant canopy tree species are *Entandrophragma excelsum, Parinari excelsa, Prunus africana, Ocotea usambarensis, Ficalhoa laurifolia* and *Chrysophyllum gorungosanum*. The ground vegetation is dominated by ferns. The altitudes between 2 300 m and 2 500 m a.s.l. (43% of the total area) are dominated by *Podocarpus latifolius* which reaches 15 to 20 m in height. Mosses and lichens occur, but the grass layer is poor and discontinuous at this range. At very high altitudes between 2500 to 2700 m a.s.l (19% of the total wooded area), the vegetation is dominated by shrubs and herbs. Tree species found at these altitudes include *Philippia benguelensis, Agauria salicifolia, Faurea saligna* and *Hagenia abyssinica*. Mosses, lichens and epiphytes are present (Ndayambaje 2002).

Nyungwe is known for having some of the world's most threatened primate species and one of the most species rich montane rainforest primate communities in Africa (Vedder 1988). Of particular interest is the spectacular association of more than 300 black-and-white Colobus monkeys (*Colobus angolensis ruwenzorii*) and an estimated 500 chimpanzees (*Pan troglodytes schweinfurthii*), the owl-faced monkey (*Cercopithecus hamlyni*) and possibly golden monkey (*Cercopithecus mitis kandti*) (Masozera 2002; Plumptre *et al.* 2002). Nyungwe is very rich in birds and is second only to Itombwe Massif in DRC in Albertine Rift bird endemics (Plumptre *et al.* 2002). Rizinjirabake (2002) stated that *Oricia renieri, Pentadesma reyndersii, Pavetta troupinii, Psychotria palustris* and *Tarrena rwandensis* are local endemics. Nyungwe forest is also one of the most important sites for bird conservation in Africa with a total of 270 bird species, 25 of which are endemic to the Albertine Rift. Thirteen species of primates, including chimpanzees, are known to inhabit the forest.

Tourism

Nyungwe is becoming a more attractive site since it became the National park and muchg infrastructureis being set up for more visitors. Tab. 3 shows the flow of tourists in NNP. It appears that the number of tourists have been reduced after the genocide war of 1994 but has again increased in recent years. Nevertheless, the carrying capacity of NNP can exceed 50 000 visitors per year (Katarebe 2002).

Tab.3 Visitors flow in NNP (1988-2005).

Year	Nb. of tourists	Year	Nb. of tourists
1988	441	1997	65
1989	2981	1998	225
1990	2658	1999	374
1991	900	2000	777
1992	941	2001	646
1993	2299	2002	707
1994	0	2003	1785
1995	157	2004	2041
1996	149	2005	2385

Source: Nyandwi 2005 and ORTPN (Uwinka archives).

Buffer zones

The current study was conducted in the eastern part of Nyungwe buffer zone area. The buffer zones are defined as areas adjacent to protected areas adding to their protection and providing valued benefits to the neighbouring rural communities (Sayer 1991). One of the pressing challenges resource managers have been facing all over the world is conflicts with local communities in resource management (Masozera *et al.* 2004). Buffer zone concepts have been adopted as a strategy to make a good balance between the long-term objectives of protected areas and immediate needs of the people living in and adjacent to these areas.

Although the application of the buffer zone concept is quite new in some countries, it has been emerging as a viable strategy in linking ecological and economic objectives. In the Rwandan case, the buffer zone around the Nyungwe forest has been planted with economically important species and is a source of building poles and firewood for local people (Ndayambaje 2002).

Different projects divided into management units, UGZ (Unité de Gestion de la Zone) established exotic plantations with the objective of marking the boundaries of Nyungwe Forest and keeping it from encroachment by neighbouring communities but also for managed pastures (MINAGRI 1984, Weber 1989). All these projects did not cover the whole buffer strip between Nyungwe forest and local people. Therefore they did not by their deeds reach the adequate protection. The forest degradation continued, particularly due to illegal logging and gold mining (PCFN 1989).

The various UGZ established forest plantations (Tab. 4) of predominantly exotic tree species (MINAGRI, 1992) which have been managed by the government (Stainback 2004). The current law establishing a buffer zone of Nyungwe National Park, estimates its area to 10 085 ha (GOR 2005). Different activities including crop production, grazing and timber harvesting from thinning and marketing of timber products were conducted after establishment of this buffer zone (MINAGRI 1992) which is made with a variety of species, including mainly the exotics *Pinus patula, Cupressus lusitanica* and *Acacia melanoxylon* (USAID2003).

Tab. 4 The division of the Buffer zone by UGZs* until the end of 1993

Project	Area (ha)	Current Districts						
	***Pinus* spp.**	***Acacia melanoxylon***	***Cupressus lusitanica***	**Other exotic species**	**Indigenous species**	**Total**	**Natural regeneration**	
UGZ1	2400	0	400	600	650	**4 050**	300	Nyamasheke
UGZ2	2700	700	600	60	40	**4 100**	0	Nyamagabe
UGZ3	1200	800	20	100	50	**2 170**	0	Nyaruguru
UGZ4	550	200	20	250	15	**1 035**	0	Rusizi
MUDAS	300	250	50	100	20	**720**	0	Nyamagabe
TOTAL	**7 150**	**1 950**	**1 090**	**1 110**	**775**	**12 075**	**300**	
Rate (%)	59.21	16.15	9.03	9.19	6.42	**100**		

Source: PAFOR, 2007 (in publication)
*UGZ: Unité de Gestion de la Zone 1-4 (Management Units)

In the eastern part, which includes the districts of Nyamagabe and Nyaruguru, the buffer zone plantation covers 58% of the total plantations surrounding NNP.

Surrounding human population

Nyungwe forest remains as an island surrounded by areas densely inhabited by humans (between 250 and 500 persons/km^2). In fact, the forest reserve was reduced in size through encroachment by local farmers (Weber 1989).

The two districts surrounding NNP are densely populated and as the whole country the population is young; 80% of the population is below 34 years of age (Kagaba *et al.* 2003). Table 2 shows the population of former surrounding districts in the Eastern part of Nyungwe National Park.

Tab.2 The population of the Eastern Nyungwe districts in 2002

District	Male	Female	Total
Nshili	38 225	42 735	80 960
Mudasomwa	32 451	36 746	69 197
Mushubi	40 254	46 361	86 615

Source: GOR 2002

Socio-economic aspects

The situation for people in the former Gikongoro province, under which the eastern part of NNP falls, is very critical. The incidence of poverty is as high as 77% (Kagaba *et al.* 2003), and 59% have less than 2.0 ha of agricultural land (MINECOFIN 2002; UNEP/IISD 2005). According to Rutagwenda (2007), 50% of the children suffer from malnutrition in Gikongoro Province, this being the highest in the country.

Agriculture is the main economic activity in the area (Plumptre *et al.* 2004). In the southern part of Nyaruguru district (former Nshili district) for example, where the land is more or less available, the average was 2.89 ha per household. 50% of the land is used for food crops, 30% for tree plantation and 13% fallowed (Brown and Zayac 2007). There are many tea plantations in extension in order to generate income to the local population. The most important crops are potatoes, sorghum, wheat, peas and maize, but the production remaining insufficient, the region has been suffering from chronic food shortage.

In the region near NNP, the wood is the main source of energy, used for cooking, light and other uses (Weber 1989, Musabe 2002) and various wood products from the forest offer great opportunities to develop trade in the area (Plumptre *et al.* 2004). Plumptre *et al.* (2004) also noted that the source of fuel wood is the field for 44%, forest for 2%, buffer-zone for 18% and other sources, including buying for 35%. The two districts Nyamagabe and Nyaruguru are the main providers of charcoal for Kigali, the capital city, and for almost the whole of the Southern province.

Methodology

The data for this study were gathered using two methods: an inventory of regeneration and a socio-economic survey. The first method allowed collection of data related to the regeneration of woody indigenous species and site characteristics in the buffer zone while the second provided data related to local people's perception on the area. Data collection was carried out in the period between August 2006 and March 2007.

Inventory of regeneration

The data collection was done with a team of two technicians and six to eight labourers including local knowledgeable farmers on forest and plants.

The instruments used were calliper and measuring tape for tree diameter measurements and distance, respectively. Global Positioning System (GPS) and compass were used for the position and aspect of the stand and we used a digital camera for taking pictures. Shears were used for collecting botanical samples for identification in the herbarium, if they were not identified directly in the field.

The field study was done in the buffer zone of the national park in the two districts Nyamagabe and Nyaruguru, where most of the plantations have been established and maintained. Approximately 58% of the total plantations of exotic species in the buffer zone are found in these districts. More samples have been collected in Nyamagabe district, which is more wooded than Nyaruguru. In total, six sites stretched in five administrative sectors (Nkomane, Gatare, Buruhukiro, Kitabi and Kivu) of the buffer zone were sampled. The criteria of the selection were the availability of plantations and the closeness of the natural forest.

In each stand, latitude, longitude, altitude, slope, crown and ground cover were recorded. Information on the age of plantation, disturbance and abundance of species was noted. The topographic category of the point location was noted and designated as follows: bottom, middle or top of hills. Ground and crown cover was estimated for each plot within the stand. The density, height and diameter at breast height (dbh) of exotic species were also measured (Fig.6).

Fig. 6. Diameter and height measurements in Gatare and Nyamagabe districts.

Data on regeneration were gathered in circular plots of 5 m radius. There were three such plots at each stand. Distance between plots was made at 50 m and from the edge of both natural forest and plantations. The total area measured was 0.6 ha. Samples were collected in plantations of four exotic species, *Acacia melanoxylon* (A), *Cupressus lusitanica* (C), *Eucalyptus maidenii* (E) and *Pinus patula* (P), in six sites of each. Natural forest has been sampled as well as control.

All trees, shrubs and saplings were recorded on data sheets according to Owiunji *et al.* (2005). Much of the results are based on data from individuals between 2.5 and 10 cm diameter (denoted diameter class D1), but also all young plants with diameters ranging between 0.4 cm and 2.5 cm at stump height (class D2) were identified as saplings. Trees thicker than 10 cm (class D3) were identified as well. Some vouchers have been sent to IRST herbarium.

Socio-economic survey

Social data were collected again in the previously mentioned sectors as well as in the Ruheru sector, which was selected because of its geographical position, more south than the others and not having old plantations at all. Data were collected with the help of two assistants. Respondents were stratified with facilitation of local authorities and classified according to their main occupations. In each sector more or less 20 inhabitants were interviewed using a questionnaire for gathering local people's perceptions on the buffer zone (appendix 2.).

Fig.7 Social data collection in Kitabi sector, Nyamagabe.

The major issues dealt with in the questionnaire included role of the buffer zone in biodiversity conservation, in providing forest products, and in facilitation of regeneration of woody species, particularly on which medicinal tree species were most collected.

The questionnaire was addressed to the farmers, bee-keepers, charcoal and timber sellers and hunters. The traditional healers, sellers or collectors of medicinal plants were involved in drawing up the list of most used medicinal plants. Responses were coded as 0 for none, 1 for less and 2 for high. Some comments were recorded for every question. In addition, discussions were held with the local administrators, park and project managers about the proper management of the buffer zone.

Analysis methods

Ecological data analysis

Species diversity indices have been calculated using Shannon (H) and Simpson (D) indices. A high value of H or D indicates a large number of species with similar abundance; a low value indicates few species regenerating (Magurran 2004). The Shannon Wiener index is calculated using the following formula:

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

H: Shannon's diversity index
S: Total number of species in the community (richness)
p_i: Proportion of *S* made up of the i^{th} species

The Simpson's index (D) is calculated using the following formula:

$$D = \frac{1}{\sum_{i=1}^{S} p_i^2}$$

The comparison of different species has been done according to different parameters, including their richness, abundance, basal area, relative dominance and importance value. The exotic species have been measured for all individuals in the stand, the average DBH and total height.

The species richness was compiled from the plot data in order to compare stands with the four exotic species. According to Nduwamungu (1997), Shannon index of diversity or Shannon-Wiener index is the fair index which combines species richness and evenness and the most widely used. It is not affected by the sample size (Pielou 1975; Krebs 1989; Kent &Coker 1992).

Species accumulation curves were plotted for all plots representing sites, species and the natural forest. These curves were used to show the trend of species encountered for the same sampling effort as expressed by number of individuals measured.

According to Owiunji (2005), Shannon indices show the percentage similarity in species composition and abundance between sites. Those communities that are identical have an index of 1 while those that are completely dissimilar (i.e. share no common species) have an index of zero. The Importance value index of indigenous species was calculated using the summation of relative frequency, relative density and relative abundance.

Social data analysis

Descriptive statistics were used to define the informant profile. Graphs and tables were used based on frequency, mean and percentages of the responses.

Some of the independent variables included districts, administrative sectors, gender, occupation and age groups. Dependent variables were the role of buffer zone, its drawbacks, use of non-timber products, indigenous species most regenerating, medicinal plants most used and exotic species valued in the buffer zone.

Results

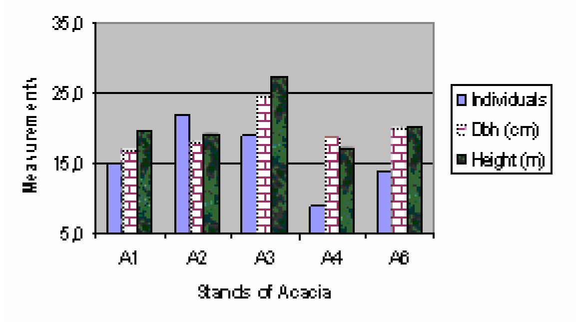
Ecological results

Site characteristics

The six sites were selected randomly where the plantations remain. The longitude of the sampled area differed by 0°2'033" stretching from 29°25'453"E (Kivu-Gahurizi-Uwingwe) to 29°21'540"E (Buruhukiro-Rugege). The latitude differed also by 0°20'215" ranging from 2°19'054"S (Nkomane-Kabuga) to 2°39'269"S (Kivu-Kigogo). The average GPS points and altitudes, age, aspect, slope, crown and ground covers are given in Appendix 3.

A total number of 2 750 individuals were measured. This included the standing trees in plantation (exotics) and the regeneration of indigenous trees which occupied 86% of the total. For each exotic species the number (density) and performance (diameter and height) varied from stand to another and site.

Species are distributed in the different sites and differed in densities, growth and the number of exotic standing trees. Figs. 8-11 explain how the number of individuals, diameter at breast height (dbh) and height varied from stand to another. This is done separately for stands of each exotic species planted purposely as buffer zone. The stands of each species are numbered from 1 to 6.



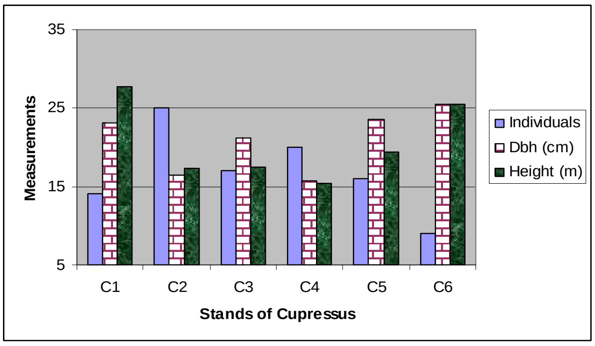
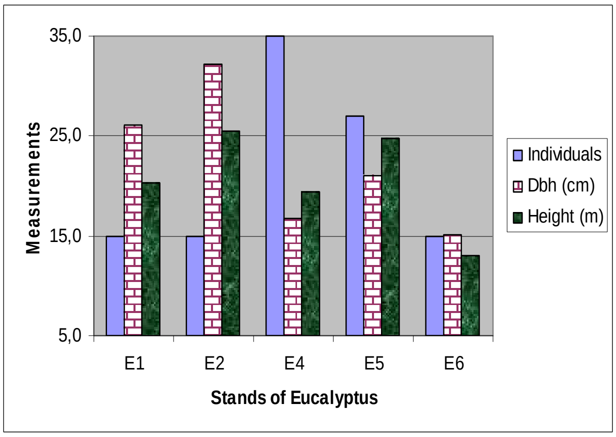


Fig. 8 and 9. Diameter, height and number of trees for Acacia and Cupressus stands.



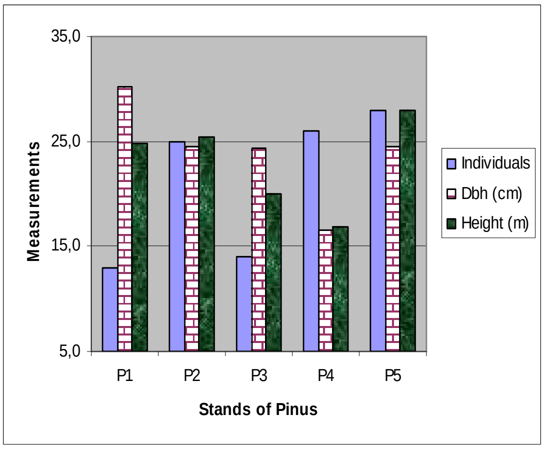


Fig. 10 and 11. Diameter, height and number of the planted trees in Eucalyptus and Pinus stands.

Figures 10 and 11 show that *Acacia* stands have taller trees and larger diameter in stand A3, but more individuals are found in A2. For the *Cupressus*, the stand C1 has tall trees, C6 has big trees and C2 is denser than the others. *Eucalyptus* has a large diameter and height in E2, but a big number of trees are located in E4. *Pinus* has a high number of trees and height in P5, but P1 has a high diameter.

Assuming that all species have been planted in similar ecological conditions, and considering that they have been established in the same period using the same spacing at 3m x 3m Fig. 12 shows that *Pinus* has big and tall trees whereas the number of individuals is identical to *Eucalyptus*.

