ASSISTED NATURAL FOREST REGENERATION TOWARD NATURAL FOREST RECOVERY IN BURNED AREAS OF NYUNGWE NATIONAL PARK

Assessment Report, Project "Sustaining Biodiversity Conservation in and around Nyungwe National Park, Rwanda. Associate Cooperative Agreement No Aid-696-La-10-00001 under Leader Cooperative Agreement No Eem-A-00-09-00007-00

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Introduction background of assisted natural forest regeneration

Wildfires in most undisturbed, tall, closed canopy, tropical rain forests are virtually impossible because a moist microclimate, moist fuels, low wind speeds and high rainfall that create nearly non-flammable conditions. However, rain forests, which were once thought to be resistant to fires, are now experiencing large-scale fires due to unsustainable management practices. The worst forest fires, in terms of burnt area, in recent times occurred in 1997-98 following severe droughts, as experienced during El Niño years.

The fires in the rain forests had a significant negative impact on the seed-bank, seedlings and saplings, which did little to assist the recovery of the original species (Shono et al., 2007[1], Dugan, P. 2000[2], Dalmacio 1987[3]). One of the most important ecological effects of burning is the increased probability of further burning in subsequent years, as dead trees fall over to the ground, opening up the forest to drying by sunlight, and building up the fuel load with an increase in fire-prone species, such as pyrophytic grasses. As consequences, researchers noted that the forest generally "dries out" and light tolerant species such as grasses shrubs and herbs colonize the forest floor (Shono et al., 2007). The need to restore forest in degraded areas to improve their productive capacity, environmental functions, and biodiversity values has been widely recognized (Shono et al., 2007).

Various ecological restoration methods involving planting of tree seedlings have been developed to reforest degraded lands (Shono et al., 2007). One constraint of these methods is the high labor and financial inputs required, which limits their application to relatively large-scale projects (Lamb 1998[4]). A method of reforestation exploiting the natural processes of vegetation recover, known as Assisted (or Accelerated) Natural Regeneration (ANR) has recently been developed and applied in the Philippines, and is a potentially rapid, efficient and cost-effective means to reforest critical watersheds (Dalmacio 1987). Compared to conventional reforestation methods involving planting of tree seedlings, assisted natural regeneration offers significant cost advantages because it reduces or eliminates the costs associated with propagating, raising, and planting seedlings (Dalmacio 1987).

The most destructive fires occurred in Nyungwe National Park in 1997-98 and have opened up the forest canopy in various areas totaling 12% of the forest. As consequences, forest in these areas dried out and light tolerant species such as fern (*Pterdium aquilinum*) rapidly colonized the forest floor building up the fuel load and had negatively impacted seedlings and saplings leading to little or lack of forest regeneration.

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[1] Kenichi Shono, Ernesto A. Cadaweng, and Patrick B. Durst, (2007). Application of Assisted Natural Regeneration to Restore Degraded Tropical Forestlands. Society for Ecological Restoration International, Restoration Ecology Vol.15, No.4,pp.620–626 DECEMBER2007

[2] Dugan, P. 2000. Assisted natural regeneration: methods, results and issues relevant to sustained participation by communities. Pages 195–200 in S. Elliot, J. Kerby, D. Blakesley, K. Hardwick, K. Woods, and V. Anusarnsunthorn, editors. Forest restoration for wildlife conservation. International Tropical Timber Organization and the Forest Restoration Research Unit, Chiang Mai University, Chiang Mai, Thailand.

[3] Dalmacio, M. V. 1987. Assisted natural regeneration: a strategy for cheap, fast, and effective regeneration of denuded forest lands. Manuscript, Philippines Department of Environment and Natural Resources Regional Office, Tacloban City, Philippines.

4 Lamb, D., P. D. Erskine, and J. A. Parrotta. 2005. Restoration of degraded tropical forest landscapes.Science310:1628–1632.

The fern sprouts from fire resistant rhizomes that persists fire in the soil and spread through air-borne spores quickly becoming the dominant species on newly burned areas. Once established, the bracken fern produces a large frond and rhizome biomass that promotes litter accumulation which out compete tree seedlings and saplings. The presence of bracken fern has significantly inhibited, slowed or arrested the natural forest regeneration process on much of the areas affected by fires. These ferns grow fast and rigorously and formed a very dense litter layer of 1 to 2 meters. The dense fern cover gradually depletes the seed bank, which slow down potential regeneration of trees. In additional, bracken fern fronds become highly flammable in the dry season and foster repeated fires that kill seedling and saplings of trees.

