# Impacts of Biodiversity Threats on the Attainment of Sustainable Development Goal15 "Life on Land" in Albertine Rift Forests of Rwanda, Nyungwe National Park.

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## ABSTRACT

The $SDG_{15}$ "Life on the Land" aims to sustainably manage forests, combat desertification, and halt and reverse land degradation, halt biodiversity loss. This research tends therefore at providing information to establish the pathway to lead to SDG15 in Nyungwe natural forest. A forest resource assessment was carried out to identify the stock of the threatened tree species in Nyungwe National Park. In this study we conducted a patrol with rangers and staff of NNP inside the forest, where all signs of illegal activities uncounted along way were recorded with the help of a hand held Global Positioning System devises. High elevation sites show the lowest occurrence probability of threats, and near the park boundary and ranger posts. The study established that four species were targeted for use as timber, of which the most sought after were *Prunus Africana, Pentadesma reyndersii*, *Podocarpus folicatus,* and *Entandrophragma excelsum.* These timber trees were found in low densities in the study area, suggesting that they were targeted for pitsawying. Thus these species were present critically in abundance and sizes to allow sustainable utilization. The vulnerability of species was based on different criteria including abundance, dominance, diameter size-class distribution and regeneration. The results found that there is no significant relationship between species richness and threats uncounted at R (6) = 0.096 at P-Value of 0.8. This study also found that the sites differ in threats, with respect to the distance from the edge of the forest toward inside. The chi–square calculated 35.71 was greater than the expected one 0.9. However, this study found that the difference is significant in terms of number of threats per distance walked from the edge of the forest. The similarity between plant communities for the eight Sites surveyed was calculated Using *Bray-Curtis cluster Analysis (Single Link).* The results Shows that Kivu, Ruheru & Bweyeye, Butare, were the most similar by 95.2% and by 93% respectively. Sites Cyato, Unkingi & Kivu and Kitabi were the most dissimilar. Cyato, Unkingi were similar by 58.5% while Kivu, Kitabi were similar by 66.9%. In order to reduce threats, the civic engagement and revenue sharing scheme review were suggested to help restore and conserve this important wildlife habitat while engaging community around the forest. Revenue sharing scheme need to be revised so that it can fit with the sustainable livelihood appraisal as it has been mentioned in the conceptual framework developed for this study.

**Key words:** Biodiversity threats, Albertine rift forests, Sustainable development goal 15, and Nyungwe National Park.

## Introduction

Mankind faces earth degradation problems whose solution becomes increasingly urgent every year. Climate change, social conflicts and demographic movements generate uncertainties that require the maximum awareness of society to fight its negative effects on the efficient and fair management of life around the world. The United Nations sustainable summit (2015) world leaders adopted the 2030 Agenda for sustainable Development as key solution of those challenges by setting goals, among goals the Sustainable Development 15 ($SDG_{15}$) focus to the Life on the earth" by focusing on Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (Life on Land). There is growing recognition that achieving SDG15 need to concentrate on biodiversity loss, climate change, Poverty, inequality, deforestation, and land degradation as cross cutting issues that have been recognized by different organizations at global level (UN, 2018).

During the review of SDG 15 implementation, reviewers were agreed that Forests is foundation and a strong pillar of SDG15 as source of economic wellbeing, social inclusion and environmental sustainability (UN, 2018). However, the overexploitations of forest lead questionable challenge especially in developing countries where people rely on nature resources. Paris agreement, halting deforestation and decreasing forests degradation should be in the agenda of all actors and stakeholders (Köthke et al, 2013). At a global level, millions of people depend on forest resources as a means of subsistence and benefit directly, through the consumption of food produced or obtained in or around forest. Admittedly, Rwanda as developing countries is also struggling on how to meet the present human need in sustainable way without exhausting the resources available for future generation. In that respect, the Government has decided to uphold the conservation effort of forests coverage in Rwanda from Forest reserves to National Parks which is contributing to the tourism industry of Rwanda hence formed to protect and keep animals from getting extinct and wondering off (RDB, 2017). Recently two natural forests Gishwati and Mukura are upgrade at national park in 2015 in that respect.

The government has also promoted responsible natural resources management in order to recognize the crucial role of ecosystem services and civil society participation on policy elaboration and

implementation as well as the engagement of local and indigenous people, men and women; boys and girls. Co-management between government and communities was also useful as governance solution for protected areas, also offering an opportunity to incorporate the traditional knowledge of local people and their skills in monitoring and other management activities (FAO, 2014). Community involvement in natural resource management different socio-political and bio-physical contexts such as protected area Outreach; Collaborative Management, and Community-based Conservation was played significance role in protecting and bring conservation achievement of the earth biodiversity (Binot et al 2009).

The research of Binot and his colleagues (2009) reported in Ghana showed that the Community Resource Management areas (CREMAs) had delivered some success for conservation of natural resources through a reduction in illegal activities, believed to be based on the expectation of future returns in the nature forest. Both Thomas and Camara (2005) and Jammeh (2008) reported increased incomes to community members from community forestry in Gambia was being derived from a number of enterprises such as selling fuel wood, timber, poles, furniture, honey and from ecotourism.

In Rwanda, Local communities living around National Park are organized in association with the support of the Rwanda Development Board like a Ubwiza bwa Nyungwe bee-keeper Union, Banda culture village and Ecotourism (BIOCOOP) in Nyungwe National Park. A research conducted by Umuziranenge et al. (2018) on conservation challenges of Gishwati Mukura National Park, many respondents live surrounding proved that little active involvement of local communities in the park's conservation and protection is based on a lack of community empowerment through community conservation outreach and unfair tourism revenue sharing projects which lead them to involve in different illegal activities (Umuziranenge et al, 2018).

Man authors have indicated that the loss of biodiversity in Nyungwe Forest results from illegal use of surrounding local communities (Gapusi, 1999; MINAGRI, 1998; MINITERRE, 2000). The loss of wildlife and its habitats, and conflicting relations between Protected Areas management and neighboring communities continue to challenge conservation efforts and threaten the survival of Rwanda's protected areas and high levels of poverty and a lack of employment opportunities are the main causes of resource access conflicts in

Nyungwe (Umuziranenge et al, 2018). However, research was point out some of the causes of threats found in the Nyungwe natural forests that directly impact wildlife conservation such as lack of income generating activities and lack of other alternatives resources as be the main causes of illegal activities where People need incomes to support themselves and their families, by turn to park resources such as; timber, minerals, bush meat and honey for that support (Wittemyer et al., 2008).

