Feasibility study on the value of honey bees for sustainable livelihood and biodiversity conservation: Case of Nyungwe landscape

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Executive summary

The role of honeybees in sustaining forests and forest dependent livelihoods remains poorly known and appreciated. Their service to mankind is enormous as they carry out pollination of different crop plants without which development of fruits and seeds cannot occur in cross pollinated crops.

Honey is probably the most product that people usually associate to beekeeping although it generates much more than that. The maintenance of biodiversity and pollination of crops are perhaps the most valuable services provided by honeybees. Honeybees produce other hive products of high value such as beeswax, pollen, propolis, royal jelly and bee venom. Hive products are a source of food and nutritional security, raw materials for various industries, medicine, increased government revenue through levies and taxes, improved biodiversity conservation and enhancing environmental resilience.

This investigation showed how beekeeping would get associated to forest conservation and livelihood improvement. The study investigated opportunities and challenges associated to beekeeping development in Nyungwe landscape.

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I.INTRODUCTION

1. Introduction

The service of honeybees to mankind is enormous as they carry out pollination of different crop plants without which development of fruits and seeds cannot occur in cross pollinated crops. They are considered a very successful bee species due to their capacity to adapt to diverse environments and to out-compete many species of native bees (Santos, 2006).

They also are an important element in sustainable agriculture. Their role is essential in maintenance of biodiversity and conservation by their pollination service both to crops and wild plants (Payette, 1996; Dongock *et al.*, 2007).

Many cultivated crops do not yield seeds or fruits without cross-pollination of their flowers by pollinators such as honeybees and other insects. With regard to bees' contributions, about one-third of our total diet comes directly or indirectly from bee-pollinated crop plants (Hoopingarner and Waller, 1992; Jagadish, 2008).

Beekeeping offers a great potential for development and is comparatively less demanding in terms of investment, labor and time. Also, beekeeping is advocated to improve human welfare by alleviating poverty through increased household income: it is a source of food and nutritional security, raw materials for various industries, medicine, increased government revenue through levies and taxes, improved biodiversity conservation and enhancing environmental resilience (Kihwele *et al*, 1999; MNRT, 2004). A decline in bee colonies and bee species could therefore threaten the survival of plant species that depend on the pollination by bees. Some types of plants depend uniquely on their pollination by bees (FAOa, 2007).

It gives local people and the Government economic incentive for the retention of natural habitats, and is an ideal activity in any forest conservation program (Mwakatobe , 2001 ; Okoso-Amaa *et al*, 2004).

Nevertheless, the potential of beekeeping is far too often not exploited in forest activities and development programs, because the benefits of bees and beekeeping are not well known to stakeholders (C. Lietaer, 2009).

In spite of the great economic and biological importance of honeybees as pollinators of agricultural crops and natural vegetation, it has yet not been made an integral part of agriculture and forest management in the developing countries (Verma, 1992).

Munyuli (2011) showed that 90% of interviewed farmers in Uganda were not aware of the role played by bees in coffee yield increase. Beekeeping industry, one of the important agricultural and forest based rural industries in the world, is basically traditional and of non commercial nature in Rwanda. It is often promoted as being a pro-poor income generating activity for poor communities (Sreejith A. *et al.*, 2011).

There is little or no empirical evidence on the potential of honey bees' value for income generation and forest conservation in Rwanda. Beekeeping in Rwanda (universally categorized under 'livestock related' activities) remains underutilized, receives little support or recognition if any, and therefore assumes a peripheral role in relevance with contributions to the national economy. Information on the sector remains scattered with most of the information available amongst various sector stakeholders merely assumptions due to the lack of well defined monitoring and evaluation systems in the sector

(MINAGRI/RARDA, 2007). Honeybees contributions to rural people have hardly ever been assessed (Nel & Illgner, 2004).

In addition, the unsustainable management of honey bees would compromise the livelihood of the population as well as biodiversity conservation especially flowering plants depending on honeybees pollination and associated animals if there are no proper management of African honeybees as well as other pollinators.

Given the socio-economic conditions in Rwanda, protected area conservation is closely linked to community issues and community management of natural resources. The market potential and value of ecosystem services is not well understood. Equally uncertain is the potential for developing viable investments. In addition, raising awareness about the value of ecosystem services provided by forests is an important first step. Several attempts to improve the benefit from beekeeping for people surrounding Nyungwe National Park have been made by institutions active in the area in the last 30 years.