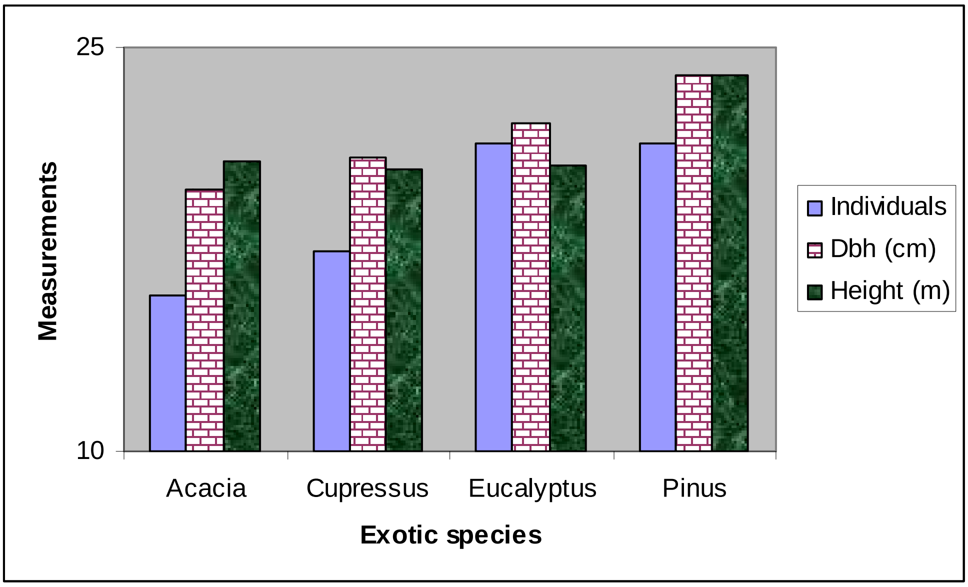


Fig. 12. Diameter, height and number of individuals of the exotic species.

Distribution of regenerating species and individuals in the different diameter classes.

A total number of 2 750 regenerating plants were measured and identified, 86% of which were indigenous. In all plots 46 species were recorded and identified. Some species occur in all the diameter classes. The species belong to 30 families and the most common is Euphorbiaceae (Appendix 4). The indigenous species recorded as regenerating were categorized in three stump diameter classes, taken at 10 cm from the ground. The findings are presented in Appendix 5.

The diameter class D2 has more individuals (saplings) than the other two diameter classes. Fig.13 shows the *Acacia* stands (1-6) as an example. There is a significant difference in the number of individuals between stands for the D1 (2.5-10 cm) and D3 (>10 cm) classes but not for D2 (0.4-2.49 cm) ($P<0.05$; ANOVA one way).

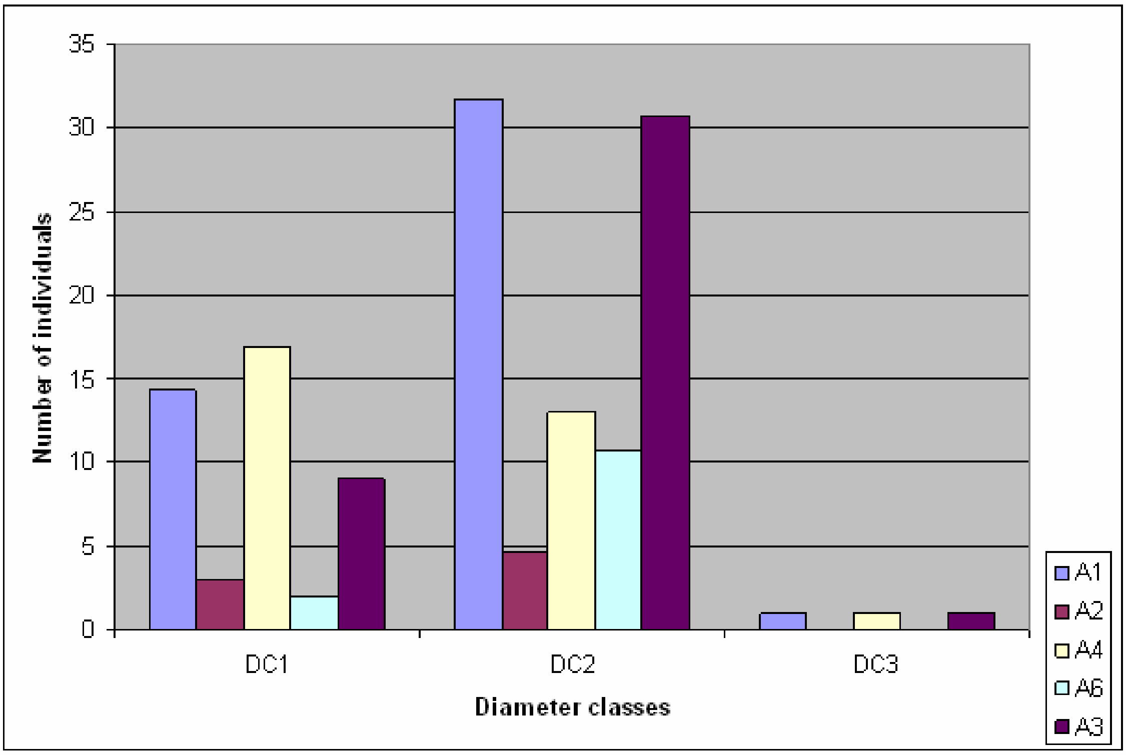
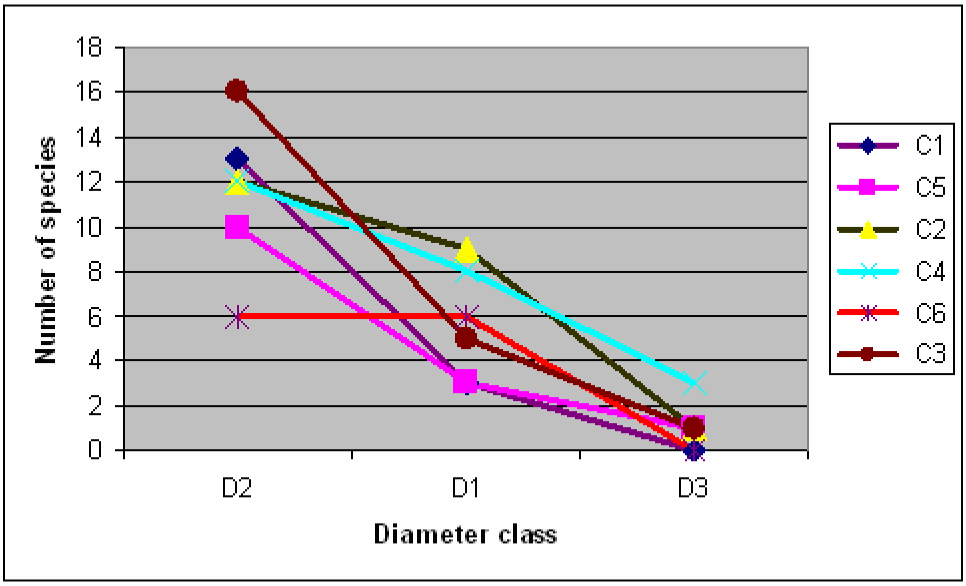


Fig. 13. Distribution of individuals in diameter classes in Acacia stands A1-A6 (DC1: 2.5-10 cm, DC2: 0.4-2.49 cm, DC3: ≥10 cm).

The number of species differs significantly between stands and for each diameter class (ANOVA one way; $P<0.05$). The general trend is that more species are found in D2 and decreasing with the growth, except two cases in natural forest and two from eucalypts. Fig.14 shows as an example how the species are distributed in *Cupressus* stands.



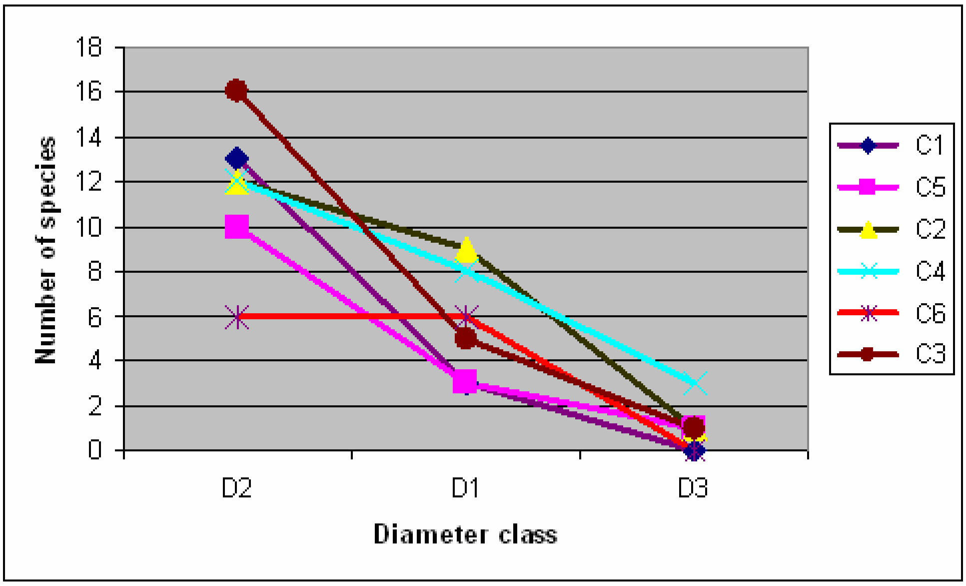


Fig. 14 Distribution of regenerating species in three diameter classes of Cupressus stands (C1-C6).

Number of species

The focussed diameter class was D1. In Fig. 15 the distribution of species in all sites and stands is compared. It comes into view that the forest stand 3F3 is the richest followed by two *Acacia* stands (5A6 and 6A3). The poorest is *Pinus* (3P2) which does not have any species in this diameter class.

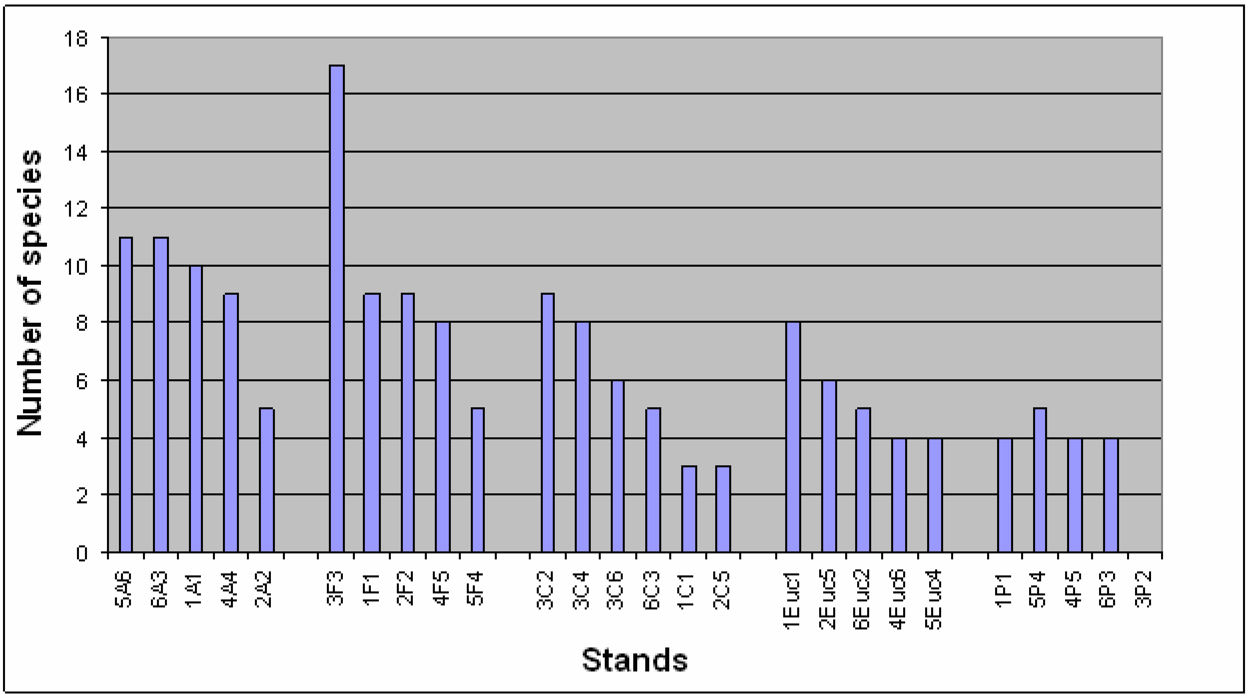


Fig. 15. Number of species by stands for diameter class D1 (A: Acacia, F: Forest, C: Cupressus, Euc: Eucalyptus, P: Pinus. The first number is the site and the last is the stand).

The accumulative curves for *Acacia* woodlots (Fig.16) and all stands combined (Fig.17) show how the number of species was added in the area.

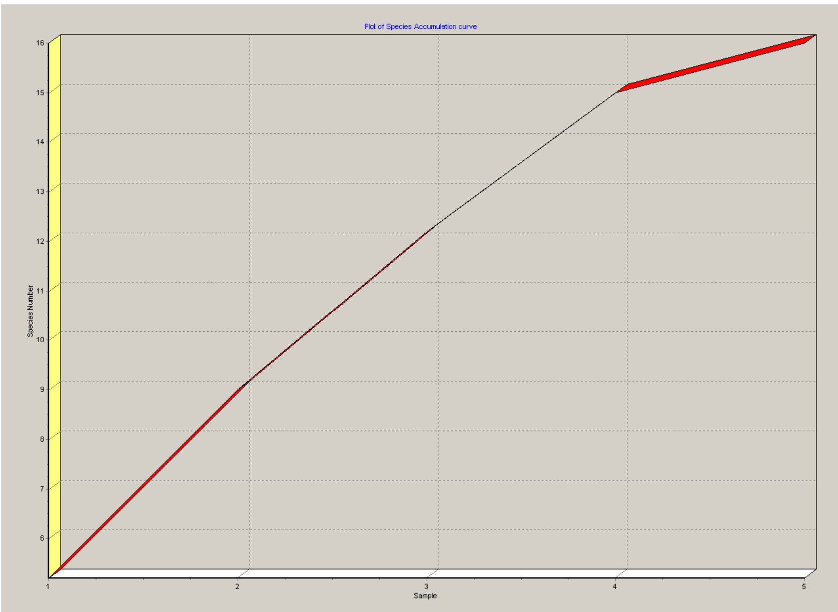


Fig. 16. Species accumulation curve for diameter class D1 in Acacia stands.

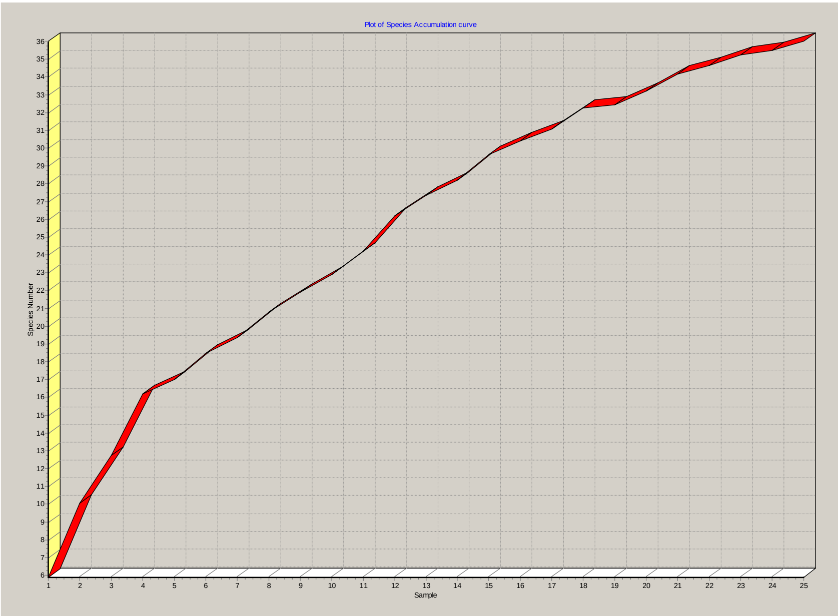


Fig. 17. Species accumulation curve in diameter class D1 for all stands.

The species gathered during the ecological survey, have been listed and classified in their respective families. Tab. 5 lists the families encountered in diameter class D1 and the number of species and individuals for each family.

Tab. 5. Number of species and individuals for the families represented in diameter class D1 (2.5-10 cm).

Rank	Family	No of species	Number of Individuals
1	Euphorbiaceae	5	213
2	Rubiaceae	2	135
3	Myrsinaceae	3	63
4	Myrtaceae	1	42
5	Dichapetalaceae	1	37
6	Monimiaceae	1	21
7	Meliaceae	3	10
8	Araliaceae	1	7
9	Oleaceae	1	5
10	Aquifoliaceae	1	4
10	Clusiaceae	1	4
10	Rosaceae	1	4
10	Sapindaceae	1	4
14	Amygdalaceae	1	3
14	Celastraceae	2	3
14	Melastomataceae	2	3
14	Moraceae	2	3
18	Fabaceae	2	2
18	Melianthaceae	1	2
18	Liliaceae	1	2
18	Rhizophoraceae	1	2
18	Verbenaceae	1	2
23	Chrysobalanaceae	1	1
23	Ericaceae	1	1
23	Sladeniaceae/Theaceae	1	1
	Total	**38**	**574**

Shannon index

The species diversity indices were calculated using the Shannon-Wiener index for comparison of exotic stands within them and with forest. Fig. 18 presents the Shannon index for the individual stands.

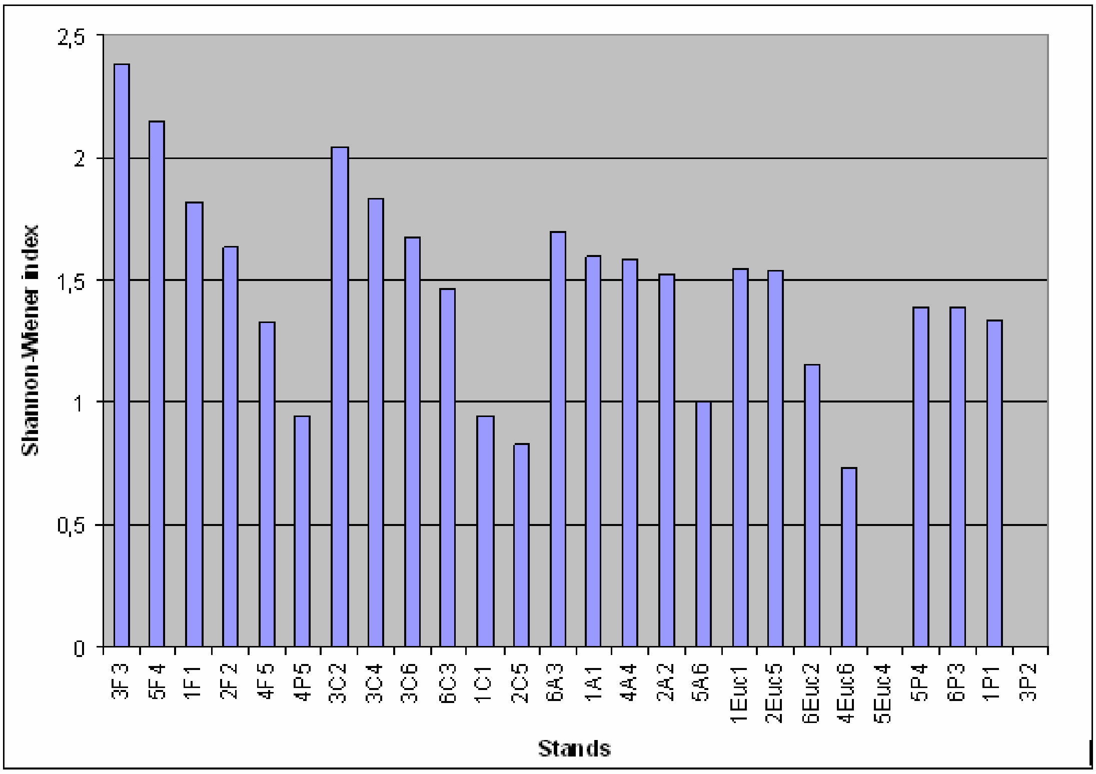


Fig. 18. Shannon index for the sample units (for explanations refer to Fig. 15).