The analysis of history regional resources dependency can explain the relationship between the biodiversity treats and management strategies that are still a big challenge to the management of this forest. For example continued and in some cases increasing market demand for bamboo products, traditional medicines and animal products, as well as high prices for minerals such as gold and coltan, mean that this resource exploitation is likely to continue in the absence of appropriate enforcement (Crawford, 2012). Anthropogenic activities within the natural forest are believed to bring considerable negative effects on the entire environment and hence to the attainment of global targets lead barrier to achieve the global target.

According to the research of Douglas and his colleagues, they recommended efforts focused on identifying the most important sites for sensitive management in different natural forests of the world **(**Douglas *et al,* 2003). However, in the case of Nyungwe Forest, no work has been done on resource exploitation and impacts on the life on land in the future. Therefore, this study aimed at providing information on the availability, identification, abundance, distribution and harvesting impact for these products on the attainment of SDG15 in Nyungwe forest. In this paper we first identified biodiversity threats in Nyungwe National Park. We assessed life on Land with respect to biodiversity threats and then we determined the relationship between the existing level of biodiversity threats and the future Life on Land in Nyungwe National Park.

## Methodology and Study areas

Data for this research were collected in Nyungwe national park. Nyungwe National Park is highly diverse hotspot in terms of endemic and globally threatened species not only in the eco-region but also internationally and supplies enormous ecosystem services including water provisioning and touristic attractions (Masozera et al., 2006). Nyungwe National Park covers an area of 1019 $km^2$ and

is contiguous with Kibira National Park in Burundi. Nyungwe is one of the largest remaining forest tracts in east-central Africa and populations there occur in high densities with an average of 300 inhabitants per square kilometer and about 90% of the population has been engaged in subsistence farming (Masozera et al., 2006).

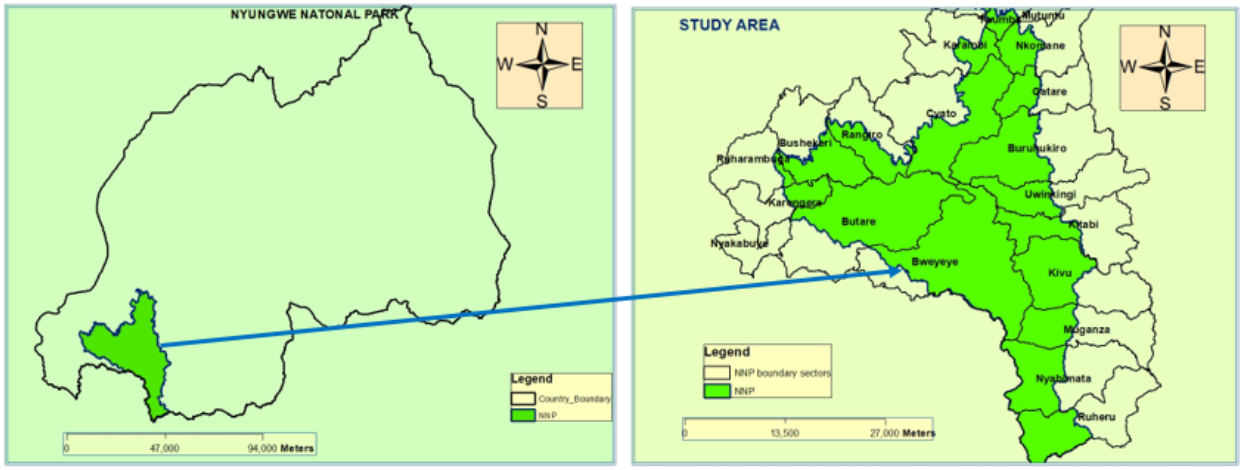


***Figure 1. Map of Nyungwe National Park, Rwanda showing its boundary sectors which served as study sites.***

The study is basically a quantitative research and little qualitative. Quantitative measures were used to collect statistical data from sample population. Qualitative study was guided by grounded theory approach, where mixed methods were used. It encompasses desk research, Participatory observation to be familiar with research area and patrol with rangers and staff of NNP inside the forest, where all signs of illegal activities uncounted along way were recorded with the help of a hand held GPS devises in period of one month, October 2018.

The research was stratified into two sections, based on canopy cover using closed canopy and broken canopy characteristics and threat types. The closed canopy comprised of mixed forest, Monodominant and hill forest while broken canopy comprise of five distinct features; forest with herbaceous understory, Forest with liana understory, fallow, Mined site - outcrop forest and Swamp forest. A further subdivision of the region was based on park ranger monitoring zones. Within each zone, one in south-east and eight sectors was selected on the other sides to represent the area. Purposive sampling was used due to the intensity and the abundance of the threats as shown by the secondary data in nine sites were Bweyeye, Gasumo, Gisovu, Ruzizi and Uwinka, Gisakura at the western ridge of the

Forest, Nshili in the south-east, Kitabi and Musebeya in the eastern side of the Forest.

The study, plots were established with the aid of a Suunto Clinometer, tape measure, machete, and ranging poles. They were placed inside Nyungwe Forest from each side of the forest edge depending on the location of identified threats. In each part of the forest area, two plots each measuring 2500 m2 (i.e. 50 m x 50 m) in size (Sample unit A) with the corresponding nested areas (Sample units B and C) were established. The survey procedure was based on the method used by (Fedlmeier, 1998) for the study of the development of secondary forest in Costa Rica. Seedlings and saplings were recorded in twelve 5 m x 5 m nested sub-units (Sample unit C) within sample unit A. The sub-units were delineated following the diagonals of Sample unit A. Individuals of 0.10 m to 0.30 m height and DBH of less or equal to 2.9 cm were recorded. (Peters, 1996) Scaled small trees of this size to tree seedlings or saplings. Therefore, regeneration assessments were done on an area of 25 m2, lying in the range of plot sizes recommended by (Peters, 1996). For the study, a total number of 18 sample units with 18 corresponding nested subunits and 144 sub-subunits were use. The Biodiversity survey data sheets designed for this study. Within each sample unit, tree species, Birds, and mammals were identified in the field by a team of five local persons including two forest rangers who provided vernacular names. Data was analyzed by using triangulation method and Ranger Based Monitoring (RBM) System hence reliable, Geographical Information System (GIS) Arc Map 10.1 for mapping, Bio Diversity Pro softwares while analyzing and interpreting findings.

**Results**

Our results presented was drown from the data composed of primary and secondary data. The researcher's own observations made during the field visits were considered during analysis. Tables and graphs with relevant information in figures from GIS have been used to make the analysis simpler and easy to understand.