Conservation in Rwanda views conservation of its montane forests as a priority concern. Nyungwe National Park is a recognized site of global importance for its biodiversity and endemism values: among the highest within the biologically rich Albertine Rift ecoregion. This park is also seen as primary source of tourism revenue and ecological services, such as water catchment, pollination services, erosion control, and hydroelectric development potential among others. This forest estate remains under threat from the land and resource needs of a still-growing human population that occupies the rural landscape at average densities of 345 per km^2. These pressures have resulted in past habitat losses and degradation, as well as local species extinctions. To combat these problems, the Government of Rwanda, with support from different

partners, has invested rehabilitation of park infrastructures, restructuring of the national park service, and preliminary strategic planning.

Although many efforts have been put and positive changes achieved so far for the development of apiculture coupled with biodiversity conservation in Rwanda particulary in Nyungwe landscape by Wildlife Conservation Society (WCS), RDB-Nyungwe National Park, local NGOs as well as local authority, there is still much to do to make beekeeping much more profitable.

The aim of this feasibility study was to evaluate the relative effectiveness of beekeeping in Nyungwe landscape to reduce poverty levels and to determine the influence of the activity on forest conservation.

The objectives of the study were:
- To explore the information avairable regarding beekeeping development in Rwanda
- To conduct field survey regarding beekeeping development around Nyungwe National Park
- To analyze gaps existing in the beekeeping industry in Rwanda

II. METHODS

2. Methods

2.1. Study area

The feasibility study was carried out around Nyungwe National Park in areas of Kitabi in Nyamagabe District, Muganza in Nyaruguru District and Rangiro in Nyamasheke District.

Figure 1: Study area

This Park is Africa's largest remaining block of lower montane forest. It is Rwanda's most important water catchment, providing an estimated 40% of dry season flow in the Nyabarongo River system. More than 235 tree species are found in a rich variety of associations within Nyungwe's 1,013 km2, across an altitudinal gradient from 1600 m to 2990 m. *Entendrophragma excelsum* is a giant (50-60 m) emergent, previously overexploited for its valuable mahogany-like hardwood. The distinctive forms of *Newtonia buchanii*, *Symphonia globulifera*, and *Syzigium parvifolium* also dominate the upper canopy, while providing food and

shelter for diverse biota. Native bamboo (*Arundinaria alpina*) is limited to barely 16 km^2 in southeastern Nyungwe, where it supports the only population of owl-faced monkeys outside of the Congo Basin.

Poaching of wildlife is a prime concern for this Protected Area, as is the illegal cutting and collection of wood, bamboo, and grass. Fire is the number one threat facing Nyungwe, where more than 13,000 ha have burned over the past decade – primarily due to human-set fires, complicated by drought conditions. This in turn is linked with problems of regeneration following disturbance. Mining also ranks fairly high on the Nyungwe threats list, although this decades-old problem appears to be largely under control in recent years.

It is Rwanda's newest—and largest—national park. It is situated in the southwest of the country and, along with the contiguous Kibira National Park in Burundi, lies in Africa's most biodiverse region, the Albertine Rift. The park straddles the Nile and Congo river basins and is crucially important to Rwanda's water supply: 70 per cent of the country's rain falls in Nyungwe. It is home to a wide variety of flora and fauna, including approximately 100 species of orchids; 13 species of primates, including chimpanzees, L'Hoest's monkeys, blue monkeys and large colonies of Angolan colobus; almost 300 bird species, including a number of enigmatic turacos; and a number of other species of mammals, reptiles and insects.

The forest was first protected in 1903, when it was declared a forest reserve by the colonial administration, but protection was not expanded until more than a hundred years later, when in 2005 Nyungwe was finally declared a national park. Rwanda Development Board is responsible for the management of the park, and is supported by a strong partnership with Wildlife Conservation Society.

2.2. Methodology

The approach was to conduct a feasibility study on beekeeping development in order to develop sustainable, long-term economic activities that would benefit biodiversity and reduce poverty around Nyungwe National Park. This pilot study was conducted around Nyungwe National Park and is to facilitate the development of a full project plan on the value of honeybees for livelihood improvement and biodiversity conservation.