The approach of assisted natural forest regeneration aims to strike a balance between high-cost restoration planting to restore biodiversity and the establishment of diversity of forest in degraded areas. Assisted natural forest regeneration accelerates succession by removing or reducing barriers to natural forest regeneration: fern competition is reduced, disturbances are prevented, suitable microclimate is ameliorated by the accelerated growth of naturally established pioneers, and seed dispersal into the site by birds and animals is enhanced by the restoration of forest habitat. It offers significant cost advantages because the costs associated with propagating, raising, and planting seedlings are reduced.

Various efforts tried to address to apply assisted natural forest regeneration to larger scale. The management of Nyungwe National Park has made significant progress in piloting restoration of the original forest at the same time preventing bush fires through assisted natural forest regeneration, community awareness raising and controlling fires once they occur. These efforts are a part of USAID's five-year Sustaining Biodiversity in and around Nyungwe National Park project which seeks to protect the park's wildlife and natural resources by reducing threats such as fire, poaching, and timber harvesting. To counter these efforts, USAID financially supported Nyungwe National Park (NNP) and Wildlife Conservation Society (WCS) in regeneration efforts, including cutting of ferns in targeted plots and maintaining them fern-controlled until new forest seedlings succeed in emerging from the ground. This report highlights the results of three major activities planned and implemented in the scope of restoring natural forest in fire degraded areas.

The scope of work on assisted natural forest regeneration

Following large fires which occurred in Nyungwe National Park in 1997-98, the burned areas were colonized and created dense fern cover which gradually depletes the seed bank, which slow down potential regeneration of trees.

To address the problem of slow regeneration in burned areas, WCS-Rwanda initiated a long-term study to assess how the periodic clearing of the dense layer of ferns (including the thick layer of dry plant material) may enhance forest regeneration in 2001. The ferns, as well as the thick layer of fern litter which accumulates on top of the soil, were cleared to allow seedlings to reach the sun and seeds to reach the mineral soil. On all test plots, tree seedlings were shown to have naturally sprouted both from the seed bank and possibly through seed dispersal by animals. Results showed that cutting treatments significantly assisted forest regeneration, resulting in more trees, taller trees, and more species (Masozera, 2004[5]).

The experimental research also tested tree planting as another method to assist regeneration in burned areas. The results suggested that augmenting natural regeneration with planted trees was not as cost effective compared to clearing ferns. The tree species which did survive well and might be recommended to plant, *Macaranga* and *Neoboutonia*, also regenerated well naturally, offering no added benefit to planting.

[5] Masozera A. Behm 2004. Regeneration of Burned Forested Areas With Periodic Removal of *Pteridium aquilinum* (L.) Kuhn. Ferns (Report in Progress) Nyungwe National Park, Rwanda

The study recommended implementing a strategy of 3-month cutting intervals over a period of three years (Masozera, 2004). The study also suggested that this process would be economically viable and efficient, as well as productive for the communities, if it relied on employing local labor to carry out the majority of the work. Today, the plots initially treated over 15 years ago show steady progress of the regeneration process based solely on the removal of ferns.

During five years of the project, WCS established and maintained 9 hectares for assisted natural forest regeneration through repeated fern cutting (every 3 months for 3 years). Plots were left after trees were tall enough to out compete with fern and other herbaceous. To scale up fern removal in burned areas, WCS compared the effectiveness of using other tools such as strimmer machines instead of machetes to cut ferns in burned areas. The results showed that strimmer machines are more costly in terms of time, maintenance and fuel costs. Strimmer machines can easily cut standing ferns but it is difficult to use them to remove the accumulated layer of dry vegetation material of ferns. Other documented methods of controlling ferns such as biological and chemical control were not tested as they may have negative impacts on the integrity of a highly sensitive ecosystem such as Nyungwe National Park. Hence fern removal by hand held machete proved to be the most cost effective method to restore the forest in burned areas.