**Biodiversity threats in Nyungwe National Park**

Nyungwe faces several major threats derived largely from population growth, pressure on land resources, and lack of sustainable sources of income for local communities, and limited awareness and availability of economic incentives for sustainable use of biodiversity. Poaching of large mammals is high. Fires caused by beekeepers smoking

bees from wild hives have spread, devastating large forest areas; and mining of gold and more tree harvesting including Non Timber Forest Products Collection as presented in table 4.1.

**Table 1 Trend of threats in NNP from 2013 to 2018.**

| No. | Incidents Categories | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Grand Total |
|---|---|---|---|---|---|---|---|---|
| **1** | Arrested people | 114 | 129 | 203 | 157 | 219 | 175 | **997** |
| **2** | Snares | 5414 | 6593 | 8988 | 13639 | 9421 | 6903 | **50958** |
| **3** | Animal carcasses | 196 | 181 | 208 | 450 | 226 | 159 | **1420** |
| **4** | Agriculture (Marijuana and Crops) | 45 | 20 | 33 | 37 | 21 | 19 | **175** |
| **5** | Honey Collection in trees | 98 | 95 | 117 | 133 | 103 | 24 | **570** |
| **6** | Hives (Empty and occupied by bees) | 122 | 133 | 83 | 138 | 179 | 18 | **673** |
| **7** | Grazing | 6 | 2 | 6 | 1 | 69 | 0 | **84** |
| **8** | Poaching camps and huts | 106 | 83 | 161 | 124 | 59 | 61 | **594** |
| **9** | Bamboo cutting | 243 | 542 | 327 | 203 | 136 | 189 | **1640** |
| **10** | Firewood collection | 340 | 341 | 340 | 319 | 623 | 207 | **2170** |
| **11** | Cutting of Small and big trees, and stakes | 1758 | 857 | 2759 | 1128 | 1279 | 386 | **8167** |
| **12** | Sawing | 34 | 8 | 51 | 31 | 22 | 37 | **183** |
| **13** | Mining | 228 | 180 | 195 | 117 | 120 | 109 | **949** |
| **14** | Bush Fires | 27 | 16 | 27 | 60 | 33 | 9 | **172** |
| **15** | Medicinal plants | 3 | 3 | 1 | 1 | 3 | 10 | **21** |
| | **All Total Incidents** | **8734** | **9183** | **13499** | **16538** | **12513** | **8306** | **68773** |

The table 1 indicates that snares removed in year 2017 were 9421 constituted 73.05% as the accounted rate while 6903 constitute 82.75% of snares were removed only in five months of 2018. In 2017, the carcasses constitute 1.75% while in May 2018, the carcasses constitute 1.95%. the smallest percentage of threats is Bush fires which is represented by 0.16% in 2017 and in 2018 there was no case recorded for bush fire.

**Snares and carcasses removed in Nyungwe Forest**

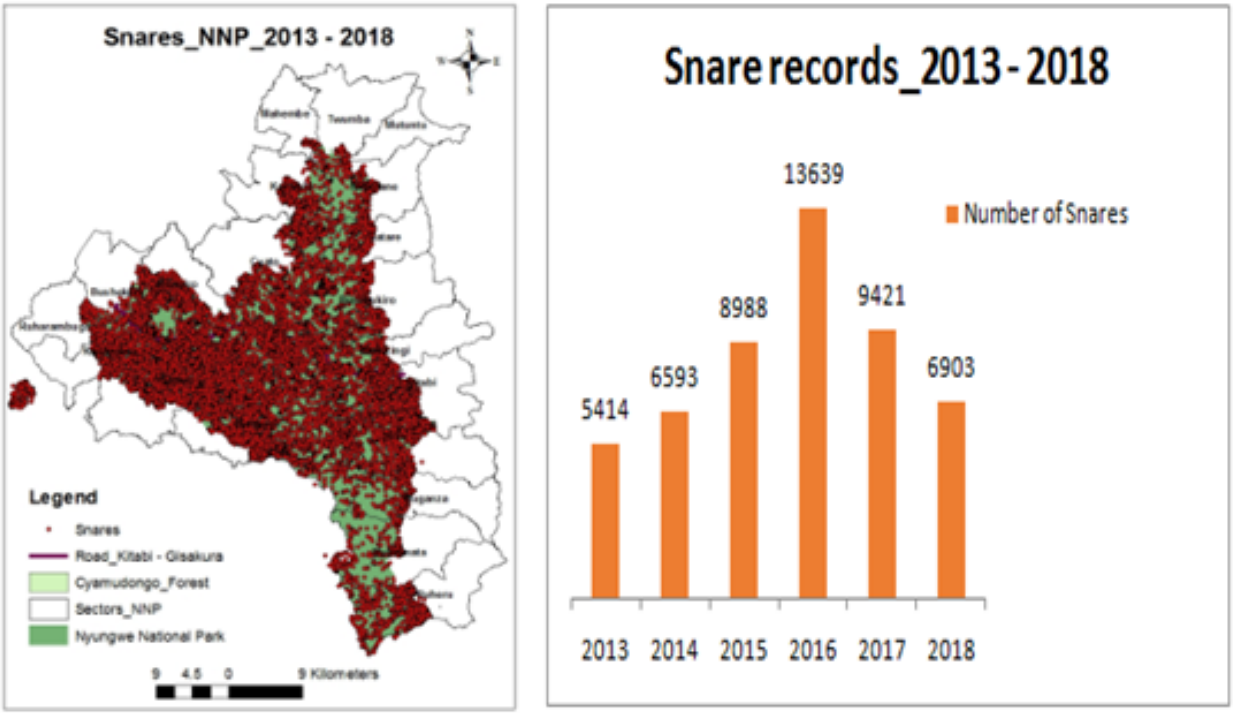


**Figure** 2 Snare uncounted from 2013 to 2018

Photo A on figure 2 is a spatial representation of snares encountered from 2013-2018 while photo B on figure 2 shows the annual trend of snares removed within the same period. Hunting in NNP is becoming a serious threat to its biodiversity.

In year 2016; 13.639 Snares were removed and year 2017; 9.421 snares were removed where a reduction of 30.9 compared to the previous year. However, only from January to May 2018; 4.077 snares were removed. In the past years, neighboring communities extracted bushmeat from Nyungwe Forest through hunting and the use of traps (O'Brien *et al*, 2019). The survey established that wildlife is not managed for utilization as part of the livelihoods of the people adjacent to the Forest. Hunting for household consumption is regarded as a threat to the conservation of wildlife, including rare and protected animals such as chimpanzees and buffaloes (MINITERRE, 2000). In the Republic of Congo, 26 000 animals are said

to be sold in Pointe Noire monthly, implying that half a million animals are killed for this market each year (Colchester, 2004). In Cameroon and in the Democratic Republic of Congo, the bushmeat consumption is estimated at 21 and 41 kg per person per year (Wilkie, 1999).