As seen in Fig. 18, the forest stands (F3 and F4) have the highest Shannon index followed by *Cupressus* (C2). The lowest index is for P2 which does not have, of course, any species.

Using the Simpson index (Fig. 19), we can see that the trends remain the same as in the Shannon index. The highest is *Pinus* (1P1), followed by the natural forest and by *Cupressus*.

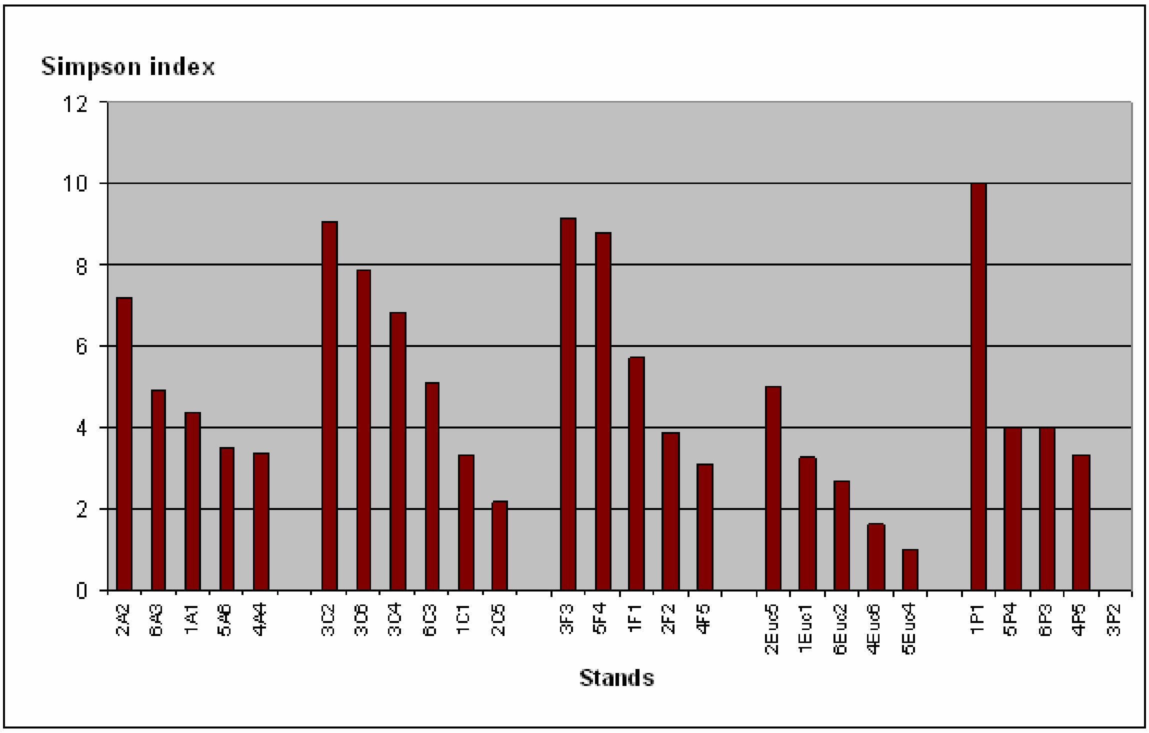


Fig. 19. Simpson index (for explanations refer to Fig. 14).

A pair wise comparison of the stands using Shannon-Wiener index has been done and the results are condensed in Appendix 6. There is no difference in most of the stands. The value for the stands which show a significant difference ($P<0.05$) are marked with shade in the table. For four stands of *Eucalyptus* the difference is significant for 5E4 compared with 1E1, 4E6, 6E2 and for 4E6 compared with 1E1. As for the forest stands; 4F5 is strongly different from 3F3and 5F4 and 5F4 differs from 2F2. For *Cupressus* the stand 2C5 differs from three others: 3C2, 3C4 and 3C6 The Shannon index has been calculated also for the regeneration in plantations of each exotic species, combining the species from similar stands (Fig. 20) and the forest. The highest index is found in natural forest followed by *Cupressus* plantations.

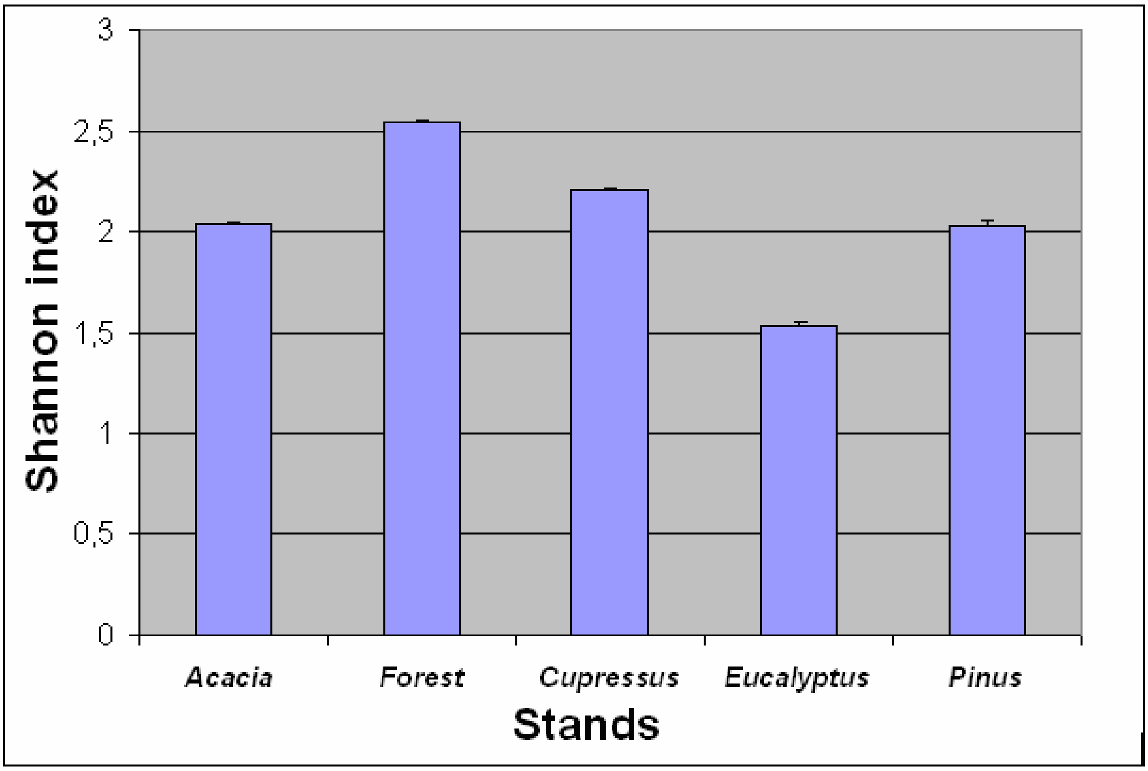


Fig. 20. Shannon index for regeneration in exotic species plantations and natural forest.

The comparison of results from forest and exotic species plantations is summarized in Tab. 6.

Tab. 6. Pair wise comparison of forest and plantation, using Shannon index.

	A	**F**	**C**	**E**	**P**
Acacia	X				
Forest	0.0001*	X			
Cupressus	0.3321	0.0396*	X		
Eucalyptus	0.0043*	0.000*	0.0001*	X	
Pinus	0.9885	0.5101	0.802	0.2795	X

* Significant difference (p<0.05).

Basal area

Fig.20 compares the basal area of indigenous species in different stands. It shows that values for *Cupressus* are higher than for other exotic species.

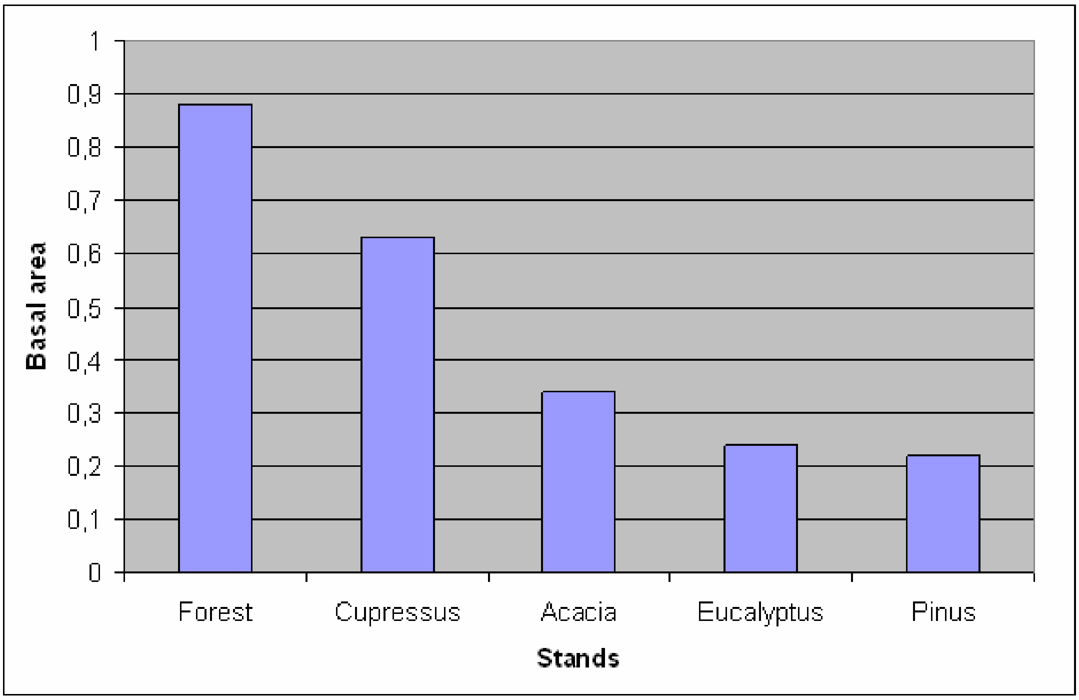


Fig. 20. Basal area of indigenous species in the five stands.

Indigenous species regeneration in the natural forest and plantations

Figure 21 shows how the important indigenous species are distributed in the forest and under different exotic species.

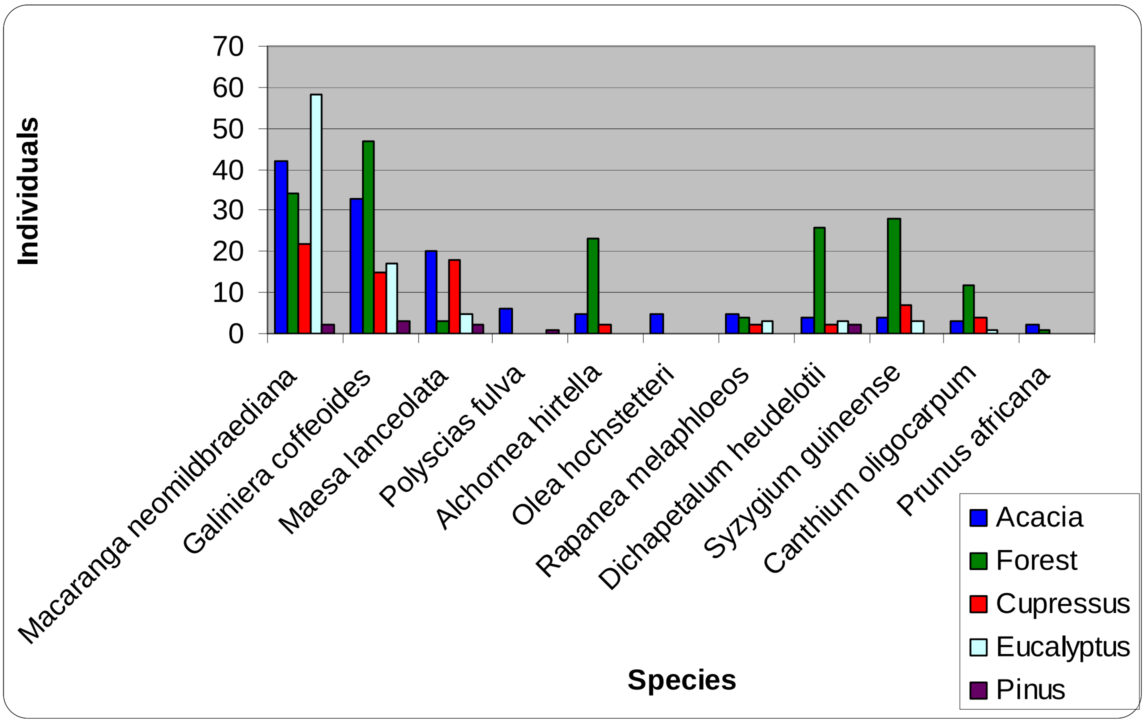


Fig. 21. Indigenous species in the stands of natural forest and plantations.

Importance value indices of indigenous species

The importance value for the indigenous species (Appendix 7) was calculated and the highest was for *Macaranga neomilbraedana* (75.9) followed by *Galiniera coffeoides* (48.7), *Maesa lanceolata* (27.7), *Syzygium guineense* (19.6) and *Dichapetalum heudelotii* (15.9). Fig. 22 shows the importance values for selected species.

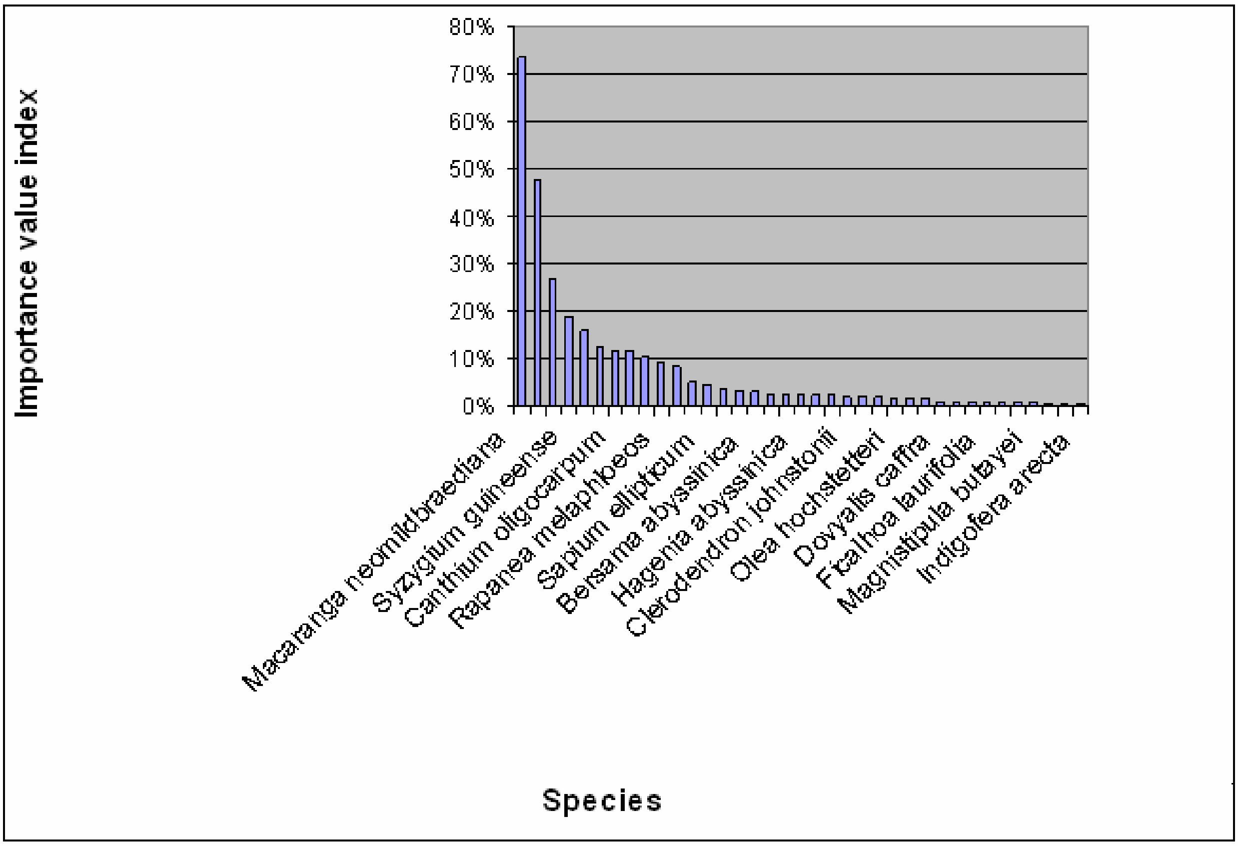


Fig.22. Importance values of selected indigenous species in diameter class D1.

Social-economic findings

Description of respondents

A total of 108 respondents from two districts (74 in Nyamagabe and 34 in Nyaruguru) with six administrative sectors (21 in Buruhukiro, 14 in Gatare, 23 in Kitabi, 17 in Kivu, 16 in Nkomane and 17 in Ruheru) neighbouring the NNP were interviewed. Of these 92 (85.2 %) were married, 5 singles, 4 widowed 1 divorced and 8 temporarily separated.

The age ranged from 20 to 83 years. Four people (4%) were less than 30 years old, 12 were between 31 and 45 (11%) and 46 people (43%) between 46 and 60. A further group of 33 interviewed (31%) belong to the interval of 61 to 75 years and 13 people (12%) were between 76 and 83 years. Tab. 7 shows the interviewed population subdivided in groups of 10 years. The major part is a group of 51 to 60 years which represent 33.3% of the whole group.