We also assessed options of extending skills and techniques of assisted natural forest regeneration to communities around the park. In additional to the park staff, WCS trained community members from two community cooperatives in skills and techniques supervision/team management in the field, plot design, fern cutting with care of seedlings and sapling, and seedling/sapling counting. Trained community members have shown positive and cost effective approach to scale up assisted natural forest regeneration through deployment of many supervised and management teams. For example, with financial support from Global Environmental Funds (GEF/SGP), WCS provided field training and mentorship to community members from two community cooperatives to implement and apply natural forest regeneration technique over 30 hectares. In additional to fern clearing, communities in this cooperative also played a vital role in raising conservation awareness through organization fire prevention campaign in fire sensitive areas around the park. However, community effort requires financial resources and technical assistance over time.

In additional to assisted forest regeneration data collected on annual basis, we also collected intensive data to assess the level of regeneration of tree species and diversity of tree species in plots that have gone under treatment over five year of the project. These data are of importance to provide information whether the project reached its objective and draw-up recommendation of further methods to assist forest regeneration in areas of Nyungwe that still show little or lack of tree regeneration.

Seedling, sapling and tree counting in assisted natural forest plot

Objectives

1. Cutting ferns with hand held machete is intensive and labor demanding work to assist forest regeneration. Upscaling method to assist forest regeneration in Nyungwe National Park aimed to find easy and cost effective method to restore forest in degraded areas of Nyungwe National Park.
2. Removal of fern in designed assisted natural forest plots aimed to restore forest in burned areas of Nyungwe. Measuring seedlings and sapling in assisted natural forest regeneration aimed to assess the level of natural forest recovery in burned areas of Nyungwe National Park in general and in established plot in particularly.

Methodology

We used vegetation plot sampling to count seedling and sapling, and trees. We measured 46 larger plots of which 184 sub plots that went through treatment and 184 untreated (control) sub plots. Plot sampled were established from 2004, 2009, 2010, 2011, and 2012.

Trees were measured at individual level from the sub plot of 3 meter radius (used a rope to measure or tape measure). For each individual tree, DBH and height was measured and recorded. The same sub plot was used to count all saplings, 1 m radius to count all seedlings (figure 1).

After the crews have completed data collection in a plot, they moved eastward and westward and measure other plots at every 20 meters until they complete entire plot. The parallel plots (control plots) were marked northward or (southward if north is not possible) outside the plot in untreated areas. If the direction of plot was North–South, control plot were marked starting Eastward (first option) and Westward (second options). Control plot was started at 5 meters from treated plot and take the same measurement as in treated plot.