2.2.1. Desk studies

During these studies, information already available in print or published online regarding beekeeping development in Rwanda was explored, gathered and analyzed. It has involved exploring organizations working or holding beekeeping related information. These included Wildilife Conservation Society and SNV, Ministry of Agriculture as well as Rwanda Development Board.

2.2.2. Field survey

Field surveys were conducted at Kitabi, Muganza and Rangiro in the vicinity of Nyungwe National Park. Apiaries in these areas were inspected and interactions with community members were held in guidance of Wildlife Conservation Society and beekeeping cooperative members.

Discussions were held with groups of varying sizes depending on the level of participation. The importance of beekeeping and problems associated with it were discussed. Local human activities were

documented by use of depth interviews and focused group discussions. Direct observations activities carried out around the park were made.

Semi-structured interview method were adopted to assess drivers such as training and information, conservation, policy-related support, and market access. Local cooperatives and individuals were selected for interview using purposive sampling (Patton, 2002; Cohen, Manion & Morrison, 2007). Information on people's perception on Nyungwe National Park and its sustainability were collected.

In order to standardize information to be gathered from field with key informants, questions about bee populations, honey yields and prices, honey processing and harvesting practices, disease symptoms and treatment, pests of bees, insecticide poisoning, hive sanitation, hive inspection practices and comments of farmers about beekeeping were formulated. These interviews targeted active stakeholders i.e beekeeping development partners (WCS), beekeeping cooperatives and their union, beekeepers themselves as well as experts.

2.2.3. Gap analysis

Gaps in the beekeeping sector were documented and analyzed. It consisted of (1) listing of characteristic factors of the present situation, (2) listing factors needed to achieve future objectives, and then (3) highlighting the gaps that exist in the beekeeping sector in the area that need to be filled.

2.2.4. SWOT analysis

This analysis helped to determine what may assist beekeeping project in accomplishing its objectives, and what obstacles must be overcome or minimized to achieve desired results.

2.2.5. Cost benefit analysis

It involved the evaluation of all potential costs and revenues that may be generated when a beekeeping project is completed. The outcome of the analysis has determined whether the project is financially feasible, or if another project should be pursued.

III. DESK STUDIES

2. Desk studies

2.1. Beekeeping development in Rwanda

2.1.1. Introduction

Apiculture is an activity in which man rears honey bees and acquires their products. So long as a honey bee is an animal, the apiculture is generally treated as a form of animal husbandry in a broader sense of the word, and consequently in many countries and regions it is supervised specifically by the administrative structure which controls livestock industry within the larger sector of agriculture (JAICAF, 2009).

2.1.2. Overview on African honeybees Apis mellifera

2.1.2.1. Introduction

Honeybees are classified into the family Apidae and the genus *Apis*. There are four accepted groupings of honeybee species with three of these species groups further subdivided into additional species. The african honeybees belong to the

Phylum: *Arthropoda*

Class: *Insecta*

Order: *Hymenoptera*

Superfamily: *Apoidea*

Family: *Apidae*

Subfamily: *Apinae*

Tribe: *Apini*

Genus: *Apis*

There are about 11 African races of honeybees namely *A. m. lamarckii, A. m. jemenitica, A. m. litorea, A. m. scutellata, A.m. sahariensis, A.m.intermissa, A. m. monticola, A. m. adansonii, A.m.major, A. m. unicolor and A. m. capensis* (Peter.G. Kevan, 1995; Friedrich Ruttner, 1988)

The behavioural and biological characteristics of each race can be distinctive and each race will have their own value and disadvantages for the beekeepers wishing to keep them. In general these differences arise in response to evolotionary pressures and so enable each race to maximise its capacity for survival within a given environment. In particular, there are significant differences between tropical and subtropical and European races of honey bees. This is an evolutionary consequence of adaptation to different habitats. The difference between races is so marked that it affects the management of these differing bees. However, even within races, there can be tremendous genetic variation and determining what is a typical honey bee race is often subjective. These naturally occurring genetic variations are what bee breeders use to enhance desired characteristics and reduce those that are less desirable.

2.1.3. Beekeeping in Rwanda

Apiculture is an activity in which man rears honey bees and acquires their products. So long as a honey bee is an animal, the apiculture is generally treated as a form of animal husbandry in a broader sense of the word, and consequently in many countries and regions it is supervised specifically by the administrative structure which controls livestock industry within the larger sector of agriculture (JAICAF, 2009).