Tab. 7. Age groups of respondents

Age group (years)	Number of respondents (%)
< 30	5
31-40	11
41-50	13
51-60	44
61-70	22
71-80	25
>80	5
Total	**100**

Tab. 8. Occupation of respondents

Occupation	Number of respondents (%)
District	2
ORTPN	2
PCFN	1
Projects	2
Sector	18
Handicraft	9
Beekeeping	19
Hunting	8
Traditional healing	15
Agriculture	8
Cattle keeping	5
Timber/Charcoal	12

The majority of respondents were men (86%); this showed that few women activities are related to the forest. Respondents were selected according to their occupation, especially those related to the buffer zone or NNP (Tab. 8). The respondents were local administrators at district or sector levels, managers of the conservation projects, craftsmen, beekeepers, hunters, farmers and stockbreeders, traditional healers and timber/charcoal makers or sellers. Fig. 23 shows that the education level for most people is restricted to primary school (52%). The number of children ranges between zero and more than 15, but as it appears in Fig. 24, most respondents have between 12 and 14 children, while others do not have any.

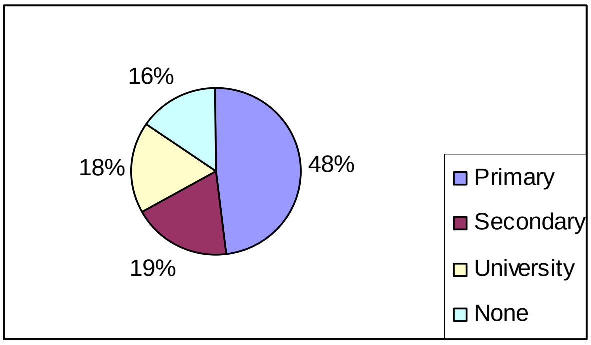


Fig. 23. Education level of respondents.

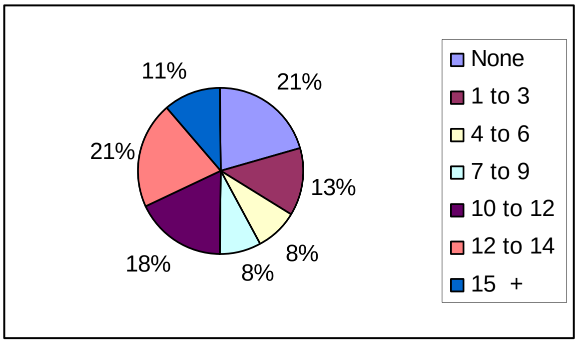


Fig. 24. Family size among respondents.

The farm size ranges between 0 and 10 ha and the majority (40%) have less than 0.5 ha as shown in Fig. 25.

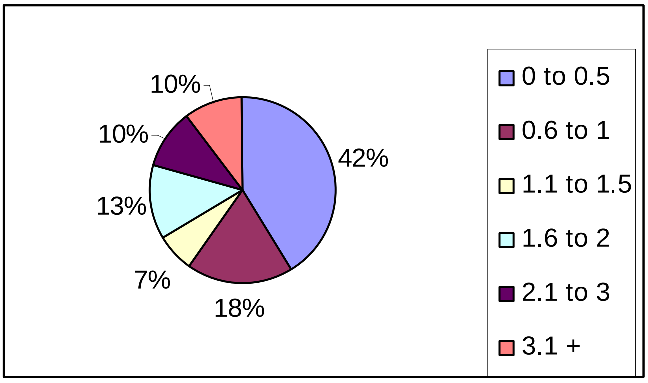


Fig.25. Farm size among respondents.

Economic benefits

The information about the economic benefits that respondents could earn from the buffer zone has been gathered and is summarized in Tab. 9.

Tab. 9. Economic benefits from the buffer zone.

	Responses		
Economic benefits	**No**	**Low**	**High**
Job opportunities and thus increased income of local people	5	37	64
Compensation of people who lost access to the strictly PA	23	47	36
Timber, charcoal and non-timber forest products	18	19	69
Hunting alternative area	79	18	11
Seedlings and saplings	32	37	38
Compensation of people who lost access to their land	65	26	16
Increased value of wildlife and vegetation	2	9	96
New introduced crops and technologies	27	37	40
Income generation from transit movements to and from NNP	44	28	34
New improved infrastructure (roads, camping houses...)	24	57	24
New area for animal grazing	91	10	7
New and improved market opportunities	51	38	19
Improved access to public services	51	26	30

The mean, median and mode of the benefits from the buffer zone showed that the difference between the diverse economic profits is strongly significant (Kruskal Wallis test and ANOVA one way; P<0.01; DF: 13 N: 1401). Fig.26 shows how the responses are distributed. It appears that many people agreed that the buffer zone has an important role, others not.

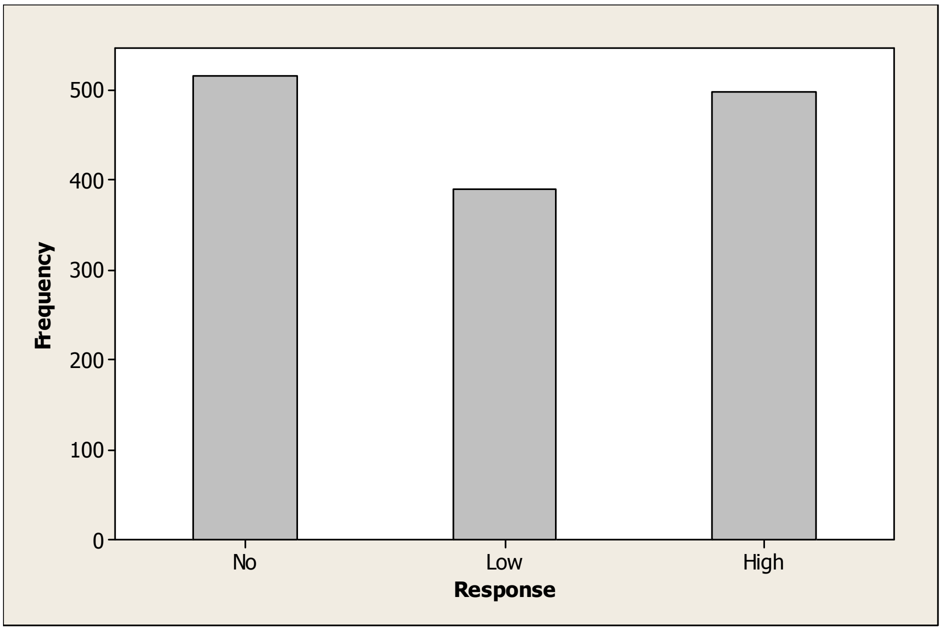


Fig. 26. Summary of the distribution of responses on economic benefits of the buffer zone.

The main economic roles as showed in Fig. 27 are to increase the value of wildlife and vegetation, to create job opportunities and thus increase the income of the local population in the area and to increase benefits from timber, charcoal and non-timber forest products.

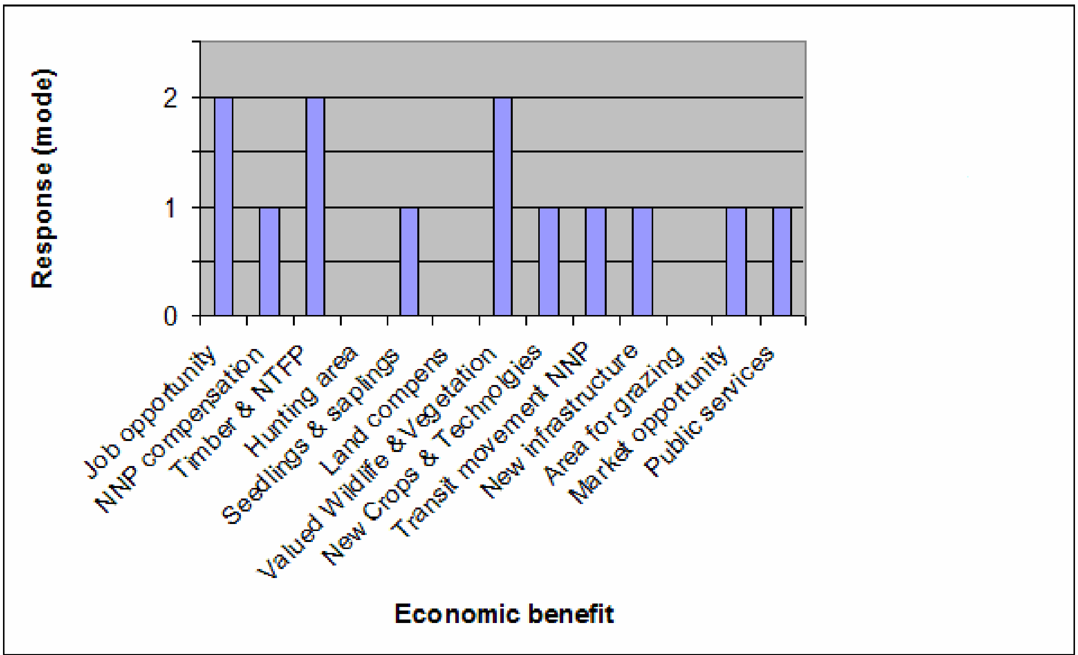


Fig. 27. Economic values of the buffer zone. 0=no, 1=low, 2=high

There is a significant difference between the two districts about the creation of jobs and the use of non timber forest products (ANOVA, $P<0.05$), but not on the value of wildlife and vegetation. The difference is due to the fact that the Ruheru sector did not benefit from jobs and non-timber forest products, whereas the two sectors Buruhukiro and Kitabi did very much. Other patterns like marital status, age groups, gender, family size, education level, activity of farm size did not show any significant difference.

Environmental benefits

Tab.10 provides a summary of responses of the questionnaire on environmental benefits.

Tab. 10. Biological benefits from the buffer zone.

Biological benefits	Response		
	No	Low	High
Providing filters or barrier against human uses of the park	0	5	102
Protects the core area from animal invasion	2	12	93
Protects against storm damage, drought, erosion	5	13	89
Enhances environmental services provided by the forest	7	27	74
Increases the population of wide-ranging species in the PA	11	15	81
Allows the regeneration of indigenous species	23	34	48

Fig. 28 shows how the responses are distributed. As we can see, the responses on biological issues are in general tending towards the highest appreciation. This means that the local people are positive to the role played by the buffer zone.

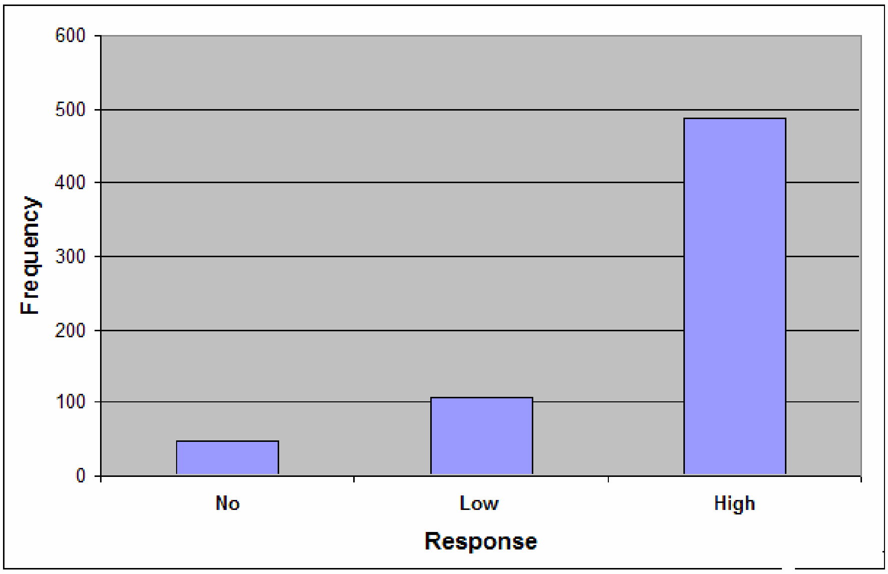


Fig. 28. Distribution of the responses of the biological benefits.

There is a strong difference (Kruskal-Wallis, $P<0.01$, DF: 5, N: 648) between the biological aspects of the buffer zone, even if it is not apparently clear in Fig. 29. The highest biological role is to provide a filter or barrier against human access and undesirable use of the park. This is followed by the similar protection against invasion by animal species.

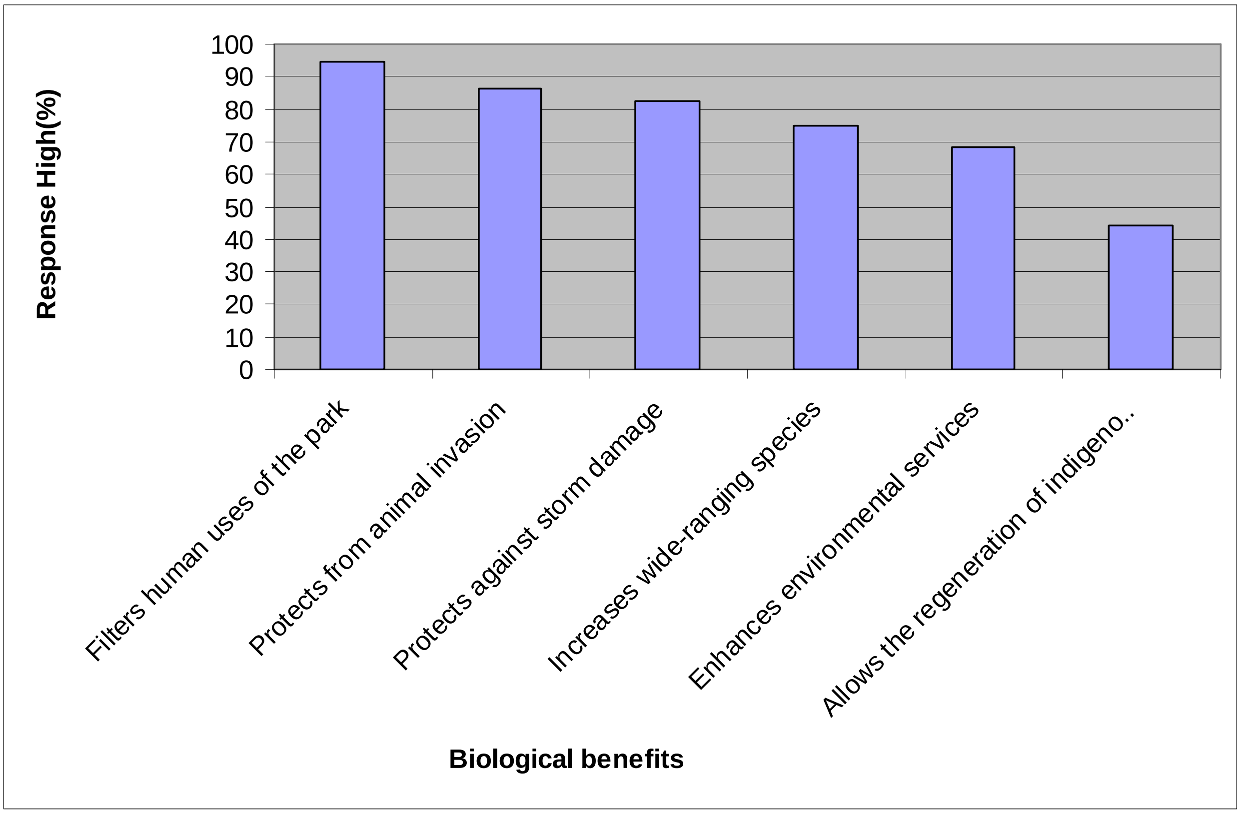


Fig. 29. Biological benefits of the buffer zone.

The responses on the role of the buffer zone in enhancement of environmental services like wind brake, shade and recreation showed a very significant difference in the two districts (one way ANOVA, P<0.01 DF: 1), people in Nyamagabe being more positive than in Nyaruguru district (Post hoc: Tukey type). The difference is also strong between the sectors. Gatare, Kitabi and Ruheru inhabitants do not feel the high value of these aspects, as shown in Fig. 30.

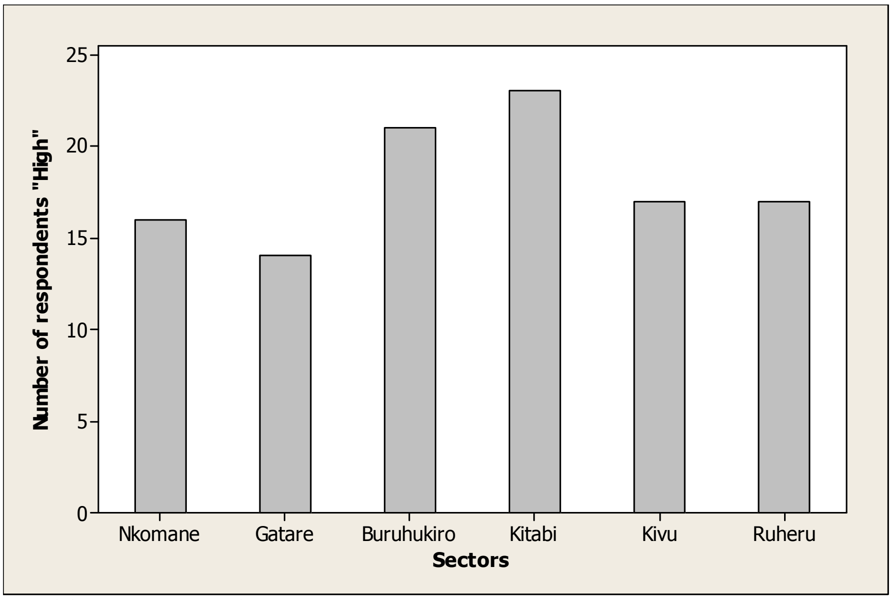


Fig. 30. Perception of sectors on enhancement of environment services.

The different categories of the respondents did not diverge about the environmental services. They all perceive in the same way the environmental values of the buffer zone.

Social benefits

The responses collected from the informants on social benefits are presented in Tab.11

Tab. 11. Social benefits from the buffer zone.

Social benefit	Responses No	Low	High
Resolves conflicts between the interest of conservation and use	5	15	86
Conciliate biodiversity conservation and benefits of local people	7	17	82
Improves the healthy environment to the local people	4	2	100
Allows the presence of diverse conservation programs	28	27	52
Safeguards traditional land rights and cultures of local people	14	40	54
Restores species and ecological processes in degraded areas	22	25	61
Increases visitors and custom flow for local products	33	30	44
Generates the income at national and regional scales	29	27	50
Raises awareness of biodiversity conservation	2	11	94
Raises awareness for contribution to buffer zone management	3	20	84

Fig. 31 shows the distribution of responses within the community. It illustrates how respondents agree that the buffer zone has a high social benefit to them.