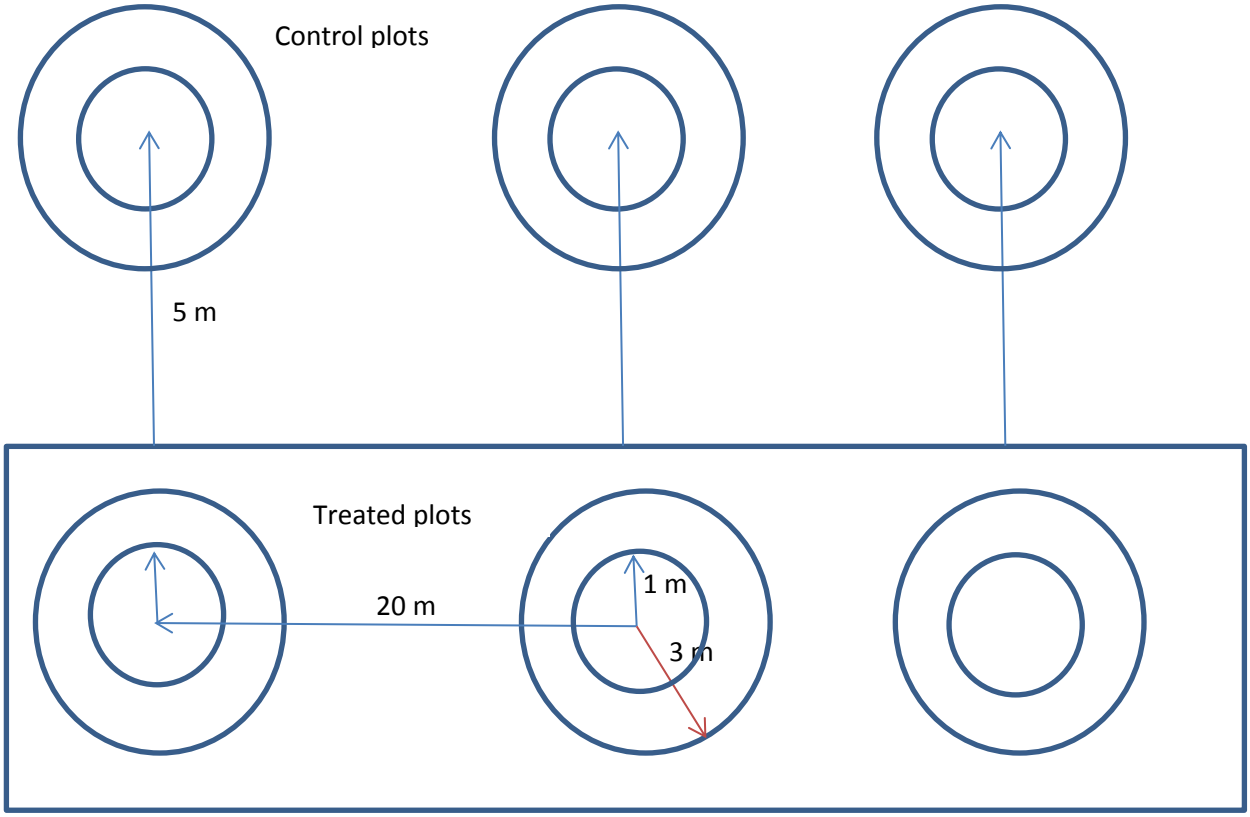

Figure 1. A diagram of sampling design for seedling, sapling and trees sampling in assisted natural forest regeneration plots

Data analysis

Comparative data analysis was used to compare treated area and non-treated area (control plots) using Biodiversity professional software (McAleece, 1997)[6] and Excel.

[6] Neil McAleece N. (1997). Biodiversity Professional beta version, The Natural History Museum, London

Results

Trees, sapling and seedlings were counted in 46 larger treated plots (4.5 hectares) of which 184 (0.52Ha) inner/treated plots and 184 (0.52Ha) plots totaling the area of 1.039 hectares. The size of larger plots ranged from 0.022 Ha to 0.214 Ha. Number of inner plots/sub plots ranged from 3 to 7 sub plots per larger plot depending on the size of larger plot. Seedlings and trees were countered in 368 plots of 3 meter cycles totaling 1.039 Ha. Seedlings were countered from the same number of plots but the size of 1m radius cycle totaling 0.11 Ha (Table 1).

Table 1. Sampling effort of plots for seedling, sapling and trees in assisted forest regeneration plots

	2004	2009	2010	2011	2012	Tot
Treated plots	8	17	55	51	53	184
Control plots	8	17	55	51	53	184
Total	16	34	110	102	106	368

Number of seedling, sapling and trees greater than 5 cm DBH

Number of trees with Diameter at Breast Height (DBH) greater than or equal to 5 cm were measured and countered in treated and control plots. Number of seedlings, sapling and trees greater than 5 cm DBH was much higher in treated plots (**2163 individuals**) than control plots (**121 individuals**) (Table 2).

Table 2. Number of trees. Seedlings and saplings sampled in 46 larger plots (368 sub plots)

Time of establishment	2004		2009		2010		2011		2012		Total	
Treatment	treat	cont	treat	cont	treat	cont	treat	cont	treat	cont	treated	control
Sapling	89	2	185	2	524	37	299		206	9	**1303**	**50**
Seedling	33	4	61	2	44	9	133	2	272	17	**543**	**34**
Trees	83	1	100	3	70	19	46	8	18	6	**317**	**37**
Total woody	**205**	**7**	**346**	**7**	**638**	**65**	**478**	**10**	**496**	**32**	**2163**	**121**

The higher number of trees with DBH greater or equal to 5 was recorded in plots established in 2004 (> 10 trees/plot) followed by 2009 (**5.8 trees/plot**) in treated plots. Number of trees with DBH greater than or equal 5 cm recorded in control plots was less than **0.5 trees/plot** in all sampled control plots (Figure 2). Higher number of trees per plot in 2004 and 2009 treated plots can explain forest recovery in established plots. Number of sapling ranged from **3.89 saplings/plot** (2012) to **11.13 saplings/plot** (2004) inside treated plot and from **0** to **0.67 sapling/plot** in control plots.