2.1.3.1. Types of honeybees found in Rwanda

There are two groups of bees that produce honey and other bee by-products in Rwanda. The first group which is domesticated belongs to the *Apis* species with *Apis mellifera*, the only *Apis* species found in Africa. According to studies, there are two races of *Apis mellifera* in Rwanda namely *Apis mellifera scutellata* which inhabits lowland areas of the country at around 500-2400 m – between the range of *litorea* and *monticola*. The *A.m.scutellata* area is characterized by two dry periods between cool rainy seasons (16-23°C). The bees are relatively large corresponding to the altitude (temperature) of its habitat. Generally *scutellata* is regarded the African bee. In several countries *scutellata* beekeeping is practiced with movable frames. The other bee race found in Rwanda, *A.m. monticola*, has a special position among honeybee races. It is entirely isolated by ecological factors showing a unique disjunct distribution. It is the bee of the mountain rain forests in East and West Africa at altitudes of 2000-3000m (11°C – 21°C). In spite of this cool climate, *monticola* can not be compared to races of the temperate zones (with cold winter) as longer periods without flight activity do not occur. *Monticola* drones are uniformly dark (as are many other bee species in higher altitudes) (Peter.G. Kevan, 1995; Friedrich Ruttner, 1988).

The second group of honeybees belongs to the group of stingless bees (Meliponae) not well known in Rwanda but much more valued in other countries including the neighboring Tanzania because people beleave that honey produced by stingless bees has a very high medecinal value. Keeping these bees is reffered to meliponiculture in contrast to apiculture (Peter.G. Kevan, 1995; Friedrich Ruttner, 1988).

2.1.3.2. Beekeeping development in Rwanda

Beekeeping activity has been practiced for many years through successive generations and along inherited patterns. The activity has basically been traditional and of non commercial nature, where honey was used as a food product, medicine and for brewing traditional liquor. Prior to the 1994 genocide, attempts were made to support the sector through modernizing systems and the Ministry of Agriculture and Animal Resources (MINAGRI) contracted ARDI, a national capacity building organization, in 1992 to undertake extension and training support of beekeepers. Subsequent support for the sector has mainly been through community based natural resource management projects around the protected areas with key organizations such as ORTPN, World Conservation Society (WCS), International Gorilla Conservation Project (IGCP) and ADAR project(now closed). Communities in these areas have been provided with some level of training, processing equipment and a number of modern hives with mixed results mainly due to the creation of unsustainable donor dependent supply chains. Production is mainly through traditional methods and the few modern techniques introduced have not been successful due to un-sustainable implementation methods. The introduction of modern technologies namely the Kenya Top Bar Hive (KTBH) and Langstroth hive have been accompanied by severe flaws in design, quality, lack of appropriate hive management training for these, and inappropriate approaches to projects supported by unrealistic 'artificial markets' for products by project grant providers. (MINAGRI, 2007). Production and harvesting of honey and beeswax has been restricted to traditional harvesting techniques leading to low production, poor quality of products due to excessive use of smoke, poor post harvest handling and inadequate bulking mechanisms. Studies undertaken on the sector in 2004 by SNV Netherlands Development Organization Rwanda show that the production of traditional hives (which is in excess

of 95% of the total hive population) per season was at an average of 3Kgs per hive, comparatively low compared to regional statistics for the same which translated to an average of 15kgs per season per hive. Recent information however peg the average production at 5Kgs per hive per season. The number of harvests seasons equate to 2 per year, thereby translating to an average of 10kgs per hive (SNV, 2004).

2.1.3.3. Importance of beekeeping

The least visible livelihood outcome is the pollination of flowering plants, both wild and cultivated: this is an outcome impossible to quantify. Honey is a traditional medicine or food in nearly all societies and whether sold in a simple way at village level or packaged more sophisticatedly, honey generates income and can create livelihoods for several sectors within a society. Beeswax is also a valuable product from beekeeping, although in some places its value is not appreciated. Industrialized countries are net importers of beeswax, and the supply comes from developing countries.