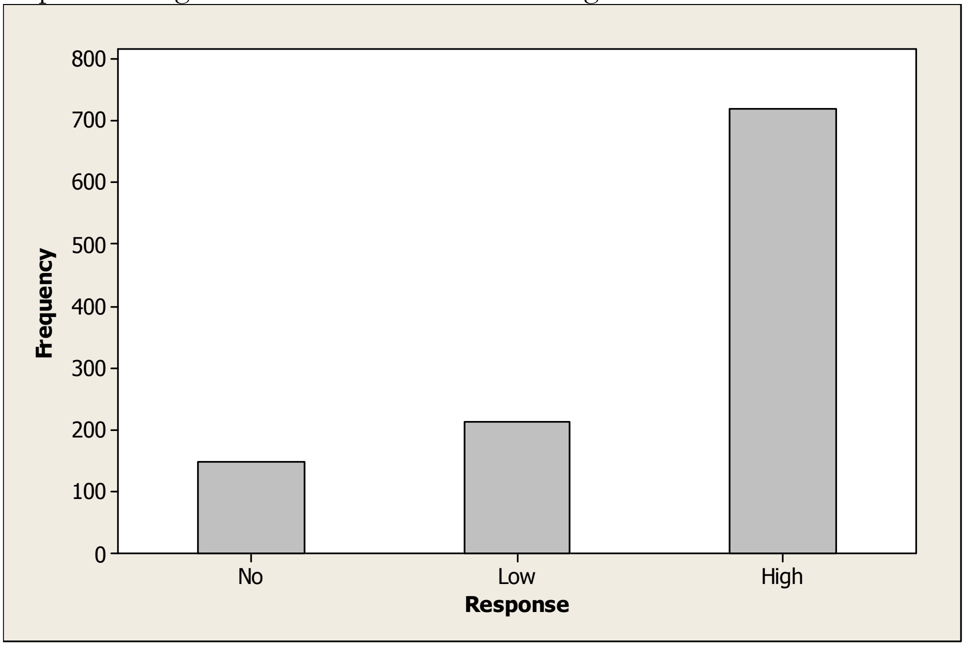


Fig. 31. Distribution of responses of social benefits.

People give unequal importance to the different social benefits (ANOVA one way, Kruskal-Wallis, P<0.001, DF: N: 1080). As is shown in Fig. 32, the five most important social benefits from the buffer zone according to the respondents are the following: improvement of earning potential; a healthy environment; raised awareness for biological diversity conservation; and contribution to buffer zone management. The buffer zone also resolves conflicts between the interests of conservation and those of the inhabitants of adjacent lands.

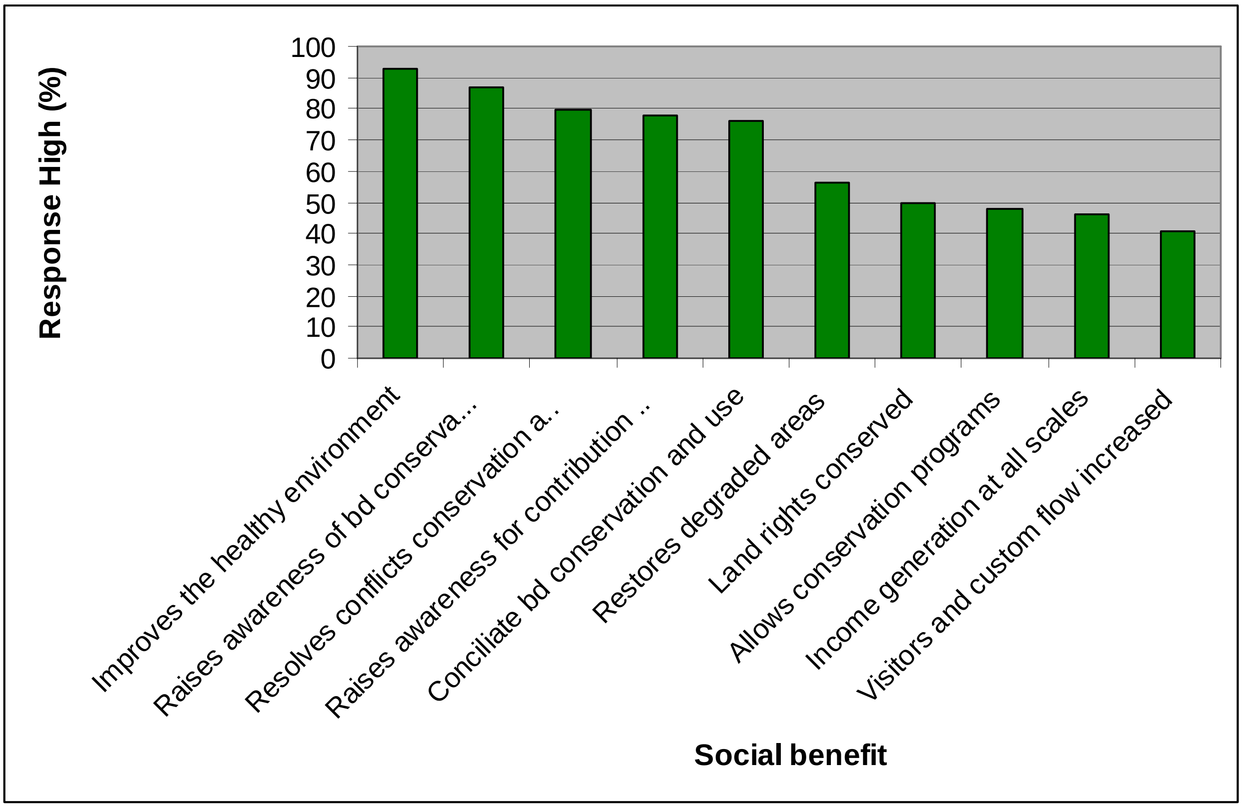


Fig. 32.Favourable responses on social benefits from the buffer zone.

There is a significant difference between districts in the answers on the presence of conservation programmes ($P<0.01$) and the presence of visitors and custom flow for local products ($P<0.05$, Tukey test). The factors which affect these patterns are particularly related to the views on the presence of visitors. There is a strong difference between the sectors of Nyaruguru and Nyamagabe districts ($P<0.05$). The two sectors of Nyaruguru district do not have visitors or customers for the local products as is the case in the sectors of Nyamagabe. For the views on the presence of local, regional and international conservation programmes, there is a very significant difference between the age groups ($P<0.01$, N: 107) with people older than 40 years having a positive view.

Use of non-timber forest products

The responses on the use of non-timber forest products according to the three categories of weighting are presented in Tab. 12.

Tab. 12. Use of non-timber forest products.

Non timber forest products	Responses No	Low	High
Medicinal plants	30	33	44
Honey	12	13	82
Seeds, seedlings and saplings	38	40	27
Food (fruits, mushrooms, spices)	63	23	20
Flowers, orchids, ornamental	45	36	26
Art craft material-ecotourism	37	26	44
Cords and canes	47	21	39
Mattresses, mats and cotton	61	40	6
Fire wood, faggot wood	16	39	52
Pods, poles, bamboos.	46	26	35
Saps, resins, dyes and Gums	90	13	5
Fodder	42	36	29
Mines	65	22	21
Wild meat, insects, …	60	16	31
Botanical specimens	46	30	30

As we can see in Fig.33, few respondents agreed that non-timber products are taken from the buffer zone.

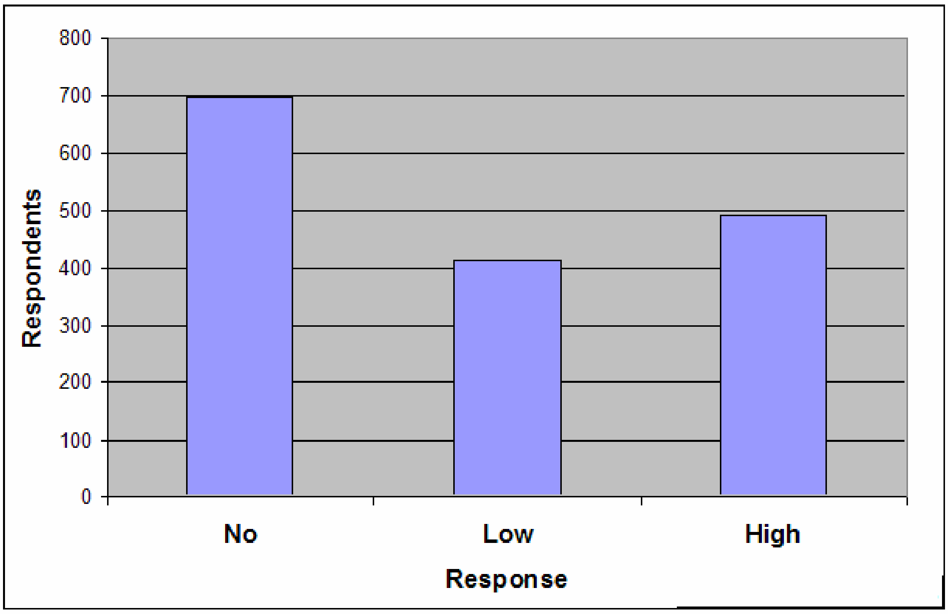


Fig. 33. Distribution of responses about the use of non-timber forest products. "High" means that the respondents consider the buffer zone important in this respect.

There is a significant difference between the perceptions of respondents about the use of non-timber forest products (one way ANOVA, Kruskal-Wallis, P<0.01 DF.14 N: 1617). Fig.34 shows that the most used non-timber forest products are honey, firewood, medicinal plants and art craft products.

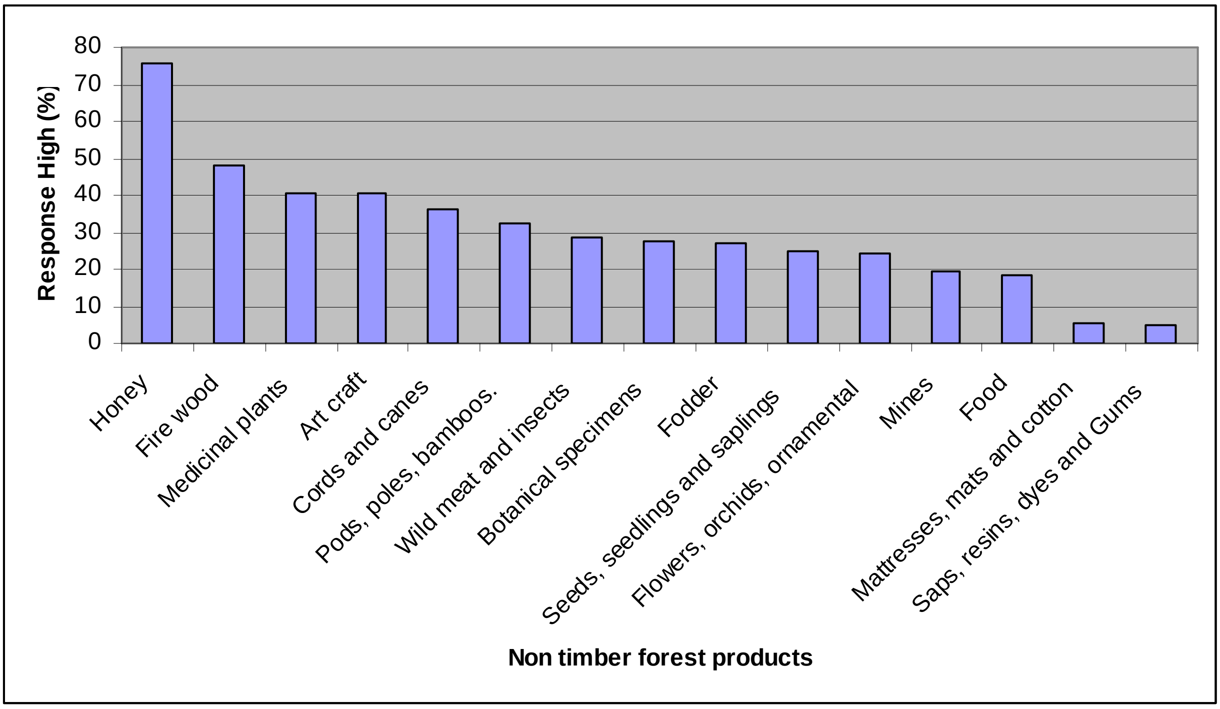


Fig. 34. Non-timber forest products used from the buffer zone.

The production of honey is clearly perceived by the local community as a useful product of the buffer zone. There is a significant difference between the perception of people in the Nyamagabe and Nyaruguru districts (ANOVA, $P<0.01$ DF: 1 N: 107). The patterns which affect this difference are the responses from farmers with different farm size. People who have small farms resort to honey production in order to compensate for the family incomes.

Fire wood is also well-known as a main need for local people. There is a difference between districts and sectors (one way ANOVA, $P<0.01$ N: 107) in people's views on the importance of the buffer zone for firewood collection. The Gatare and Kitabi inhabitants do not feel the same need or use as other sectors which have more needs of fire wood. Medicinal plants are found as being used unanimously in the area. The art craft is practiced in the area. There is a significant difference between districts and sectors ($P<0.01$ DF: 5 N: 107). The Kitabi district has more crafts than other sectors. This is due its position near the main road and several sawmills.

Drawbacks of the buffer zone

The main aim of the buffer zone was to prevent further forest clearance by better physical demarcation of the boundary of the reserve. Furthermore it provided many profits for the local communities. Nevertheless, the respondents mentioned some drawbacks of the buffer zone, although being minor. Table 13 summarizes how people reacted to the questions related to the drawbacks of the buffer zone, and Fig. 35shows how responses are distributed.

Tab. 13. Responses on the drawbacks of the buffer zone.

Drawbacks	Response No	Low	High
Insufficient jobs	17	31	60
Loss of land	13	31	64
More trees than tea	26	26	56
Hunting stopped	19	12	77
Unneeded trees	49	36	23
Insufficient wildlife & vegetation	51	28	29
Less income from NTFP	36	35	37
Trees not harvested	27	22	59
Competitiveness wildlife-livestock	47	19	42
Unused infrastructure	61	23	24
Crop-animal diseases	70	24	14
Farm size reduced	10	18	80

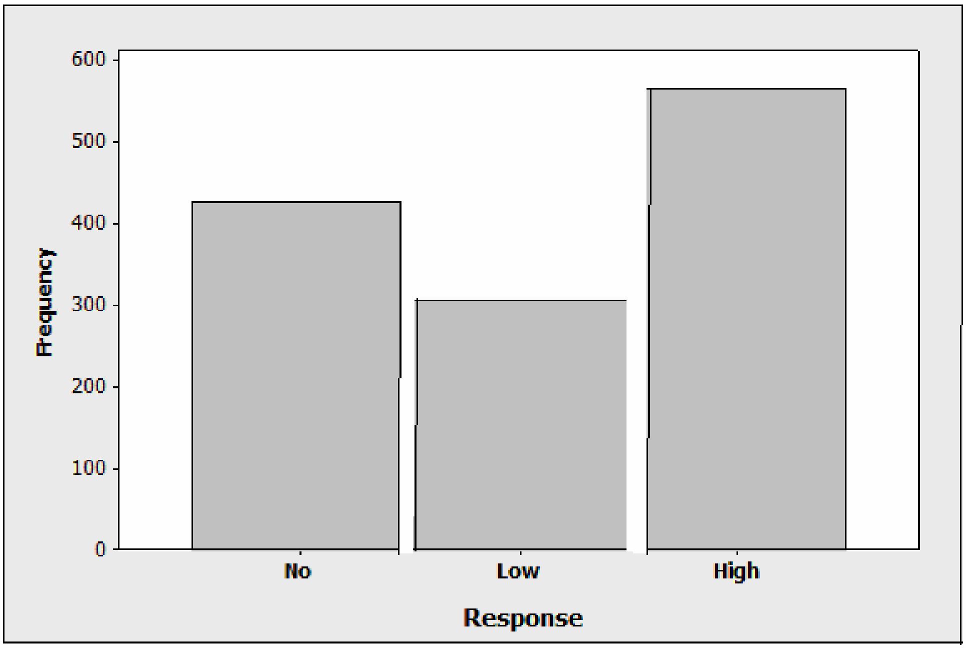


Fig. 35. Distribution of the responses on drawbacks of the buffer zone.

There is a significant difference in the responses between the different drawbacks (P<0.01 DF: 11 N: 1295). Kruskal Wallis and ANOVA one way rank the main drawbacks (Fig.36) in this order: reduction of farm size, stopping of hunting activities, loss of land for buffer zone plantation establishment and insufficient jobs.

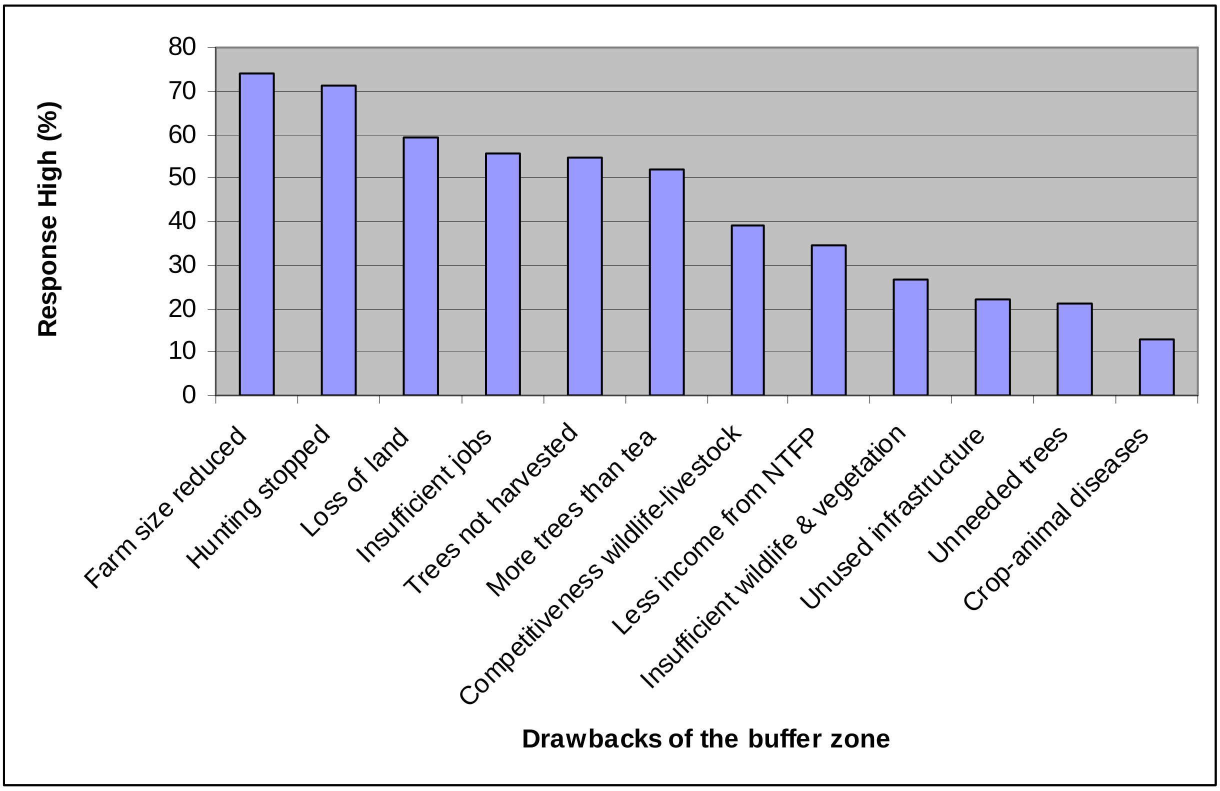


Fig. 36. Drawbacks of the buffer zone.