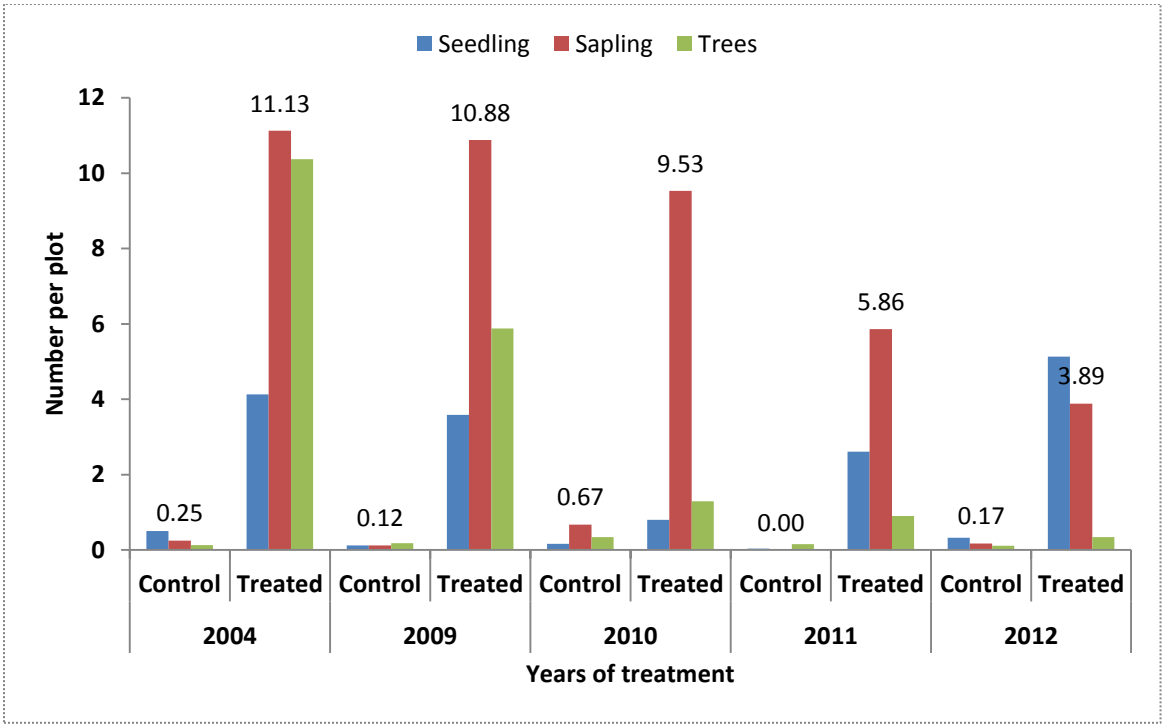

Figure 2. Recruitment of trees, sapling and seedling in assisted forest regeneration plots in NNP (N=368 sub-plots sampled in 46 larger plots).

Density of seedling, sapling and trees

We pooled all years together and calculated density of seedling, sapling and trees for plots that went under treatment and those adjacent plots that were not treated (control plots). The density of seedling, sapling and trees were far higher in treated plot than in control plot (Figure 3).