**Tree cutting in NNP**

Illegal logging for indigenous timber by neighbouring communities has been reported to be a major threat to the conservation of the Forest (MINITERRE, 2000). Since the local communities favor certain species for timber, harvesting is likely to be selective in NNP. This selective logging affects mature forests and species composition, as a result of canopy gap formation.

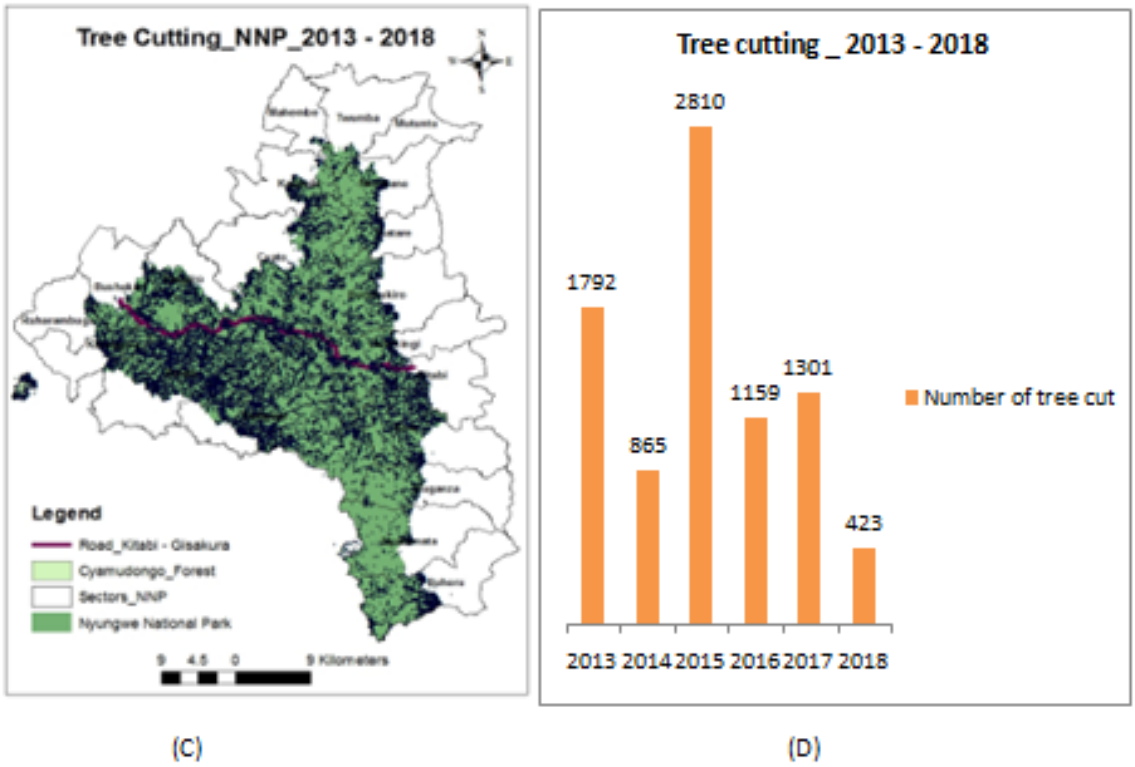


**Figure 3. Trends of Tree cutting in Nyungwe National Park from 2013-2018**

The study established that tree species were targeted for use as timber, of which the most sought after were *Pentadesma reyndersii*, *Podocarpuslati folius, P. falcatus* and *Entandrophragma excelsum.* These timber trees were found in low densities in the Forest, suggesting that they were targeted for pit sawing. This concur to the research

conducted by (Gapusi *et al*, 1997) stated that in Nyungwe Logging of valuable trees has been very selective and unmanaged, and it has resulted in some tree species becoming endangered. This study revealed that species were found at low frequencies, with fewer harvestable sizes and an increasing number of young trees. The small number of large sized hardwoods was probably a result of overexploitation. Harvesting of some parts of plant resources such as roots and bark has an impact on the availability of the forest resources and their response to disturbance as well (Peters, 1996).

The impact of illegal logging in Nyungwe Forest could be partly reflected in differences in densities of seedlings and medium trees between the study sites.

**Plant resource assessment to measure the life on land in Nyungwe National Park**

In this study, based on the data collected from field, *alpha biodiversity* (α) which is the number of species counted in a local community and *gamma biodiversity* (γ), a measure of the number of species across multiple communities were calculated. Eight major sites were identified on surveys. Based on succession stage, we classified and distinguish the sampled plots substrata types, canopy composition and structure. In this study, density measures that combined tree sizes and the number of individuals were used. Individual trees were counted in each of the sample plots and recorded in the appropriate diameter class. Frequency as a measure of species abundance was used to provide the proportion of individuals and the most threatened tree species were determined in relation to the number of individuals of all other tree species present in the sample plots

**Species Numbers**

According to (Fisher, 2008) the number of plant species known for the Nyungwe forest is home to 1,068 recorded plant species, of which about 250 are endemic to the Albertine Rift. Among fauna, 85 mammals, 278 bird, 32 amphibians, and 38 reptile species have been recorded there; of these, 62 species are endemic to the rift. All of these species recorded were previously known to exist in Nyungwe forest. However, these species still need to be reviewed by plant taxonomists. Among the species recorded 12 were Albertine Rift Endemics. 5 plant species recorded were International Union for Conservation of Nature (IUCN) red listed. The highest number of plant species was recorded in Uwinkingi (157) and least number was recorded in Cyato (65). Herbs accounted for the greatest number of plants recorded in each sites sampled as given in

Table 2. Generally, there were very few tree species that were recorded in high and subalpine altitude with the highest number of trees recorded in low altitude.