There is a significant difference in responses between farmers having different family size ($P<0.5$ DF: 2 N: 107). The families with a big number of children claim that the buffer zone has reduced the agricultural and grazing land.

There is also a significant difference between the different categories of family size on the views on the ban on hunting ($P<0.05$ DF: 2 N: 107). Also among the educational and occupation groups there was a significant difference in their views on the hunting ban. People with low education are still confirming that the end of hunting activities constitutes a drawback. The similar responses were given with people whose daily occupations are related to the forest or farm.

There is a significant difference between families of different size on the question on loss of land for buffer plantation establishment. The people with big families corroborate the disadvantage of the buffer zone more than small families.

The difference between administrators and farmers is also significant ($P<0.05$). People who work in administration do not feel a big need of agricultural land compared to those who work in farms or forests.
On the question on the job activities there is a significant difference between family sizes ($P<0.05$). The buffer zone does not provide enough opportunities for jobs, especially for those who have big families, and the need is highly perceived.

Importance of exotic species

The local people were asked to rank the four exotic species used during the establishment of the buffer zone. The responses are given in Table 14.

Table 14. Ranking of the importance of exotic species.

Species	Scale Most important	Very important	Important	Less important
Acacia	9	10	17	55
Cupressus	10	41	31	11
Eucalyptus	62	11	9	10
Pinus	11	32	36	13

There is a significant difference between the four species (one way ANOVA Kruskal-Wallis, P<0.01 DF:3 N:364). *Eucalyptus* is the most important and *Acacia* is the least important in terms of the use (Fig. 43).

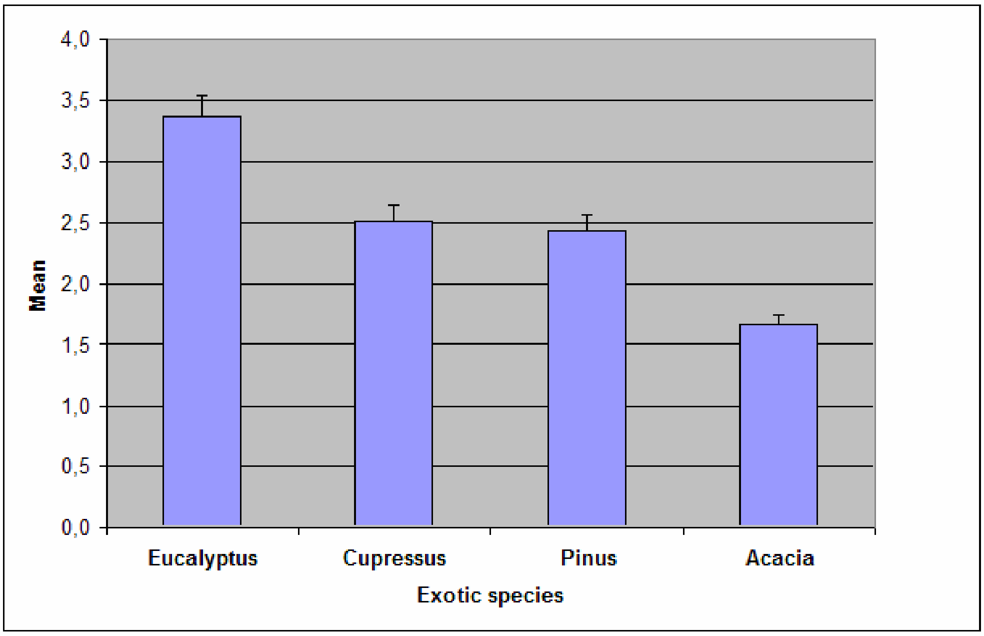


Fig. 37. Importance of exotic species. (Mean value of ranking see Tab. 14).

For the *Eucalyptus*, there was no significant difference statistically between the districts, sectors and other categories. This species is used everywhere and preferred before other exotic species, because it is a powerful multipurpose tree. Figs.38 and 39 show how it was exploited during the collection data period

Figs. 38 and 39. Sawing and drying eucalypt timbers for sale.

The attitude towards *Cupressus* depends significantly on the gender. Males find it more valuable than females. This is due to the fact that females do not use it so much as fuel wood, whilst males use it for timber, especially in Buruhukiro district where it is very abundant.

There is a significant difference between the views on the importance of *Pinus* between the two districts (P<0.05 DF: 1 N: 107). In Nyaruguru district people do not consider *Pinus* as valuable as in Nyaruguru. This is due to the fact that in Nyamagabe, more timber and charcoal from *Pinus* are on sale (Figs. 40 and 41), but of course, not at the same price as *Eucalyptus*.

Fig. 40 and 41. Sun and fire drying of Pinus timbers for sale.

Nyaruguru district has mostly young plantations of *Pinus* in the south (Ruheru sector). The value of *Acacia* varies between people with different activities. People who work in the forest or plantations prefer *Acacia* more than those who work in the administration. It is useful for charcoal making.

Management of the Buffer zone

From meetings at Nyamagabe and Rusizi districts, from Kigali and from other interviews and informal questions, we drew the figure below (Fig.42) showing that the general view on the management of the buffer zone is that the owners should be involved in the first place.

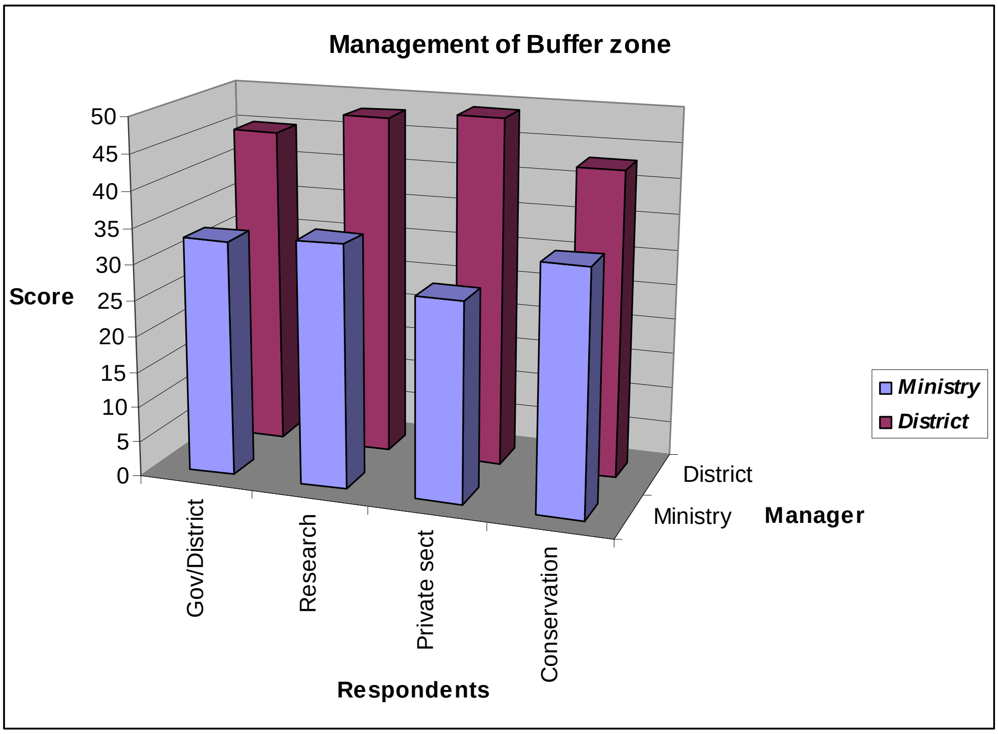


Fig. 42. Responses on how the management of the Nyungwe buffer zone should be organised.

Discussions

Indigenous species regeneration

Number of individuals

Regeneration by woody species is vitally important for forest persistence (Lawes *et al.* 2005). Plantations may foster the regeneration of native species under their canopy and provide a habitat for various wildlife (Keenan *et al.* 1997). The findings in this study revealed that the number of regenerating indigenous species with diameters between 0.4 cm and 10 cm represented 80% of the number of standing trees in exotic plantations, corresponding to 3 800-4 800 individuals/ha. The forest itself occupied 40% of the total regeneration and four upper storey exotic species represented 60%. The highest number of individuals was found under *Cupressus lusitanica* where there were more than 4 700 seedlings/ha, representing 34% of the total regeneration in the plantation.

One reason of having denser populations under *Cupressus* could be the openness of the canopy. The canopies of exotic trees can exert protective functions and have a nurse effect for the regeneration of natural forest (Feyera *et al.* 2002). This may mainly be depending on light intensity. The factors like quality and quantity of light penetrating through the canopy, microclimatic conditions, composition of the seed bank in the soil, and availability of recent seed sources in the vicinity of the plantation are also important (Feyera *et al.* 2002) for regeneration. Light in the understorey is an important factor in regeneration (Geldenhuys 1997).

In Nyungwe Natural forest, Rizinjirabake (2002) found a higher density and abundance of indigenous species in forest gaps (32 500 individuals/ha) than in the understorey forest (2 400 individuals /ha). The average density in Kwazulu-Natal ranged from 20 000 to 196 000 seedlings /ha at the edge and from 22 000 to 139 000 seedlings /ha in the interior of forest (Lawes *et al.* 2005). Species regeneration can be influenced by the slope, topography, ground cover and litter; the thickness of the litter in the forest is positively correlated with the density and abundance of species (Rizinjirabake 2002), but for *Pinus* plantations the influence of litter was negative (no individual in P2 with the diameter class D2).

Acacia plantations did not show any particular effect for the regeneration. Other authors found that *Eucalyptus* did not appear to have the suspected allelopathic effects towards many native species because it did not significantly reduce species diversity in the understorey; some plantation stands reached a density of regenerating woody plants above 18 000 plants/ha (Feyera *et al.* 2002, Da Silva *et al.* 1995). In Sudan, El-Amin *et al.* (2001) compared effects of *Eucalyptus microtheca* plantation with cultivated and fallow areas on soil properties, and concluded that no nutrient depletion was detected under *Eucalyptus* plantation compared to the other two land use practices.

However, Calder et al. (1997) showed that the water used by *Eucalyptus camaldulensis* exceeded the input supply of water rainfall and highlighted considerable concern regarding the long term sustainability of such plantation and the water resource implication of such a high water use in relation to the rainfall. In Rwanda, especially where the rainfall is not high, *Eucalyptus* deplete the quality of the soil and therefore we think its regeneration was low.

Among the regenerating individuals in plantations only 20% were found under *Pinus patula*. This result differs from Feyera *et al.* (2002) who found that regeneration of native woody species is a little better under *Pinus patula* than under *Cupressus lusitanica*.

The pair wise comparison of the Shannon-Wiener index showed that there is a significant difference between forest and all exotic species stands ($P<0.005$), except *Pinus* which did not differ from any other stands. *Acacia* did not statistically differ with *Cupressus* but differed with *Eucalyptus* stands. The former differed significantly with *Cupressus*. Then it can be noted that *Cupressus* and *Acacia* did not differ. These had both a high Shannon index, whereas *Eucalyptus* and *Pinus*, which also did not differ, had a low index.

Species richness

The number of 46 species for the surveyed area (0.613 ha) may be approximated to 75 species/ha, as the species curve was still increasing (Fig.16). Nyungwe has more than 260 species of trees and shrubs (Dowsett, 1990). For sure more than 10% of the tree and shrub species found in Nyungwe were found regenerating in the exotic plantations. These results are similar with those found in Ethiopia, where Feyera (1998) found 55 species in plantation stands. The number of individuals in the lower class (0.4-10 cm) represented 94 % of all indigenous species identified. This is similar to the findings of Gakwavu (2004) in Nyungwe Forest who found that 94-97% of the individuals of sawmill target species were in the diameter class 0-10 cm.

The findings are less than the diversity of 300 tree species/ha, considered to be a characteristic of rainforest vegetation, but more than the temperate woodland which holds only 10-15 species/ha (Royal Botanic garden Kew, 2003). Lawes *et al.* (2005) found an average of 21 species per 0.075 ha in South Africa. The mentioned cases are all from natural forests. In Tab.15 the regeneration of native species under the canopy of exotic plantations in different countries is compared.

Tab. 15. Comparison of the number of regenerating woody species under the canopy of exotic forest plantations in different counties.

Geographic area	Plantation trees	Origin	Regenerated woody species	Reference
Rwanda, Nyungwe National Park Buffer zone	*Cupressus lusitanica*	Exotic	15 (D1)-29	Original data
	Acacia melanoxylon	Exotic	16 (D1) - 22	
	Eucalyptus maidenii	Exotic	12 (D1)-15	
	Pinus patula	Exotic	9 (D1)-15	
Ethiopia, eastern escarpment of Great Rift Valley	*Eucalyptus saligna*	Exotic	27	Feyera *et al*. (2002)
	Eucalyptus globulus	Exotic	19	
	Pinus patula	Exotic	18	
	Cupressus lusitanica	Exotic	16	
South Africa, Northern Province	*Pinus patula*	Exotic	170	Geldenhuys (1997)
	Pinus elliotti	Exotic		
	Pinus taeda	Exotic		
	Eucalyptus saligna	Exotic		
Puerto Rico, northern coast	*Albizzia lebbek*	Exotic	22	Parrotta (1993
Puerto Rico, northern coast	*Casuarina equisetifolia*	Exotic	19	Parrotta (1995)
	Eucalyptus robusta	Exotic		
	Leucaena leucocephala	Exotic		
Brazil, Minas Gerais State	*Eucalyptus grandis*	Exotic	123	Da Silva *et al*. (1995)
Australia, North Queensland	*Pinus caribaea*	Exotic	176	Keenan *et al*. (1997)
	Araucaria cunninghamii	Native		
	Flindersia brayleyana	Native		
	Toona ciliate	Native		

Source: Feyera *et al*. 2002 (added).

As seen in Tab. 15, our findings are similar to those found in Ethiopia, but differ from other countries, which can be due various local conditions.

Most regenerating indigenous species

Macaranga neomildbraediana is the most regenerating in the plantations and *Galiniera coffeoides* is the most common in the forest, followed again by *Macaranga*. Five species have been found in both forest and under all exotic species: *Dichapetalum heudelotii*, *Galiniera caffeoides*, *Macaranga neomildbraediana*, *Maesa lanceolata* and *Xymalos monospora*. Three species have been found in the natural forest and in fewer than three of the four plantation species: *Canthium oligocarpum Rapanea melaphloeos, Syzygium guineense*.

The most represented families, with more than two species are Euphorbiaceae (5), Myrsinaceae (3) and Meliaceae (3). According to Rizinjirabake (2002), *Macaranga* can have more than 1 000 individuals /ha in Nyungwe NP and the presence of its seedlings is depending on closeness of mother tree seed. Further study for the regeneration process and use of those regenerating species in the buffer zone is needed.

Contribution to biodiversity conservation

As was said above, exotic plantations in the buffer zone contribute to the conservation of at least 10% of the indigenous species. This is partly associated to animals in the buffer zone like monkeys, baboons, birds, etc. This is one of the factors in the regeneration process. Many species that would be expected to regenerate in the exotic plantations do not, perhaps due to lack of seed-producing mother trees, heavy undergrowth and thick litter (Shangali and Mali 1998). Seeds of some rainforest plants are dispersed by wind, i.e. those which are light or have wings or a parachute of hairs; animal dispersed seeds are often produced in brightly coloured fleshy fruits (Royal Botanic garden Kew, Rainforest 2003). In Australia 35–45% of the species from adjacent rain forest were found in plantations (Keenan *et al.* 1997).

Performance of exotic species

From the diameter, height and number of individuals it can be seen that *Pinus* performed best among the exotic species. *Eucalyptus* plantations were denser than other exotic plantations and the maximum was found in E4. The regeneration of the exotic species was nearly absent in all sites. Parrotta (1993) found a much higher seedling mortality of the plantation trees themselves under the canopy (47% in a 1.3 year period) than that of secondary forest species (23–26%), underlining the role of the plantation as a "foster ecosystem" for successional development of secondary forest.

The site tended to exert an influence on the performance of trees, even if the difference was not statistically different. For *Acacia*, higher diameter and height were found in stand A3, but more individuals dominated A2. *Cupressus* instead had tall trees in C1 and big trees in C6, whereas C2 was denser than the others. *Eucalyptus* had high diameter and height in E2, but a big number of trees are located in E4. *Pinus* had a high number of trees and height in P5, but P1 had a high diameter. Such differences therefore depend not only on the planted species but also on the history of the site, the forest management practices employed, such as planting density and coppicing (Feyera *et al.* 2002). In turn, this has an obvious impact on the regeneration of the indigenous species.

Why buffer zone for NNP?

The high biological diversity and endemism of the plants and animals of Africa's Montane forests mean that this habitat is globally important for conservation (Plumptre et al. 2004). Nyungwe is one of the most biologically important key areas for Montane rainforest conservation in central Africa (Nsengiyumva 2001). Despite being the most important natural forest in Rwanda because of its area and biodiversity it has been under human degradation for long time.