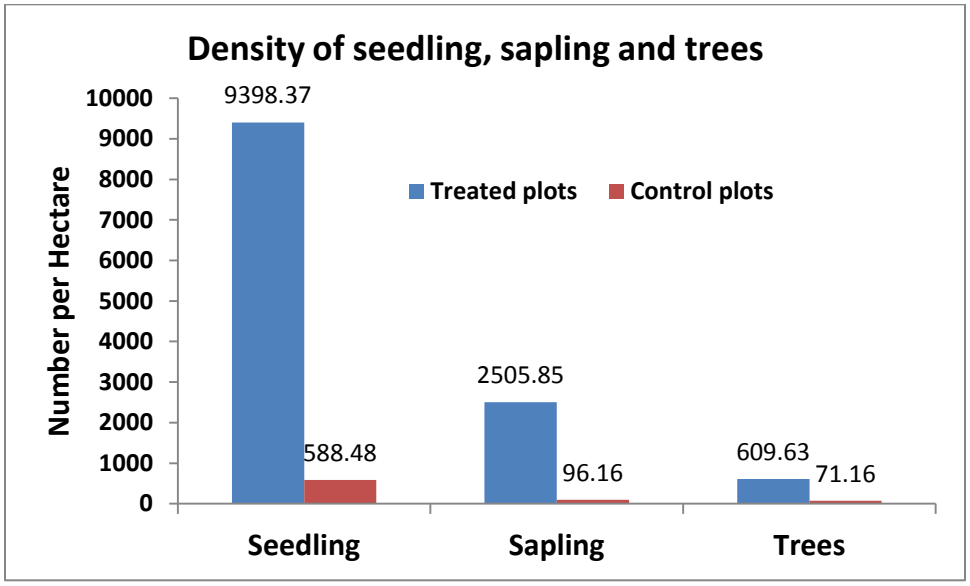

Figure 3. Density of trees, seedling and sapling in assisted forest regeneration

Species richness in treated plots

A total of **23 species of trees was sampled in treated plots** vis à vis **14 species of trees sampled in control plots**. We pooled together seedling, sapling and trees to generate rarefaction curve in treated plots. The rarefaction curve suggests that there are more species in 2004 treated plots but more species and individuals in plots established in 2010 (Figure 4). More tree species in plots established in 2004 can indicate that there is succession in assisted natural forest regeneration. It may be true that trees tend to reduce in number in a given plot when they grow bigger but number of species of trees increases as pioneer species creates shade for shade tolerant tree species. The higher number of seedlings and saplings in recently established plots can indicate that natural forests in the burned area still have capacity to regenerate if it is assisted.

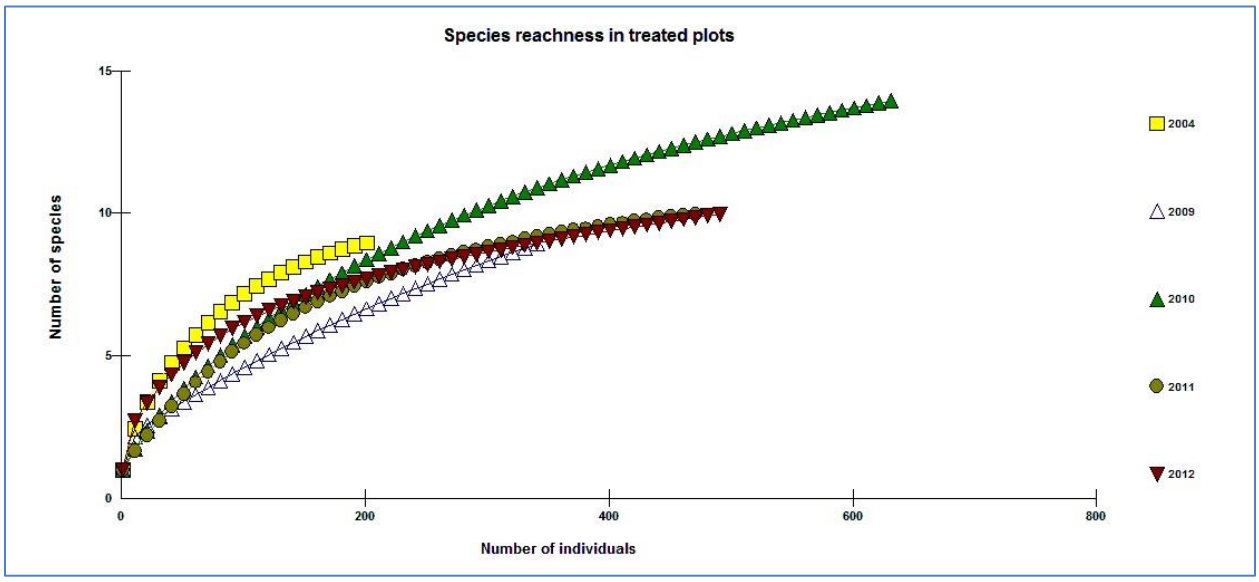

Figure 4. Rarefaction curve showing richness of species in established plots in NNP from 2004 to 2012

Similarity of species recruitment over the years of treatment

Similarity of tree species was less than 10% in treated plots compared with control plots. We compared similarity of tree species recruited in treatment plots over different years and noted that 63.8838 % and 80% similarity of species (Figure 5). The lowest similarity (63.8%) between plots established in 2004 and the rest of plots and the highest similarity (80%) was between plots established in 2010 and 2011.