Beekeeping plays a critical role in the livelihoods of the rural communities in five native dynamics:

(1) it is an income generating activity
(2) medicinal value of honey and other hive products is invaluable
(3) it supports agricultural activities through facilitating critical processes for example cross pollination and improves crop and seed yield
(4) it contributes immensely to forests conservation efforts
(5) it facilitates healthy linkages between biodiversity (insects and plants) towards sustainable livelihoods. It is also a low-investment and low-input business enterprise that directly generates economic gains for the

participating members and integrates well with agriculture that forms the main economic activity for communities living in the rural areas.

Its advantages are numerous also bearing in mind that it can be practiced by men, women, and youth. According to a baseline survey carried out by SNV Rwanda in 2007, across 17 high potential honey production Districts in Rwanda showed that there were an estimated 30,293 beekeepers of whom 18,430 were men, 7,233 women and 4,630 were youth. The total number of hives was estimated to be 92,971 with 84,255 being traditional log, mud and other indigenous hives while the modern hives were estimated to be approximately 8,716 (SNV, 2009).

Honey is the main beekeeping product. It is consumed widely across the country as a table food, for its medicinal qualities, preservative, or medicine. As a food, honey is consumed for its rich fructose and glucose levels, making it a natural source of energy. The high sugar levels and its ability to catalyze fermentation make honey a suitable raw material for brewing liquor hence it is also used for the industrial production of local beer. Its antioxidant and microbial properties make it ideal as a preservative in foods, including meat, poultry and pastry – this is mostly by large food processing companies (SNV, 2009).

The sub-sector also harbors a great potential for increasing incomes and supportive sustainable development, especially considering the varied players and activities along the broader chain. According to figures from Rwanda Development Board (RDB), in 2012, Rwanda had 83,000 beekeepers with an estimated 93,000 beehives. Available statistics from RDB show that annual production was 311 tons in 2010 and honey demand was 1715 tons in 2012 (RDB, 2012).

2.1.3.4. Beekeeping and natural environment conservation

In the areas where the acquisition of honey bees depends on wild colonies and the nectar sources depend on natural vegetation, the basic elements of apiculture derive from the richness of the nature that provides two resources. Therefore the closer the relationship between life and apiculture becomes, the much higher the consciousness of conservation of forest and natural vegetation is raised. People eventually come to realize through experience that unless they conserve and manage the natural ecosystem appropriately, apiculture itself would not be able to keep on going any more (Jun Nakamura et al.,2009).

Conservation of natural environment could be summarized into the following 6 categories

2.1.3.4.1. Conservation of natural forest and natural vegetation (breeding grounds of wild honey bees)

Since apiculture depends on swarms of wild colonies, the necessity of conservation of wild bee colonies as the source is recognized. As activities resulting from the recognition, the conservation of natural vegetation, habitat of wild bee colonies, for their breeding grounds can be cited.

2.1.3.4.2. Conservation of natural forest and natural vegetation (conservation of nectar/pollen sources)

In the apiculture which depends on the natural vegetation for nectar sources, the richness of natural vegetation assures the richness of the nectar source and sustains the honey production. The ecological structure like this can be recognized most readily by beekeepers from the viewpoint of economics that the natural vegetation as nectar sources is

equivalent to the production of honey, and constitutes the most important element in the principle of conservation. When the activities of apiculture is introduced and developed, the more heavily a region depends on the natural environment for nectar sources, the higher can become the level of improvement of awareness of conservation of natural vegetation (recognition that it is important to respect the forest preserve and to protect the remaining vegetation, from the viewpoint of conservation of nectar sources), and the level of responsive actions of the residents there.

2.1.3.4.3. Restoration and rehabilitation of natural vegetation

Beekeepers who have got conscious of the reduction of natural nectar sources will become cooperative for the cause of restoration of natural vegetation. Moreover, highly conscious farmers and those depending more on apiculture are able to take responsive actions to facilitate the restoration of vegetation suitable for apiculture on their properties and farmland, such as the exclusion of animals from such areas in order to secure the nectar sources. The activity of apiculture on its own increases the number of individual honey bees, and hence promotes the pollination by their intermediary visits, increases the seed production by plants of nectar sources and thus assists the acceleration of restoration of vegetation.