The buffer zone was created with a threefold objective: to set up a clear demarcation of the limits of the park, to provide woody products for timber and energy and to create job amongst rural communities (Plumptre *et al.* 2003). The fast growing exotic species, *Pinus*, *Cupressus*, *Eucalyptus*, *Acacia* used for its establishment (Musabe 2002) have been moreover planted in many countries like Ethiopia (Feyera 1998) and Vietnam (Hoang 1998).

These species have been managed by projects with various funds and the local population was involved in its establishment and got salaries. When the projects ended, they did not get any salary, they claimed now to exploit the mature exotic trees that they planted in the buffer zone (Gapusi 1998) of which the management belongs to the government.
In Ethiopia there was observed a growing concern regarding the disadvantages of such ventures and reluctance or even resistance of local people to the introduction and establishment of exotic species (Feyera 1998). Similar feelings were found in the local population in the beginning, because the buffer zone was to some extend established in local people's land which should be compensated. They later claimed the right to use it. Potentially, in addition to production of wood as an economic resource, exotic tree plantations may also have advantages, such as improving microclimatic conditions, protecting degraded lands against soil erosion, stabilizing soil development, thereby enhancing soil nutrient status and increasing soil organic matter through enhancement of litter and humus production and supporting water catchment values (Keenan *et al.* 1997).

Fuelwood plantation in the degraded lands around villages through people's participation, introduction of alternate fuel devices and employment opportunities have been suggested to minimize the dependence of local people on biomass resources and ensure the biodiversity conservation (Chandra 2001). The buffer zone is a cradle, the protection belt of the National Park. Positive and negative impacts all stem from the buffer zone (Hoang 1998).

Background of informants

Informants were mostly from Nyamagabe district (69%) and Kitabi sector (21%). The majority was men (86%) and married (92%). The age class between 46 and 60 years old dominated (43%). The family size of 4-6 represents 35% while the farm size is less or equal to 0.5 ha (40%) and major part of local population's activities are related to the forest and agriculture (77%). The land remains a big problem in the country. Musabe (2002) found that the majority (65.6%) of farms were less than 1.5

ha. Ndayambaje (2002) stated that 85.5% of the respondents around Nyungwe were married, the family had 5-7 members and the land for more than one third of the household was less than 0.5ha.

The people around protected areas in the Albertine Rift were described by Plumptre *et al.* (2004) as being some of the poorest in Africa making a living from very small parcels of land and being more dependent on the protected area for their subsistence.

The answers from the varied range of people could be affected by the social class the respondent belongs to. Some answers could be guesses when the informant did not properly understand the question or he could wish to satisfy the questioner, whom he assumes is representing either the government or park conservation managers, despite the careful introduction done before the survey. They could then hide the truth about illegal activities, as stated by Plumptre *et al.* (2004), like hunting and collection of bush-meat; people did not want to admit that it happened.

Providing various benefits to the local people

Our results highlighted various benefits that the local community could get from the buffer zone. Conservation of protected areas is not a private commodity traded on the open market, but a public benefit (Royal Botanical garden Kew 2003). According to McKinnon *et al.* (1986), benefits from the buffer zone can be categorized as biological, social and economic. The community living along the eastern part of NNP confirmed that they get, not fully but some of these benefits. In general biological benefits were highly appreciated by 75% of the local community; social benefits by 65% and economic by 34%. This indicates *a priori* that the local community gets only an insignificant income from the buffer zone.

Providing a filter and barrier to the use of the park by humans and animals

The clear limit of the core zone contributed to reduce the entries for encroachment, both from humans and from animals. People responded by 94% that the buffer zone is a big road block for the illegal uses. Cattle grazing have been seen in some areas, but especially in the plantations of the buffer zone. Monkeys of the genus *Cercopithecus* and baboons are said to be abundant in the buffer zone, instead of going outside for raiding the crops. In Uwinkingi sector, where the buffer zone has converted to agricultural land, we could easily observe more baboons raiding crops (wheat). The buffer zone is then the appropriate area for the wide-ranging species, when they extradite from the park. Sekamanwa Assina Paul, 57 years old said 'pers. comm.' that people who cross illegally the area to encroach the park are liable to a fine of 10 000 RWF (about 20 USD). The buffer zone is playing a big role in protecting the core zone.

People did not appreciate highly the existence of regeneration of indigenous species; only 44% agreed that there is more regeneration in the buffer zone, and some species, mainly *Syzygium guineense*, *Hagenia abyssinica*, *Maesa lanceola* and *Polyscias fulva* were many times evoked during the survey as species they find in plantations.

Enhancement of environmental services

Our results from farmers' point of view showed that 99% of the people recognise the environmental benefits like wind brake, shade and recreation provided thanks to the buffer zone. Musabe (2002) stated that 78% of respondents in Cyangugu province (today western province) found that the rainfall was improved by the presence of the forest. Similarly, Newmark *et al.* (1991) reported that the protection of Kilimanjaro Forest was supported by 55.1% of the local people because it influenced rainfall and protected the watersheds.

Raising awareness for biological conservation and contribution to buffer zone management.

The wildlife and vegetation were valued. People used to think that a tree is to be cut and an animal to be killed, but with the establishment of the buffer zone a person found that there are ethical and inner values of the biological resources in the forest and respect them. The old aged people who used to go into the park, were recruited for planting trees and got a salary, and from this period they live in peace with the buffer zone. Unfortunately, with the phasing out of the projects during the Genocide period (1994), people started to encroach the park; this was due to the lack of new financing projects and as we saw above for agricultural land. The local community are still depending on the forest for their livelihood and are highly aware of their recreation and ethical values (Masozera 2002, Royal Botanical garden Kew 2003). The Nyungwe conservation Project (PCFN) is doing some activities using the farmers as labourers and has a sensitisation programme for educating the surrounding community. The Rwandan Tourism and national park office (ORTPN) is organising a kind of revenue sharing in the area for raising awareness of local population about the conservation of the biodiversity. Establishing buffer zones to better preserve the conservation area is by all means an economic activity whereby productive resources are put to use with the aim of creating the value to the society (Royal Botanical garden Kew 2003).

Create job opportunities

Results from the survey showed that people agreed by 59.3% that they got jobs from the buffer zone, and 55.6% felt that one of the drawbacks of the park was the insufficient jobs due to the ending of Management Units Projects (UGZ) for differenet areas. Plumptre *et al.* (2004) showed that people work as park or forest rangers/guards, tourist guides, trail cutters, and in administration. The presence of local, regional and international conservation programmes was appreciated highly by the people older than 40 years. This reflects how local population got jobs in the past years, when they got employed for nurseries, planting, thereafter thinning and coppicing the plantation. Today jobs are provided by ORTPN, PCFN, and PAFOR (Projet d'Aménagement Forestier au Rwanda) and they are not sufficient to satisfy the local needs. The "Office Rwandais des Cultures Industrielles au Rwanda", Rwandan Industrial Crops Office (OCIR-Thé) is creating more opportunities in the area for tea plantation and harvesting. Tea might be an alternative crop (Masozera 2002) and provides a source of income to the people of the districts (Plumptre *et al.*

2004). Our results showed that the two sectors Kitabi and Buruhukiro benefited from jobs and non-timber products more than the sectors of Nyaruguru District.

Supplies of non-timber products

A restriction on access to protected area resources remains the main source of conflict between communities and protected area managers (Plumptre *et al.* 2004). Our results showed that 30.3% of respondents feel that they get non-timber forest products in the buffer zone. The only non-timber forest product considered important by the local population from the buffer zone is honey (76% of respondents). Other products are still lacking, and the way local population can use it in a sustainable way requests a further study.

Traditional methods of collecting honey from wild beehives within the forest including the building of smudge fires was used to repeel bees, but it has been one of the reasons why 128 km^2 have been burned in Nyungwe (Forrest 2004). Behm (2004) stated that the dry season, that span from June through September, corresponds with the pick honey season in the forest.

Honey is a very useful and popular product that the beekeepers developed in the buffer zone and gave success. The results showed that landless people resort to honey production in order to get income and compensate for the food selfsufficiency. According to information from Umugwaneza Clarisse, in charge of social welfare in Nyaruguru district, at least 1 000 individuals are involved in honey production. The example given was the AND-Nyaruguru, a beekeeping farmers' association with 800 members. Fig. 48 shows the establishment of traditional and modern bee-hives by farmers' associations in Buruhukiro and Kitabi sectors.

Figs. 48. Traditional (a) and modern (b) bee-hives in Buruhukiro and Kitabi sector, the latter found in the house.

These results are similar to those found by Plumptre et al. (2004) in Nyungwe forest, where 60.43% sell their own honey and 27.15% are in beekeeping associations.

Fire-wood is being collected by 48% of the respondents. These results could be underestimations considerng the fact that it is done illegally. The results are similar to Musabe (2002) who found that Kitabi and Mudasomwa (today sectors), were the only districts provided by firewood thanks to the presence of the buffer zone. Plumptre *et al.* (2004) found that 51.3% of households admitted to collect firewood in the forest and the bundle was sold at the equivalent of 0.33 USD.

Medicinal plants are collected by 41% of the respondents, which is notably few, because few people now know how to collect and use them. Many medicinal plants are found in the interior of the forest, and few can be found in the buffer zone. The ten plants highly cited by informants as being medicinal were known by a few people: *Syzygium guineense* (5,6%), *Carapa grandiflora* (5.2%), *Myrica salicifolia* (4%), *Maesa lanceolata* and *Magnistipila butayei* (3.6%), *Canthium oligocarpum* and *Dichrostachys cinerea (Umunkamba)* (3.2%) and *Bersama abyssinica* and *Iboza riparia* (3.2%).

Art craft raw material was admitted to be harvested by 41%. This is realistic because in Nyaruguru crafts done from bamboos, even chairs, are sold in the market. We found some farmer organizations for doing these activities. The results support the findings of Plumptre *et al.* (2004) who stated that baskets (31.58 %) and crafts (15.79%) were made from bamboos.

Only 19% of the respondents said that they got food from the forest, rarely from the buffer zone. The only plant people use to eat is the fruits of *Myrianthus arboreus*, but there are many edible plants in the forest, even if not so many respondents knew them. During our survey we could see many *Dioscorea*, *Rumex*, *Rubus*, *Amaranthus* etc. which are edible according to Nyakabwa & Gapusi (1990).

Drawbacks of the buffer zone

The results from the interviews with local people showed that the buffer zone has pros and cons. The major disadvantage was considered to be the loss of land which caused the reduction of farm size, and still is. A total of 95% of responses agreed that this was a main drawback. People who lost their land have been compensated, but in some areas it was being done only after 20 years. People with big families were more claiming this. Land remains a big problem in the area, and as claimed by Plumptre *et al.* (2004), as population increases, land and other essential resources become scarce, causing the dependence of the people on the park resources to increase, and because the soil was previously protected by forest, it becomes poor and fragile over time. The problem of soil-infertility, combined with the lack of available new land to farm, is leading to smaller and smaller farm sizes (Weber 1989).

Another drawback was the ban on hunting, which is agreed as normal for all wildlife conservationists, but Plumptre *et al.* (2004) found that quite a large percentage of households admitted that it did take place. Needs of animal proteins was related to the size of the family; a kind of substitute for the ban of hunting needs to be considered.

Management of the buffer zone

Who will better manage the buffer zone?
The current situation shows that erosion increases food insecurity as the number of people, together with their needs, continues to grow; as poverty increases in the region, the only choice local populations have is to over-exploit the available natural resources in the protected areas (Plumptre *et al.* 2004).

There is a need to work with local administrative authorities to decide how these buffer zones should continue to be managed (Plumptre *et al.* 2004). This question needs a special and urgent attention. People around the park and the buffer zone are claiming that the trees are harvested and sold by foreigners. When people were asked who should manage the buffer zone it was mostly suggested that the community or local authorities should do so. Rather many also suggested the park authority (ORTPN) with Central Government. The local community, with the ongoing decentralization process might be fully involved in the management of the buffer zone. ORTPN started by using the park guards from the neighbouring sectors, but it does not have enough power for decisions on the buffer zone.

A simple suggestion is that the manager of the park or the neighbouring districts (through sectors) could best manage the buffer zone. Masozera (2002) showed that households that felt they benefited from the buffer zones also tended to have a more positive attitude towards the conservation of the forest.

Conclusions

The current study undertook a vegetation inventory in the eastern part of Nyungwe and related the existing buffer zone with the local people's perceptions. Contrarily to what many people assume, that exotic species are harmful to the native species, the study showed that there is enough regeneration of indigenous species under the canopy of exotic species.

The total regeneration was evaluated to roughly 10% of the natural forest species; this constitutes a huge contribution to the conservation of biological diversity. Forest is a habitat of wildlife; many animal species of Nyungwe National park, including the wide-range species are believed to be found in the buffer zone and could be the main dispersal factors for the regeneration.

The regeneration varied according to the nurse tree species. Shannon-Wiener index and basal area showed that there is more regeneration in the natural forest, and *Cupressus lusitanica* was favoured for indigenous species regeneration compared to other exotic species. The results did not take into account other patterns which lead to vegetation of degraded areas. The factors like presence of seed from mother trees, seed bank and the history of each stand could be examined as well.

People showed that they prefer *Eucalyptus maidenii* for the use rather than other exotic species for its high quality in construction, timber and charcoal making, especially its potential to re-sprout after cutting. However, ecological issues were not taken into account in their choice. This aspect must be considered, being important for soil quality and water consumption.

Our study showed that the buffer zone plays an important role in regulation of environmental conditions. Since it has been created, this physical and living barrier reduced the human and animal intrusion into the park and protected the core zone against other damages. The consideration will be that the illegal access to the park will be fully terminated when people around the park will be satisfied in terms of food security. These people are poor, depending on agriculture and having very small farms. This situation has been characterised by lack of alternatives and was leading neighbouring people to resort to the biological resource of the park.

The findings highlighted the interaction between population and the buffer zone. The awareness of local population about the importance of conservation of biodiversity is raised and the value of wildlife and vegetation seems to be increased. During this study we found that few non-timber forest products are provided to the surrounding community. This is one of the major objectives of buffer zone conception. More extension of the way to supply forest products to the local population is needed. Beekeeping is highly appreciated but traditional knowledge is disappearing, particularly in the young generation.

Recommendations

The current study tried to put a baseline situation of the buffer zone. Further studies should be concentrated on the process of regeneration, dispersal and factors which lead to expansion of indigenous trees in the buffer zone and outside plantations. A socio-economic study on the cost benefit from the buffer zone is suggested.

Sustainable management of the buffer zones around all National Parks is needed and a choice of appropriated trees is the precondition. Buffer zone could be part of the parks and managed in the integrated vision of the park (ORTPN). Local people, districts bordering the park should be involved in decision making about the buffer zone (Districts). Since medicinal plants are less known, a capacity building and domestication could be promoted in the areas surrounding the parks. The agroforestry in the bordering villages of the parks is tremendously needed.

The progress of farmers' associations should be lifted up in beekeeping and medicinal plant collection activities. Livestock is needed in the areas, in order to supply animal proteins.

Nyungwe is the source of the Nile River, the biggest montane forest in Africa and rich in biodiversity. Being a trans-boundary park, the lobby to UNESCO for enlisting it as a World heritage could raise its conservation values and facilitate the people surrounding the park to get funds and do other economic activities which can generating income rather than being dependent on agriculture or forest products.

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Appendix 1. Data collection form

		No	**Sector/Cell**		
Site	**Name**	**Number**	**Topography**		
Stand	**Code**	**Longitude**		**Altitude**	***Top***
	Age	**Latitude**		**Slope (%)**	***Middle***
	Ccr (%)	**Gcr (%)**		**Aspect**	***Down***
	Disturbance rate (%)	**Causes**			

Number	**Diameter** (cm)	**Height** (m)	**Species**		**Observation**
			Vernacular name	**Scientific name**	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					

Appendix 2. Questionnaire for Survey

Number:

I. Identification of the interviewees/respondents

District: Nyaruguru ☐ Nyamaga ☐

***Sector s: A** Nkomane/ Kivu* ***B** Gatare/Muganza* ***C** Buruhukir/Nyabimat* ***D** mwinking/Ruheru* ***E** Kitabi*
Cell: *a: .... b: ………….. c: ………… d: ………….. e: ……….*
Names : ________________________ **Code**: ______

Marital status: Married ☐ Single ☐ Widow ☐ Divorced ☐ Temporally separated ☐
Year of birth: ______
Sex: Male ☐ Female ☐
Number of children: ________

Education: None ☐ Primary ☐ Secondary ☐ University ☐
Job/activities: Agriculture ☐ Government ☐ NGO's ☐ Business ☐ ☐
Farm size (ha): ………..

Response codes for sections II to V

2	1	0
Yes, High/remarkable	**Yes, Small/little**	**No/no idea**

II. Role of buffer zone

Question: What do you think is the main role of the buffer zone?

2.1 Economic benefit

2.1.1 Create job opportunities and thus increased income of local people in area
2.1.2. Compensate people who lost access to the strictly protected zone
2.1.3 Increased benefits from timber, charcoal, and other non timber forest products
2.1.4 Alternative area for hunting provided
2.1.5 Provision of seedlings and samplings
2.1.6 Compensation to people for loss of access to their land
2.1.7 Increased value of wild life and vegetation
2.1.8 Increased benefit from newly introduced crops or technologies
2.1.9 Income generation from transit movements to and from park
(Roadside stalls, resting places, food & drink establishments, hotels etc).
2.1.10 New & improved infrastructure (*roads, camping houses,..*)
2.1.11 New area for animal grazing
2.1.12 New & improved market opportunities

2.1.13 Improved access to public services

2.2 Biological benefits

2.2.1 Providing filter/barrier against human access or undesirable use of the core zone
2.2.2 Protecting the conservation area from invasion by animal species
2.2.3 Providing extra protection against storm damage, drought, erosion and others
2.2.4 Enhancing environmental services provided by the reserve (Wind brake, shade, recreation,...)
2.2.5 Increasing the population of large, wide-ranging species in the protected areas *(Cercopithecus, Chimpanzees, Baboons ..)*
2.2.6 Allows the regeneration of indigenous species

2.3 Social benefits

2.3.1 Resolving conflicts between the interests of conservation and those of the inhabitants of adjacent lands
2.3.2 Conciliate conservation of the biodiversity and benefits of local people
2.3.3 Improving the earning potential of healthy environment to the local people
2.3.4a. Presence of local, regional and international conservation program
2.3.4b. Safeguarding traditional land rights and cultures of local people
2.3.5 Restoring species, populations and ecological processes in degraded areas
2.3.6 Increased visitors and customs flow, for local products
2.3.7 Income generation at national and regional scales
2.3.8 Raising awareness of biodiversity conservation
2.3.9 Raising awareness and willingness to contribute to buffer zone establishment and management
General comments:

III. General use of non timber forest products from the buffer zone

Question: Which non timber forest products did you take from the buffer zone?