**Table 2 Different plant life forms (Trees and Shrubs) recorded in each plot in each site.**

| Sites | Kitabi | Uwinkingi | Bweyeye | Butare | Rangiro | Cyato | Ruheru | Kivu | Total |
|---|---|---|---|---|---|---|---|---|---|
| Herbs | 73 | 84 | 54 | 62 | 44 | 23 | 48 | 42 | 430 |
| Shrubs | 16 | 32 | 23 | 21 | 23 | 16 | 33 | 35 | 199 |
| Trees | 16 | 41 | 23 | 19 | 31 | 26 | 36 | 39 | 231 |
| No. Endemic spp | 12 | 9 | 13 | 17 | 16 | 13 | 14 | 17 | 111 |
| No.IUCN Red List spp | 2 | 1 | 2 | 2 | 1 | 2 | 3 | 2 | 15 |
| Total | 105 | 157 | 100 | 102 | 98 | 65 | 117 | 116 | 860 |

Species richness varied between the different sites surveyed with the highest number of species recorded in sites of Uwinkingi with 157 species followed by Ruheru site with 117 species while the least number of species was recorded in Cyato with 65 species. The North east part of the forest was richer in total number of species and endemics.

**Diversity indices**

A Shannon-Wiener Index of diversity and evenness was calculated for each of the eight sites

Surveyed based on the plot data (Table 2). The result shows that Kivu and Ruheru Sector were the most diverse at $\alpha = 0.997$ and 0.988 respectively and both sectors are in Nyaruguru District.

**Table 3 Shannon Diversity Index Values for each sites sampled for this study**

| Index | Kitabi | Uwinkingi | Bweyeye | Butare | Rangiro | Cyato | Ruheru | Kivu |
|---|---|---|---|---|---|---|---|---|
| **Shannon H' Log Base 10.** | 0.359 | 0.438 | 0.438 | 0.409 | 0.462 | 0.469 | 0.471 | 0.476 |
| **Shannon H max Log Base 10.** | 0.477 | 0.477 | 0.477 | 0.477 | 0.477 | 0.477 | 0.477 | 0.477 |
| **Shannon J'** | 0.752 | 0.919 | 0.918 | 0.857 | 0.968 | 0.982 | 0.988 | 0.997 |

**Relationship between species richness and threats uncounted**

The correlation coefficient was calculated between species uncounted (frequency). The results found that there is no significant

relationship between species richness and threats uncounted at R (6) = 0.096 at P-Value of 0.8. This study also found that the sites differ in threats, with respect to the distance from the edge of the forest toward inside. The chi –square calculated 35.71 was greater than the expected one 0.9. Therefore, the difference is significant with respect to the number of threats per distance walked from the edge of the forest. Therefore, this study found that the sites with the highest probabilities of poaching-related threats were in the southern portion of the park near Burundi, while the sites with the lowest probabilities of poaching-related threats were near the park boundary, especially around ranger posts.

**The Vulnerability of the preferred tree species to exploitation in the future**

Nyungwe Forest has different species with a variety of ecological characteristics that make sustainable harvesting a very difficult objective. The major problems identified by the study are the high diversity and low population density in same area, the unstable size-class distribution and the low density of regeneration of many species (Table 2). Ignoring these characteristics could cause an unsustainable exploitation of timber, poles and medicinal materials.

According to Hall and Bawa, 1993, in their study on Methods to assess the impact of extraction of non timber tropical forest products on population, they found that extraction is considered sustainable if the impact of harvesting has no significant effect on the reproduction and regeneration of the population being harvested. A combination of criteria including density, size-class distribution and regeneration could convey an impression about the vulnerability of tree species to exploitation.

Obviously, abundant species with many seedlings (e.g. *Carapa grandiflora, Symphonia globulifera*and *Strombosia scheffleri)* are less vulnerable to exploitation. More important than the overall abundance of the preferred tree species is the size-class distribution of individuals of each species. Stem densities of some species including *Cassipourea ruwenzoriensis* and *Newtonia buchananii* were dominated by the preponderance of small trees, large trees being very few. The exploitation of such species could not be maintained on a sustained yield basis and therefore species which approximate an inverse J-shaped curve are recommended for exploitation. Felling of large trees of species including *Entandrophragma excelsum, Newtonia buchananii* and *syzygium paryifolium* for

timber could eliminate these species from the Forest in a much shorter period of time because of low densities of their stems and instability of their populations. Another criterion, part of plant used, could be added to the other criteria in order to determine the vulnerability of harvesting medicinal materials. As no data was available on the impact of harvesting medicinal materials from the species, the information about vulnerability of medicinal species to exploitation is not fully determined. In addition, it is clear that many of the tree species are favoured for more than one products, which might lead to overexploitation as observed by (Fedlmeier, 1998).

However, If the removal of trees across the different size classes is proportional to the relative densities of the stems in each size class, then there will be no change in the size-class distribution of the species at a time when absolute densities are declining. Information on the life history of the species can guide decision over exploitability of species, as the removal of some trees might not enhance the regeneration of shade tolerant species.

Species such as *Entandrophragma excelsum* require enrichment planting or the re-introduction of locally extinct herbivores (e.g. elephant, buffalo) that will induce disturbances needed for the regeneration of the species.

Given the short time of the survey and the limited access to certain areas of the massif we would recommend that further botanical survey work be undertaken, particularly at the higher altitudes, to improve on the species lists we have compiled to date.

**Discussion**

This study revealed that hunting for the bush meats and habitat loss through logging or shifting agriculture and mining have a direct impact on wildlife and represent major challenges to the conservation and management of almost all species across the entire forest. The effect of hunting on endemic species of Nyungwe has been the subject of a number of studies. Despite specific differences in vulnerability to overhunting are likely linked to a variety of factors, including reproductive rates, rates of movements (hence exposure to snares and hunters), and risk of predation. Whereas some of these factors have been documented, the basic reproductive biology including birth intervals, gestation periods, and growth rates of many species remain inadequately known, thus limiting the opportunity to direct model productivity in relation to hunting activities.

The effect of logging on forest fauna have been a point of controversial debate. For example, plumptre's (1994) surveys in logged and unlogged Cynometraforsts in the Budongo Reserve, western Uganda, revealed marginally lower blue duiker densities on logged as compared to unlogged sites. in Borneo, two species of mouse deer, *Tragulusjavanicus* and T. napu, tragulids similar in their basic ecology to the African duiker and chevrotain, had lower densities in logged than in unlogged lowland forest. In contrast to these results, Wilkie and Finn (1990) suggest that secondary forests regenerating after shifting cultivation may support higher densities of same ungulates, including duikers, than do primary forest stands in the northern ituri forest. Differences between sites in the areal extent of disturbance, numbers of trees removed, and the composition of secondary forests makes it difficult to generalize from the available data about the effect of logging or shifting agriculture on the wildlife population in Nyungwe Forest.