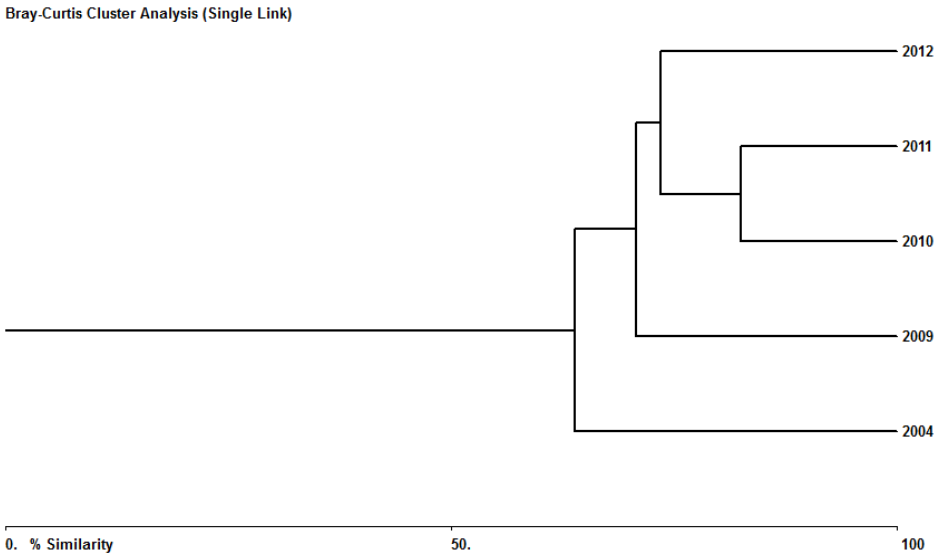

Figure 5. Cluster analysis showing similarities between plots established in different years for assisted forest regeneration in Nyungwe National Park.

Cover of fern and other herbaceous species

Assisted natural forest regeneration aimed to reduce barriers that outcompete tree seedling and sapling. We measure fern and other herbaceous cover in treatment and control plot. The average percentage of fern and other **herbaceous cover was higher control plot (ranging from 60 to 93%)** than in **treated plot (ranging from 12 to 45%**) (Figure 6). Higher percentage of fern and other herbaceous cover in untreated/control plots can indicate slow or luck of tree regeneration by the presence of physical barrier to forest regeneration after 17 years of massive bush fires in Nyungwe.

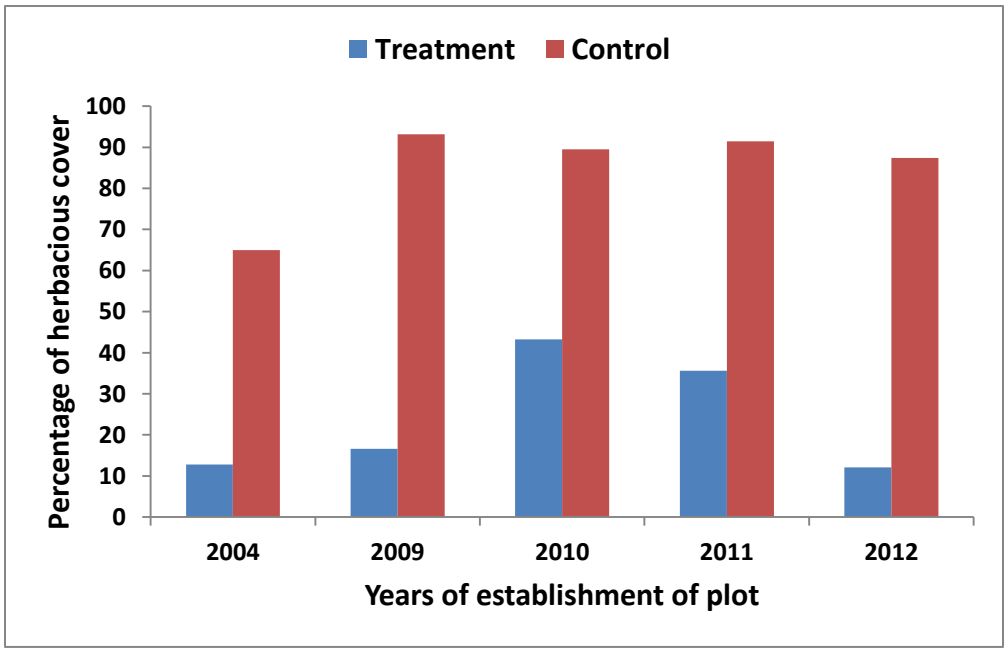

Figure 6. Herbaceous/fern cover in assisted forest regeneration treated and control plots (N=46 larger plots, n= 184 sub plots for each treated and control plots)