3.1 Medicinal plants
3.2 Honey
3.3 Seeds, grafts, seedlings, saplings…
3.5 Food (*edible fruits, vegetables, mushrooms, spices*)
3.4 Flowers, orchids, ornamental trees
3.6 Art craft raw material, products and ecotourism
3.7 Cords and canes
3.8 Mattresses, mats and cotton
3.9 Fire wood, faggot wood
3.10 Pods, poles, bamboos,lianes,…
3.11 Saps, oils, resins, dyes and Gums
3.12 Fodder
3.13 Mines: gold, coltan and cassiterites
3.14 Wild meat, insects, worm, termites...

3.15 Botanical specimens
General comments

IV. Drawback of buffer zone

Question: What do you think is the major drawback of buffer zone?

4.1 Insufficient job after projects phase out in area
4.2 Loss of land for buffer plantation establishment
4.3 More space taken by trees in stead of tea plantation
4.4 Hunting activity stopped
4.5 Plantation of no needed trees
4.6 Insufficient wildlife and vegetation
4.7 Less income from non timber products
4.8 Old trees not harvested by local population
4.9 Grazing competitiveness of wildlife with livestock
4.10 Establishment of unused infrastructure
4.11 Crops and domestic animals affected by diseases, pests, or other damages
4.12 Reduction of farm size *(agricultural/grazing land*)

V. Indigenous species regeneration

Which indigenous species are more regenerating in the buffer zone? (1-6)

VI. Identification of medicinal plants most used

Which medicinal plants are the most used? 1-6)

VII. Importance of exotic species

Rank the following introduced species from 4 (most important) to 1 (less important)
Acacia ☐ Cupressus ☐ Eucalyptu☐ ☐us

Comments

VIII. What is the general comment on the importance of the buffer zone and the regeneration of indigenous tree species?

IX. Who can better manage the buffer zone? District ☐ Ministry ☐

Appendix 3. Site characteristics

Site Number	Code	Topography	Age	Longitude	Latitude	Altitude	Aspect	Ccr (%)	Gcr (%)	Dist. rate (%)
1	A1	D	1984	29 22 440	2 23 482	2498	W	35	70	17
1	F1	M	NA	29 23 342	2 29 194	2296	S E	82	90	0
1	E1	D	1985	29 22 628	2 22 933	2498	W	14	30	45
1	P1	M	1985	29 22 620	2 23 058	2505	N E	62	10	10
1	C1	M	1985	29 22 428	2 25 590	2446	W	61	30	60
2	A2	M	1984	29 23 256	2 27 683	2295	S W	76	75	20
2	F2	M	NA	29 23 336	2 29 233	2310	S E	70	50	0
2	C5	M	1985	29 23 520	2 28 981	2368	S E	58	20	5
2	E5	M	1986	29 23 561	2 29 190	2315	S W	45	73	26
3	C2	T	1986	29 22 337	2 25 226	2464	S E	63	98	20
3	P2	T	1986	29 22 222	2 26 849	2453	S E	78	10	30
3	C4	M	1988	29 21 535	2 27 922	2404	N	63	80	5
3	F3	T	NA	29 21 545	2 25 955	2407	S	78	16	0
3	C6	M	1985	29 22 436	2 25 906	2444	S	30	98	58
4	A4	M	1989	29 24 035	2 32 736	2317	W	33	53	5
4	P5	D	1985	29 25 124	2 32 549	2363	S	74	6	10
4	E6	M	1985	29 25 099	2 33 019	2263	S	64	32	32
4	F5	D	NA	29 24 009	2 32 540	2351	S	57	52	0
5	E4	M	1985	29 25 437	2 37 336	2234	E	50	10	20
5	A6	M	1989	29 25 054	2 39 206	2372	SE	62	40	10
5	F4	M	NA	29 24 973	2 39 235	2240	S	65	35	10
5	P4	M	1989	29 25 084	2 39 259	2450	N	65	10	0
6	P3	M	1987	29 22 089	2 19 136	2465	S W	70	15	10
6	C3	T	1987	29 22 189	2 19 394	2490	S W	60	30	40
6	E2	M	1986	29 22 728	2 19 530	2497	S	40	30	35
6	A3	M	1987	29 22 237	2 19 282	2511	S W	75	60	20

Ccr: Crown cover rate, Gcr: Ground cover rate, Dist. Rate: Disturbance rate.

Appendix 4: List of indigenous species, families and vernacular names

Species	Family	Vernacular name
Agauria salicifolia (Comm. ex Lam.) Hook. f.	Ericaceae	Umukarakara
Alchornea hirtella (Beille) Pax & K.Hoffm	Euphorbiaceae	Gasenge, Bwiza bw'ishyamba
Asparagus falcatus L.	Liliaceae	Umushabishabi
Bersama abyssinica Fresen. complex	Melianthaceae	Umukaka
Canthium oligocarpum Hiern	Rubiaceae	Umushabarara
Carapa grandiflora Sprague	Meliaceae	Umushwati
Casearia runnsorica Gilg	Flacourtiaceae	Umuhandagore
Cassipourea congensis R.Br.	Rhizophoraceae	Ingongo
Clerodendron johnstonii Oliv.	Verbenaceae	Umukumbuguru
Clutia abyssinica Jaub. & Spach	Euphorbiaceae	Umutarishonga
Dichaetanthera corymbosa (Cogn.) Jacq.-Fél	Melastomataceae	Ikeba
Dichapetalum heudelotii Engl.	Dichapetalaceae	Umu(i)menamabuye, urutovu
Dichrostachys cinerea (L.) Wight	Fabaceae	Umuyebe, Umunkamba
Dovyalis caffra (Hook f. & Harvey) Warb.	Salicaceae	Umushubi
Ekebergia capensis Sparrm.	Meliaceae	Umujuga
Embelia schimperii Vatke	Myrsinaceae	Umukaragata
Faurea saligna Harv	Myrtaceae	Umutiti
Ficalhoa laurifolia Hiern	Sladeniaceae/Theaceae	Umuhumba
Ficus spp	Moraceae	Umuvumu
Galiniera caffeoides Delile	Rubiaceae	Umu (Iki)bonobono
Hagenia abyssinica (Bruce) J. F. Gmel.	Rosaceae	Umugeti, umugeshi
Ilex mitis Radlk.	Aquifoliaceae	Umunywande
Indigofera arrecta A.Rich.	Fabaceae	Umusororo
Lepidotrichilia volkensii (Gürke)	Meliaceae	Umunywamazi
Macaranga neomildbraediana Lebrun	Euphorbiaceae	Umusekera
Maesa lanceolata Forssk	Myrsinaceae	Umuhanga
Magnistipula butayei De Wild.	Chrysobalanaceae	Intambasha
Maytenus acuminata (L. f.) Loes	Celastraceae	Umu(i)nembwe
Maytenus undata (Thunb.) Blakelock	Celastraceae	Umupyisi
Memecylon walikalense A.& R.Fern.	Melastomataceae	Urusuri
Myrianthus holstii Engl.	Moraceae	Umwufe (icyufe)
Neoboutonia macrocalyx Pax	Euphorbiaceae	Umwanya, Icyanya
Ocotea michelsonii Robyns & R.Wilczek	Lauraceae	Umutake
Olea hochstetteri Baker	Oleaceae	Intobo
Pancovia golungensis (Hiern) Exell & Mendonca	Sapindaceae	Urutitiri
Podocarpus milanjianus Rendle	Podocarpaceae	Umuhulizi
Polyscias fulva (Hiern) Harms	Araliaceae	Umwungo
Prunus africana (Hook.f.) Kalkman	Amygdalaceae	Umwumba
Rapanea melaphloeos Mez	Myrsinaceae	Urubumburi
Sapium ellipticum Pax	Euphorbiaceae	Umusasa
Symphonia globulifera L.f.	Clusiaceae	Umushishi
Syzygium guineense DC.	Myrtaceae	Umugote
Xymalos monospora Baill.	Monimiaceae	Nyarubombwe, Umuhotora

Appendix 5. Distribution of species, individuals (I)/ha, average diameter (D) and height (H) in three diameter classes.

Site	Stand	2.5-10 cm (D1)				0.4 – 2.49 cm (D2)				> 10 cm (D3)			
		I	D	H	S	I	D	H	S	I	D	H	S
Gatare (1)	A1	43	4,7	4,1	10	97	1,2	1,6	10	3	11,5	11,5	1
	F1	63	5,0	5,0	9	85	1,7	2,5	9	21	18,1	15,9	3
	C1	6	4,3	3,9	3	120	1,1	2,1	13	0	0,0	0,0	0
	E1	45	4,5	2,6	8	78	1,4	1,4	9	1	15,6	2,8	2
	P1	5	5,1	3,3	4	38	1,1	1,1	6	0	0,0	0,0	0
BKizim. (2)	A2	9	5,5	5,3	5	14	1,5	2,2	6	0	0,0	0,0	0
	F2	51	4,5	4,3	9	91	1,3	1,9	8	33	22,6	13,2	3
	C2	14	4,8	5,9	3	77	1,1	1,5	10	1	25,6	2,2	1
	E5	11,0	5,1	5,4	6	34	1,2	1,5	6	1	17,0	17,5	1
BMunini (3)	F3	57	5,0	5,6	17	125	1,4	2,2	17	15	22,4	16,9	7
	C2	21	4,5	5,6	9	57	1,5	2,5	12	3	22,0	23,0	1
	C4	24	4,6	4,3	8	125	1,1	1,8	12	6	11,7	9,6	3
	C6	12	3,5	4,5	6	36	1,2	1,7	6	0	0,0	0,0	0
	P2	0	0,0	0,0	0	37	1,0	2,0	9	0	0,0	0,0	0
Kitabi (4)	A4	51	4,8	5,3	9	39	1,5	2,4	9	3	11,4	10,2	2
	F5	27	5,1	5,2	8	38	1,4	2,0	7	6	22,9	14,7	4
	E6	27	5,0	5,4	4	5	1,5	1,8	2	0	0	0	0
	P5	4	6,3	3,0	4	8	1,3	1,9	4	0	0,0	0,0	0
Kivu (5)	A6	27	4,1	3,3	11	92	1,2	1,6	14	3	10,2	15,0	1
	F4	12	4,3	4,2	5	64	1,2	1,5	16	6	15,5	11,6	1
	E4	27	5,0	5,4	4	5	1,5	1,8	2	0	0	0	0
	P4	18	5,0	4,4	5	37	1,2	1,6	6	0	0,0	0,0	0
Nkomane (6)	A3	27	4,1	3,3	11	92	1,2	1,6	14	3	10,2	15,0	1
	C3	12	4,3	4,2	5	64	1,2	1,5	16	6	15,5	11,6	1
	E2	18	5,0	4,4	5	37	1,2	1,6	6	0	0,0	0,0	0
	P3	6	5,4	4,9	4	71	1,0	1,4	7	0	0,0	0,0	0

Appendix 6. Pair wise comparison of Shannon-Wiener index

	1A1	1F1	1C1	1E1	1P1	2A2	2F2	2C5	2E5	3F3	3C2	3C4	3C6	4A4	4F5	4E6	4P5	5A6	5F4	5E4	5P4	6A3	6C3	6E2	6P3
1A1	**X**																								
1F1	0,14	X																							
1C1	0,5	0,31	X																						
1E1	0,82	0,09	0,59	X																					
1P1	0,92	0,87	0	0,906	X																				
2A2	0,9	0,67	0,2	0,981	0,6	X																			
2F2	0,89	0,29	0,56	0,739	0,9	0,88	X																		
2C5	0	0	0,81	0,051	0,3	0,1	0,02	X																	
2E5	0,9	0,66	0,29	0,989	0,7	0,93	0,9	0	X																
3F3	0	0	0,17	9E-04	0,6	0,31	0	0	0,2	X															
3C2	0,05	0,34	0,13	0,103	0,6	0,26	0,21	0	0,2	0,4	X														
3C4	0,4	0,95	0,26	0,366	0,7	0,54	0,56	0	0,5	0,1	0	X													
3C6	0,86	0,81	0,15	0,783	0,6	0,6	0,94	0	0,7	0,3	0	0,7	X												
4A4	0,97	0,21	0,58	0,887	0,9	0,91	0,85	0,1	0,9	0	0	0,5		X											
4F5	0,44	0,13	0,57	0,575	1	0,68	0,47	0,1	0,7	0	0	0,1	0,9	0,5	X										
4E6	0	0*	0,63	0,011	0,4	0,09	0	0,8	0,1	0	0	0	0,4	0		X									
4P5	0,51	0,39	0,68	0,561	0,3	0,21	0,57	0,8	0,3	0,2	0	0,2	0	0,6	0,6	0,7	X								
5A6	0,27	0,11	0,99	0,369	0,4	0,11	0,35	0,6	0,1	0	0	0,1	0,2	0,4	0,4	0,5	1	X							
5F4	0	0,07	0,03	0,002	0,6	0,33	0,01	0	0,2	0,2	1	0,2	0,1	0	0	0	0,1	0	X						
5E4	0,39	0,68	0,5	0	0,3	0,3	0,69	0,6	0,4	0	0	0	0	0	0,5	0	0,5	0	0,2	X					
5P4	0,9	0,98	0,27	0,932	0,6	0,73	0,98	0,3	0,7	1	1	0,7	0,7	1	0,9	0,2	0,3	0,3	0,9	0	X				
6A3	0,71	0,59	0,41	0,588	0,8	0,74	0,84	0	0,7	0	0	0,7	1	0,7	0,3	0	0,4	0,2	0,1	0,61	0,8	X			
6C3	0,74	0,44	0,35	0,856	0,8	0,85	0,79	0,1	0,9	0,1	0	0,3	0,5	0,8	0,7	0,1	0,3	0,3	0,1	0	0,8	1	X		
6E2	0,12	0,01	0,7	0,28	0,7	0,39	0,18	0,3	0,4	0	0	0	0,2	0,3	0,6	0,3	0,7	0,7	0	0	0,6	0	0	**X**	
6P3	1	0,99	0,26	0,988	0,7	0,96	1	0,4	0,9	0,9	1	1	0,9	1	0,9	0,3	0,4	0,6	1	0	0,4	1	1	0,84	**X**

: Significant difference (P<5%

Appendix 7. Importance value index of indigenous species

Species	Frequency value	Relative Frequency	Abundance	Relative Density	Dominance value	Relative dominance	Importance Value
Agauria salicifolia (Comm. ex Lam.) Hook. f.	1	0,63	1,00	0,17	9,79	0,08	0,88
Alchornea hirtella (Beille) Pax & K.Hoffm	6	3,77	30,00	5,23	356,18	2,93	11,93
Asparagus falcatus L.	2	1,26	2,00	0,35	85,18	0,70	2,31
Bersama abyssinica Fresen. complex		1,89	3,00	0,52	111,95	0,92	3,33
Canthium oligocarpum Hiern	9	5,66	20,00	3,48	365,98	3,01	12,16
Carapa grandiflora Sprague	3	1,89	8,00	1,39	270,66	2,23	5,51
Cassipourea congensis R.Br.	2	1,26	2,00	0,35	56,22	0,46	2,07
Clerodendron johnstonii Oliv.	2	26	2,00	0,35	82,12	0,68	2,28
Clutia abyssinica Jaub. & Spach	2	1,26	3,00	0,52	23,71	0,20	1,98
Dichapetalum heudelotii Engl.	11	6,92	37,00	6,45	316,28	2,60	15,97
Dichrostachys cinerea (L.) Wight	2	1,26	2,00	0,35	12,55	0,10	1,71
Dovyalis caffra (Hook f. & Harvey) Warb.	1	0,63	1,00	0,17	40,60	0,33	1,14
Ekebergia capensis Sparrm.	1	0,63	1,00	0,17	7,60	0,06	0,87
Ficalhoa laurifolia Hiern	1	0,63	1,00	0,17	25,79	0,21	1,02
Ficus spp	1	0,63	1,00	0,17	6,70	0,06	0,86
Galiniera caffeoides Delile	20	12,58	115,00	20,03	1956,36	16,09	48,71
Hagenia abyssinica (Bruce) J. F. Gmel.	1	0,63	4,00	0,70	147,22	1,21	2,54
Ilex mitis Radlk.	3	1,89	4,00	0,70	157,62	1,30	3,88
Indigofera arrecta A.Rich.	1	0,63	1,00	0,17	6,20	0,05	0,85
Lepidotrichilia volkensii (Gürke) J.-F. Leroy	1	0,63	1,00	0,17	21,81	0,18	0,98
Macaranga neomildbraediana Lebrun	22	13,84	158,00	27,53	4210,36	34,63	76,00
Maesa lanceolata Forssk	17	10,69	48,00	8,36	1057,60	8,70	27,75
Magnistipula butayei De Wild.	1	0,63	1,00	0,17	8,81	0,07	0,88
Maytenus acuminata (L. f.) Loes	2	1,26	2,00	0,35	21,73	0,18	1,79
Maytenus undata (Thunb.) Blakelock	1	0,63	1,00	0,17	17,72	0,15	0,95
Memecylon walikalense A.& R.Fern.	1	0,63	2,00	0,35	12,47	0,10	1,08
Myrianthus holstii Engl.	1	0,63	1,00	0,17	38,37	0,32	1,12
Neoboutonia macrocalyx Pax	4	2,52	14,00	2,44	425,73	3,50	8,46
Olea hochstetteri Baker	1	0,63	5,00	0,87	39,84	0,33	1,83
Pancovia golungensis (Hiern) Exell & Mendonca	2	1,26	4,00	0,70	50,24	0,41	2,37
Polyscias fulva (Hiern) Harms	3	1,89	7,00	1,22	252,80	2,08	5,19
Prunus africana (Hook.f.) Kalkman	2	1,26	3,00	0,52	87,64	0,72	2,50
Rapanea melaphloeos Mez	8	5,03	14,00	2,44	227,73	1,87	9,34
Sapium ellipticum Pax	2	1,26	8,00	1,39	232,29	1,91	4,56
Symphonia globulifera L.f.	2	1,26	4,00		84,30	0,69	2,65
Syzygium guineense DC.	8	5,03	42,00	7,32	893,01	7,35	19,69
Xymalos monospora Baill.	9	5,66	21,00	3,66	435,47	3,58	12,90
Total	**159**	**100,00**	**574,00**	**100,00**	**12156,63**	**100,00**	**300,00**