However, Tutin et al. (1997) have attempted to evaluate the possible effect of forest loss and fragmentation on forest mammals in Gabon by comparing population densities recorded in isolated forest fragments and galleries with population densities of the same species in adjacent contiguous forest. Although natural fragments supported high densities of a number of species, including ungulates, it is not clear that human-engendered forest fragmentation resulting from logging or agriculture would lead to comparable conditions. Forest islands in largely deforested landscape would likely be heavily exploited and impoverished, and are rarely remnants of intact habitat. In addition, formerly forested areas cleared by farmers are unlikely exploited to support the same potential for animal dispersal that may be important in maintaining population densities of same species.

In the absence of such a disturbance, these species whose regeneration is limited (e.g. *Parinariexcelsa, Pauridianthapaucinervis, Casearіarunssorica*and *Cassipourearuwenzoriensis)* may temporarily disappear from the Forest, their populations being represented only by seeds lying dormant in the soils. The results of the study concur with the findings of Zimmermann *et al.* (1994) that regeneration in tropical wet forests is an important life history attribute of the species. Significant differences in the abundance of seedlings of different species across sites indicated poor regeneration and recruitment of some species in some sites. This may be caused, in addition

to differences in environmental conditions (e.g. soils, rainfall) and the ability of the species to reseed, by differences in canopy cover or light gaps in the Forest. Fire is reported to be the most common disturbance in Nyungwe Forest (Gapusi, 1999) and could have affected differently the part of the Forest being surveyed.

The total species list of a site describes the diversity of a site and the presence and absence of threatened, endemic and rare species is used as an indicator of the importance of the site for conservation. The cluster analysis showed that sites (Kivu, Ruheru, Bweyeye & Butare) were similar in species composition (Similar altitudinal range with mixed forest as the dominant vegetation type) compared to the other sites.

The plant species lists (species abundance) were compiled from the plot data and the opportunistic observations. This information was used to compare species in the eight sites. Density and size-class distribution are indicators of the impact of exploiting a given population. Density describes not only the degree to which the site is being utilized, but also the intensity of competition between trees. These differences could be attributed to environmental conditions and types of disturbances including fire and grazing among others. The periphery of the Forest has been altered; this has been substantiated by the chi-square analysis of the densities of trees of different sizes among and within the study sites. The Hypothesis that Biodiversity threats in Nyungwe National Park threaten SDG15 were rejected since results of this research found that there is no significant relationship between species richness and threats uncounted at R (6) = 0.096 at P-Value of 0.8. we concluded that the difference was due other factors which were not under our control and therefore, we suggested that further researchers may explore more about the threats in NNP and their impact using advanced models.

**Conclusion**

This research has shown that Biodiversity threats in Nyungwe Forest exist and this is shown by illegal cutting of trees for various uses, and poaching of animals for food, gathering of wild vegetables and fruit, the harvesting of medicinal plants and mining in the Forest. Hence our first research question has been answered. The study found that NNP is important to the livelihoods of many people living on its periphery, through the provision of wood and non-wood forest products. It was noted that many individuals do not think about the damage they are causing on NNP biodiversity and our second research question have been answered as

discussed in chapter four. Third research question also have been answered as we found that life on land is in danger and If no changes are made in the ways humans use resources on earth, there will continue to be a degradation of biodiversity until human lives can no longer be sustained. Humans affect biodiversity by their population numbers, use of land, and their lifestyles, causing damage to habitats for species. It is important for humans to realize how their actions affect biodiversity and the importance of maintaining what biodiversity is left on the earth.

Through proper education, and by demanding that governments make decisions to preserve biodiversity, the human population will be able to sustain life on land in Nyungwe National Park. The preference and demand for forest products is highly linked with insufficient resources for sustainable livelihood development hence declining levels of factors of production and the lack of livelihood alternatives in the study area. Our finds concur with the findings of (Barbier, 2005) who proposed that In order to attain sustainable development in an economy dependent on exploiting natural resources, this exploitation should satisfies" weak sustainability" Conditions. That is the development path must ensure that, first, natural resources must be managed efficiently so that any rents earned are maximized, and second, the rent resulting from the depletion of natural capital must be invested into other productive assets in the economy. Our finds also emphasis the theory of sustainable livelihood developed by DFID (Bennett, 2010), for analyzing sustainable livelihoods which again reflect the issue of biodiversity threats and sustainability of protected areas.

All in all, despite many advantages and perceptions, Nyungwe Forest is threatened by illegal activities that impact negatively on its size and biodiversity. Human disturbances and unlawful activities are the major causes of regression and losses of plant and animal species.

Due to insecurity, it was not possible to cover the whole forest evenly but every attempt was made to cover the range of habitats and altitudes. Within each sector at least two plots were established to cover as much of the sector as possible.

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## Works Cited

Annonymous. (2002). Poverty and Climate Change: Reducing the Vulnerability of the Poor I. *nter-agency discussion paper* (pp. 1-5). washington: worlD Bank.

Assessment, M. E. (2005). *Ecosystems and human well-being:*. washington DC: World Resources Institute.

Bahigiriki, E. a. (1987). *Etude Socio-economique et Proposition ecologique sur la Foret de Nyungwe (UGZ3).* Kigali: Min. Agric.Elev. et Foret, Direction des Forest.

Balakrishna, P., & E. W. (un dated). Biodiversity and the Millennium Development Goals. *Asian Biotechnology and Development Review*, 1-40.

Barbier, E. B. (2005). *Natural Resources and Economic Development.* New York: Cambridge University Press.

Barlow J. (2007). Quantifying the biodiversity value of tropical primary, secondary, and plantation forests. *Proc. Natl Acad. Sci USA 104,(doi:10.1073/pnas.0703333104)*, 18 555–18 560.

Belshaw, R., & B. B. (1993). The effect of forest disturbance on the leaf litter ant fauna in Ghana. *Biodiversity conservation 2, (doi:10.1007/BF00051965)*, 656–666.

Bennett, N. (2010). Sustainable Livelihoods from Theory to Conservation Practice:An Extended Annotated Bibliography for Prospective Application of Livelihoods Approaches in Protected Area Community Research. *Protected Area and Poverty Reduction Alliance Working Paper No. 1.Victoria, Canada: MPARG (UVic); PAPR (VIU).*, 5.

Bradshaw, C. J. (2009). Tropical turmoil: a biodiversity tragedy in progress. *Front. Ecol. Environ. 7,(doi:10.1890/070193)*, 79–87.

Budowski, G. (1976). *Proposition pour un programme de sauvegarde de la foret de Nyungwe.* Kigali: Roneo, Min. Agric., Elevage.

Campbell, J. S. (2004). *The Science of Sustainable Development: Local livelihoods and the Global Environment.* Cambridge, United Kingdom: Cambridge University Press.