2.1.3.4.4. Reduced expansion of agricultural land

If sufficient cash income is generated by apiculture, the necessity for dependence on agricultural crops is reduced, and hence the necessity for expansion of agricultural land by felling and clearing natural forests diminishes. Under the current situation that the reduction of forests has

become a continuous trend, this fact can be considered as an important activity of conservation in a different connotation.

2.1.3.4.5. Reduction of cutting down pressure (conversion from charcoal production)

Although it does not apply to all areas, in many parts of semi-arid regions in Africa, because of insufficient rainfalls, the crop productivity is low and the interval between rainy seasons is long. Consequently, at the time before and immediately after the beginning of the rainy season, farmers often run out of provisions and have to purchase food by cash. Many local residents lacking other means of earning cash, such as selling of animals, practice charcoal production around this time to raise the cash for purchasing food by selling the product to urban areas. If apiculture is introduced and cash is earned by the activity before the rainy season, the reduction of forests cut down by charcoal production can be expected. Furthermore, among tree species used for charcoal production, there are many species which are particularly important as nectar sources. If apiculture can be introduced and developed in those areas where these species still remain, it is likely that many local residents would come to convert their attitude toward the forest trees, recognizing that they are the nectar sources and not the crude material for producing charcoal. Such conversion signifies a direct change of paradigm of exploitation of existing forest trees from utilization by cutting down to that by conservation (Jun Nakamura et al.,2009).

2.1.3.5. Challenges to beekeeping development

2.1.3.5.1. Bee colony loss

1. Starvation of bees

Lack of food is a major contributing factor to disease susceptibility in bees, but can also result in death of a colony. Starved bees are often found with their heads stuck inside dry combs or dead on the bottom of hives with no honey. Prolonged dearth periods, cold temperatures in some places, and over-cropping of honey without sufficient supplementary feeding leads to starvation of bees. In the rain season, if honey stores have not been sufficiently accumulated before the start of the heavy rains, bees can be unable to go out to collect sufficient food due to rain. Sufficient flowers yielding nectar may also be unavailable (Naomi M. Saville and Narayan Prasad Acharya, 2001).

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2. Wax moth

The wax moth is a Lepidopteron that specialises on eating beeswax. Two species of wax moth are known, the greater wax moth (*Galleria mellonella*) and the lesser wax moth (*Achroia grisella*). The wax moth larvae burrow through combs eating beeswax, pollen and honey, damaging developing bees in the cells through which it tunnels. As it eats the combs it creates a silky trail like spiders web. Eventually whole combs become covered in this kind of 'web' and disintegrate when handled. Usually wax moths are only able to infest empty combs that cannot be covered by bees, so colonies that have become weaker and have left previously covered combs empty of bees are more susceptible than strong colonies that cover all the combs in the hive. The wax moth larvae grow in size up to about 2cm long and then pupate in corners of

the hive. The pupae spin cocoons that dig themselves into the wall or corners of the hive. These leave a small distinctive 'scar' on the wood, which can show even after wax moth have stopped infesting a hive (Naomi M. Saville and Narayan Prasad Acharya, 2001). There are many options available to beekeepers to practice integrated management of wax moths (The State of Western Australia, 2007):

a) Preventive Cultural Practices

Beekeepers should maintain strong and healthy colonies by practicing good colony management to help the bees defend against wax moths.

b) Genetic control

Wax moth control can be enhanced indirectly by the use of bees that have been selected for resistance to disease and other pests. These resistant strains of bees should be more tolerant of some of the primary problems that affect bee colonies which often create stress conditions that "open the door" to secondary invaders like wax moths. Bees that have been selected for hygienic behavior are normally better housekeepers which remove colony debris that creates conditions favorable for increased wax moth reproduction

3) Mechanical control

Traps can play an important role in a wax moth integrated management plan because of their safety in providing control without fear of hive product contamination. The most used is a 2 liter clear soda bottle. A 1.25 inch (3.2 cm) diameter hole should be cut in the side of the bottle just below the shoulder of the neck. The ingredients for the bottle trap include one cup white vinegar, one cup granulated sugar, one cup water,

and one banana peel. The bottle should be set aside a few days until the contents begin to ferment after which the bottle should be suspended a few feet off the ground using wire or string making a noose opposite the side of the entrance hole. Wax moths adults will be attracted by the trap contents and will enter the bottle entrance and die because they are unable to escape.

d) Physical control

- Cold Treatment: minimum cold temperature storage time required to kill all life stages of wax moths in honey-extracted comb include: 20ºF (-7ºC) for 4.5 hours, 10ºF (-12ºC) for three hours, or 5ºF (-15ºC) for two hours

- Heat Treatment: heat can be used to kill all life stages of wax moths by using the following exposure periods: 115ºF (46ºC) for 80 minutes or 120ºF (49ºC) for 40 minutes.