Key notes

- ✓ Compared to conventional reforestation methods involving planting of tree seedlings, physical removal of fern by hand held machete was to be cost effective for assisted natural regeneration. It offers significant cost advantages because it reduces or eliminates the costs associated with propagating, raising, and planting seedlings.
- ✓ Assisted natural forest regeneration accelerates succession by removing or reducing barriers to natural forest regeneration: fern competition is reduced (herbaceous/fern cover reduced, suitable microclimate is ameliorated by the accelerated growth of naturally established pioneers, and promotes tree species diversity and tree density.
- ✓ If nothing is done in fire degraded areas of Nyungwe National Park, These areas are likely to remain disturbed/forest not recovered from fire effect. Though forest has regenerated in some burned areas, other areas areas are still showing higher percentage of fern cover, low density of trees, sapling and seedling, low diversity of tree species limiting vegetation succession. There is a need therefore to continue physical removal of fern on larger scale to accelerate forest recovery in areas showing low or lack of tree regeneration. Data collected in plots that have recently treated suggest that burned areas still have potential capacity for tree regeneration without additional seed propagation and or tree planting.
- ✓ In additional to the park staff, WCS selected people from community and trained them in skills and techniques supervision/team management in the field, plot design, fern cutting with care of seedlings and sapling, and seedling/sapling counting. These are added value human resources in the community that can be used to accelerate natural forest regeneration through physical removal of fern by hand held machetes. They will require therefore minimum supervision and technical support for them to be able to carry out all process from plot design, fern cutting and plot maintenance, and regeneration data collection for monitoring.

Appendix 1. Methods most used to control ferns

Methods	Description	Applicability to the NNP context
Biological control		
Live stock grazing*	Bracken ferns are low palatable and are not favored by livestock Bracken fern is considered to be poisonous to domestic sheep and cattle Trampling may cause serious damage to other species including disease transmission	Fern collection for animal bedding and manure for soil fertilization is possible but the cost would be higher than products
Other biological control	Many of biological control failed to significantly destroy bracken fern. No biological agent to control bracken fern	Not applicable
Planting tree species*	Planting first growing native tree species reduces fern cover Planting first growing exotic tree species	Planting native species is possible but it is expensive to implement Planting exotic plant species is not applicable for NNP
Prescribed fire*	Light to moderate prescribed burns tend to have little damaging impact on existing fern plant. It may increase spread out of bracken fern since it creates more light and bracken fern has its rhizomes deep in soil	Not applicable in Nyungwe context
Chemical and physical control		
Foliar applications of glyphosate and others*	Have been successfully used for controlling the fern. Timing for this herbicide is critical, bad timing can affect only above ground fronds	Not easy to apply herbicide in Rwandan national parks, requires multidiscipline EIA study, thus discouraged
Slashing/physical removal**	At least 4 entry manual cuts per year over three years of bracken ferns to slow down re-sprouting of rhizomes.	This method was tested in Nyungwe and was proved successful.
Lime/chalk	Used to reduce acidity	

*[7] Engelman and Nyland (2006)

**[8] Gryze et al., 2009

[7] Interference to Hardwood Regeneration in Northeastern North America: Assessing and Countering Ferns in Northern Hardwood Forests. http://library.umaine.edu/cfru/pubs/CFRU352.pdf

[8] Evaluation of the opportunities for carbon asset development from forest conservation, avoided deforestation, and reforestation in the Congo-Nile Divide Forest Region of the Republic of Rwanda
A carbon feasibility study commissioned by the Government of Rwanda in collaboration with the Wildlife Conservation Society

Appendix 2. Datasheet used to collect data on seedling and sapling counting in assisted natural regeneration plot

Date:_____Site: _____ Plot number:_____ year of establishment:_____

Year/month of last treatment: _____ Treated: Yes____ No_____ GPS: 07……., 97……

Subplot #	# sapling		# of seedling		Tree species			Herbaceous cover		Altitude
	Species	#	Species	#	Species	DBH (cm)	Height	species	% cover	

Long (m)=_____ Larg 1 (m) = _____ Larg 2 (m) = _____ Larg 3 (m) = _____ Larg 4 (m) = _____

Reference

Patrick C. Dugan, Patric B. Durst, David J. Ganz and Philip J, MacKenzie (2003). Advanced assisted natural regeneration (ANR) in Asia and Pacific), RAP PUBLICATION 2003/19

Kenichi Shono, Ernest A. Cadaweng, and Patrick B. Durst (2007). Application of Assisted Natural Regeneration to Restore Degraded Tropical Forestlands. Society for Ecological Restoration International