Chazdon, R. L. (2008). *Chance and determinism in tropical forest succession.* Oxford UK: Wiley-Blackwell.

Colchester, M. (1994). Slave and enclave: The political economy of Equatorial Africa. *World Rainforest Movement*, Penang.

Condit, R. H. (1996). Changes in tree species abundance in a Neotropical forest: impact of climate change. *J. Trop. Ecol. 12*, 231–256.

corlet, R. T., & Primack, R. B. (2008). Tropical Rain Forest Conservation; a global persepective. *Tropical forest community ecology*, 16-23.

Crawford, A. (2012). *Conflict-Sensitive Conservation in Nyungwe Natinal Park: Conflict Analysis.* Manitoba, Canada: The International Institute for Sustainable Development.

Cunningham, A. (2010). *Woodcarvings, drums and monitoring tree resources. A test-case of local level monitoring in Mpanga Forest, Uganda.* Paris: Unpublished report. WWF/UNESCO/Kew People and Plants Initiatives.

D.Wanyoike, P. K. (2015). Effects of Green Public Procurement Adoption in Public Sector: A case stuudy of Pyrethrem and other Industrial Crops Directorate in Kenya. *International Journal of Economics, Commerce and Management (IJECM), III*, 6.

Deutsch, C. A. (2008). Impacts of climate warming on terrestrial ectotherms across latitude. *Proc. Natl Acad. Sci. USA 105*, 6668–6672.

Didham, R. K. (1996). Insects in fragmented forests: a functional approach. *Trends Ecol. Evol. 11,* , 255–260.

Douglas Sheil, R. K. (2003). *Exploring biological diversity, environment and local people's persepectives in forest landscapes, Methods for a multidisciplinary landscape assessment.* Bogor Barat, Indonesia: Center for International Forestry Research.

Ewers, R. M. (2006). Confounding factors in the detection of species responses to habitat fragmentation. *Biol. Rev. 81,(doi:10.1017/*, 117–142.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annu. Rev. Ecol. Evol. Syst. 34, (doi:10.1146/annurev.ecolsys.34.011802.132419)*, 87–515.

Farahani, S. (2018). Ecological Engagement in Tribal Communities in the Context of Common-Pool Resources. *Texas State University*, 19-21.

Fedlmeier, C. (1998). *The Development of secondary forest on abandoned grazing areas, using Costa Rica as an example.* Tubingen: Institute of Scientific Co-operation.

Fikret Berkes, L. C. (2005). Co-management: Concept and Methodological Implications. *journal of Environmental Management*, 65-76.

Gapusi, R. a. (1997). *Espêces rares et en extinction dans la flore Rwandaise. Revue bibliographique.* Butare.: ISAR-RUHANDE.

Gapusi, R. J. (1999). *Identification et Analyse des Options pour la Conservation de la Biodiversite dans la foret Naturelle de Nyungwe,.* Kigali: Direction de l'Environment.

Gasana, K. (1988). *La foresterie sociale au projet Crête Zaire-Nil.* CZN, Gikongoro.

Ghazoul, J. S. (2010). *Tropical rain forest ecology diversity, and conservation.* Oxford, UK:: oxford University Press.

Grainger, A. (2008). Difficulties in tracking the long-term global trend in tropical forest area. *Proc. Natl Acad. Sci. USA 105 (doi:10.1073/pnas.0703015105)*, 818–823.

Hall, P. a. (1993). Methods to assess the impact of extraction of non - timber tropical forest products on plant population. *Economic Botany 47, New York Botanical Garden, New York*, 234-247.

Hardin. (1968). *tragedy of the common.* US.

Imanishimwe A, T. N. (2018). Contribution of Community Conservation and Ecotourism Projects on Improving Livelihoods and Sustainable Biodiversity Conservation in and around Nyungwe National Park (NNP). *Journal of Tourism and Hospitality*, 3-5.

Jamie D. Bechtel, J. P. (2010). *Gender, Poverty and the conseravtion of biodiveristy.* US: MacArthur Foundation.

Jennifer F. Moore, F. M. (2017). Are ranger patrols effective in reducing poaching-related threats within protected areas?

Kibuika F. Mwnagi, W. D. (2014). Assessment of factors affecting sustainability of rural water supply schemes in Nyandarua

county, Kenya. *International Journal of science and Research*, 580.

Killmann, E. F. (2008). *Guide to the Plants of Nyungwe National Park. Illustrated Field* . Kigali .

Klein, M. a. (1998). *About tropical hardwood, hunters and gorillas: Conservation of forest faunain Cameroon.* Netherlands: The Congo Bassin, IUCN.

Köthke, M. L. (2013). *Uniform global deforestation patterns - An empirical analysis.* 23-37: Forest Policy andEconomics, 28 .

Kruger, L. M. (1997). Resprouters vs reseeders in South Africa forest trees: a model based on canopy height. *Functional Ecology 11* (pp. 101-105). Great Britain: British Ecological Society.

Lawton, J. H., & etal. (1998). Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. *Nature 391, (doi:10.1038/34166)*, 72–76.

Levin, S. (2018). *Sustainable Development Goal 15:Life on land.* UN Headquarters, NewYork: UN.

Macdougall, A. S. (2005). Are invasive species the drivers or passengers of change in degraded ecosystems? *Ecology 86*, 42–55.

Magret, O. (2016). *SDG and Biodiversity- the private sector impact.* chicago: PYXERA Global .

Masozera. (2008). Valuing and capturing the benefits of ecosystem services of Nyungwe Forest National Park, SW Rwanda. *University of Florida. Gainesville, U.S.A.*

Mathew. (2016). *Manorama Year Book.* bangladsh: Hind.

Mayaux, P. H., P. A., & Branthomme, A. (2005). Tropical forest cover change in the 1990s and options for future monitoring. *Phil. Trans. R. Soc. B 360,(doi:10.1098/rstb.2004.1590)*, 373–384.

Mbonyitwari, A. (1989). *L'Evaluation ecologique des terres dans le cadre de l'amenagement des foret naturelles de la Crete Zaire- Nil du Rwanda. Memoire presente en vue de l'obtention du grade de maitrise en sciences (MSc).Ecole des Gradues.* Universite Laval.

McNeely, J. A. ( 1994). *Protecting nature: Regional reviews of protected areas.* . Gland, Switzerland: IUCN.

Michael Leone, D. C. (2015). *M. Sc. Thesis: The role of frames on Landscape Management in forest Landscape Restoration: A case study in the Nyungwe Landscape, Rwanda.* Wageningen: Wangeningen University, The Netherlands.

Michael P., M. P. (2010). *Protecting life on Earth: an introduction to the science of conservation.* Berkeley and Los Angeles, California: University of California Press, Ltd.

Milner-Gulland, E. J. (2002). Annual Meeting Wild Meat Group 2003 Wild meat the bigger picture. *Trends Ecol. Evol. 18,(doi:10.1016/S0169-5347(03)00123-X)*, 51–357.

MINAGRI. (1998). *Strategy and action plan for foof security.* . Kigali: Ministry of Agriculture, Livestock, Environment and Rural Development.

MINITERE. (2003). *National Strategy and Action Plan for the Conservation of Biodiversity in Rwanda.* . Kigali: Ministry of Lands, Resettlement and Environment (MINITERE).

MINITERRE. (2000). *Strateies et Plan d'Action pour la Conservation de la Biodiversite dans les Aires Protegees.* Kigali: Direction de l'Environment.

Muderevu, F. (1974). *Estimation de la Regression de la foret naturelle du Rwanda par photo-interpretation.* Kibuye: Project Pilote Forestier.

Mukerji, I. (2012). *Greening of Himalayas through peoples's participation in the state of Himachal Pradesh (Western Himalayas).* Oxford: Paper prepared for the conference on wise management of tropical forest.

Mulindahabi Felix, A. N. (2011). *Ranger-Based Monitoring: 5-Year analysis 2006 to 2010.* Kigali: Wildlife Conservation Society, Rwanda Program.

Nations, U. (2016). *Sustainable Development Goals Report.* New York: UN Publications, Department of Economic and Social Affairs (DESA).

Nations, U. (2016). *Sustainable Development Goals Report.* New York: UN Publications, Department of Economic and Social Affairs (DESA).

NDUWAMUNGU et al. (2010). *Forest Growth and Yield Estimation.* Kigali: GHD Publishing Are LTD.

Nunez, C. (2019, july Tuesday 23). *national Geographical.* Retrieved from national Geographic: https://www.nationalgeographic.com/environment/habitats/rain-forests/

PAB, P. A. (2007). *Joint Commission Field Mission Report. Nyungwe National Park Buffer Zone and Road Issues: March 2007.* Kigali: Protected Areas Biodiversity Project (PAB).

Peters, C. (1996). Beyond nomenclature and use: A review of ecological methods for ethnobotanists. Alexiades M.N eds. *Selected guidlines for ethnobotanists research: A field manual*, 241-276.

Pranav Pal, D. (2016). managing Biodiversity with emphasis on sustainability development. *Ecosy ecology*, 2157-7655.

Rawat U.S., N. K. (2015). Biodiversity: Concept, Threats and Conservation. *Environment Conservation Journal 16(3)*, 19-28.

RDB. (2017). *Guidebook: Gishwati Mukura National Park.* Kigali: Rwanda Development Board.

Renner, D. (1992). *Discussion sur la Phase initiale 1991/92 du Programme de Sensibilisation-vulgarisation de l'UGZ1 Concernant la conservation et l'utilisation durable du massif forestier de Nyungwe.* Kibuye: AUGZ1.

sala, O. (2000). Global biodiversity scenarios for theyear 2100. *Science (doi:10.1126/*, 1770–1774.

Sanjeev, R. (2012). *beware of theloss of diversity.* punjab: RAJ.

Sorg, J. (1978). La Foret de Nyungwe: Exploitation ou protection? *Schweizerischen, zeitschrift fur forstwesen*(129), 445-452.

Stanley, A. a. (1959). *Manual of Vegetation Analysis.* New York: Harper & Brothers, Publishers.

Sue Lautze, A. R.-R. (2003). *"Food Security in Complex Emergencies: building policy frameworks to address longer-term programming challenges".* Tivoli: FAO International Workshop.

Tan, A. (2009). COMMUNITY DEVELOPMENT THEORY AND PRACTICE:. north amarica: IPRC KITABI.

Timothy G. O'Brien, J. A.-H. (2019). Camera trapping reveals trends in forest duiker populations in African National Parks.

*Remote Sensing in Ecology and Conservation*.

Umuziranenge, G., & Muhirwa, F. (2017). Ecotourism asn Potential Conservation Incentive and its Impact on Community Development Around Nyungwe National Park. *Imperial Journal of Interdisciplinary Research*.

UN. (2018). *Review of SDC15 Implementation* . New York: United Nations.

USAID. (2003). *RWANDA ENVIRONMENTAL THREATS AND OPPORTUNITIES ASSESSMENT: Task Order No. 818 under the Biodiversity & Sustainable Forestry (BIOFOR) IQC.* Chemonics International Inc.

USAID. (2015). *UGANDA ENVIRONMENTALTHREATS AND OPPORTUNITIES ASSESSMENT (ETOA).* Task Order Contract: AID-617-TO-15-00005 (REPLACE IDIQ: OAA-I- 14-00016).

WCED, U. (1987). *Our Common Future.* New York: UN.

whitmore, T. C. (1998). *An introduction to tropical rain forests.* Oxford , UK: Oxford University Press.

Wiles, G. J. (2003). Impacts of the brown tree snake: patterns of decline and species persistence in Guam's avifauna. *Conservation Biology 17*, 1350–1360.

Wilkie, D. a. (1999). Bushmeat Hunting in the Congo Bassin: An assessment of impacts and options for mitigation. *Biodiversity and Conservation*.

Wilson, R. J., Davies, Z. G., & Thomas, C. D. (2007). Insects and climate change: processes, patterns and implications for conservation. *Insect Conservation Biology* (pp. 245–279). Wallingford, UK: CABI Publishing.

Wong, C. (2011). *Guidance for the preparation of ESTR products – classifying threats to biodiversity. Canadian Biodiversity: Ecosystem Status and Trends,2010. Technical Thematic Report No. 2.* Ottawa: Canadian Councils of Resource Ministers.

WRI. (2002, june 13). *Why care about Ecosystems systems.* Retrieved from (http://www.wri.org/wr2000/why_care.html): http://wri.org/wr

Wright, S. J. (2005). Tropical forests in a changing environment. *Trends Ecol, Evol. 20. (doi:10.1016/j.tree.2005.07.009)*, 553–560.

WWF. (2014, july Wednesday 22). *htt//wwf.panda.org/ourwork/forest deforestation fonts 2/.* Retrieved from wwf Amazon: htt//wwf.panda

Zimmermann, J. ,. (1994). Responses of trees to hurricane winds in tropical wet forest in Puerto Rico: Imlications for tropical life histories. *Journal of Ecology 82*, 911-922.