- Carbon Dioxide Treatment: carbon dioxide can be used as a fumigant to control wax moths in stored comb or comb honey.

e) Biological Control

- B401, a microorganism, is a product manufactured by Vita-Europe Ltd. for the biological control of wax moths.

- The product is a bacterium, *Bacillus thuringiensis* subspecies *aizawai* that is manufactured specifically for wax moth control in stored comb

- The bacteria is used to kill young wax moth larvae as they attempt to feed on comb and must be used as a preventive before combs are infested.

f) Chemical control

- The use of chemicals in an integrated pest management program is recommended as a last resort when other options have failed or are not possible.

- Paradichlorobenzene (PDB) and Aluminum Phosphide (Phostoxin) are used in the USA to control wax moths

- PDB is only used on stored combs as it may contaminate honey while used in live bee colonies.

3. Queenlessness and worker laying

Colonies die if they lose their queen for some reason. Reasons for death of the queen could be predation on mating flights, disease or damage by pests, old age, or weakness resulting in usurpation of the queen by the workers. Too much swarming and / or untimely destruction of queen cells by the beekeeper can also lead to queen-less-ness. Worker laying

results after a new queen fails to emerge from queen cells (special cups that the workers produce for raising queens once the old queen has gone). The scent of the queen 'controls' the worker's urge to lay eggs so once the queen has died workers 'try to become queens' by laying eggs. Since worker bees can only lay drone (male) eggs a queen less worker-laying colony will slowly die unless provided with a new queen (that gets accepted by the bees). The colony only comprises old workers and drones. Drones do no work and do not help the colony to survive and new workers cannot be raised, so gradually the bees die off.

Worker laying can only be remedied completely by replacing the lost queen, but first the laying workers need to be disposed of, otherwise they will kill a new queen or queen cell. All combs of a laying worker colony and all bees need to be shaken out so that all the bees fall to the ground 50-100m from the hive. The laying workers, which are full of drone eggs and thus very heavy, cannot fly back to the hive and so only non-laying workers remain. Once the bees have been shaken a queen may be introduced in a cage a day after shaking off the bees. If no queens are available combs with new eggs, sealed brood, pollen and honey stores (and if possible a comb with a queen cell already formed too) can be given to the colony from a good strong non-diseased colony to help the bees rear a new queen (Naomi M. Saville and Narayan Prasad Acharya, 2001).

4. Robbing

Robbing is the term for fighting between 2 or more colonies of bees. Usually it is caused by non-resident bees entering another colony's hive in order to steal honey. The resident bees detect the intruder bees by their smell and fight with them, usually attempting to sting them to death. Once alarm pheromones (smells secreted by the stinging bees) reach a certain level in the air these can stimulate nearby colonies to join in the fight, which means that very large numbers of bees can be killed. If robbing reaches sufficiently high levels weaker colonies can be totally destroyed by stronger ones. Beekeepers can control robbing by never spilling sugar syrup or honey around the apiary and by removing any remaining sugar syrup or honey feed from weak colonies that are unable to consume their entire feed overnight.

If bees from another colony are found to be robbing at the hive entrance sprinkling water on the fighting bees and putting scented herbs such as *Artemisia indica* beside them to break down the pheromone signals can help stop it (Naomi M. Saville and Narayan Prasad Acharya, 2001).

5. Absconding

Absconding is the term for when all the bees from a hive leave and desert the combs. Usually absconding occurs as a result of disturbance or attack by pests and diseases. Soaking with rain, excessive smoke, too much human disturbance, jarring of the hive causing combs to fall and other such disturbances are common causes of absconding (Naomi M. Saville and Narayan Prasad Acharya, 2001).

6. Mice

Mice may invade beehives and eat comb, honey and even developing brood. Generally they cause a problem in winter when the bees are dormant, rather than at times when the bees are very active. If a colony is weak a mouse attack could kill it but usually mice are less likely to destroy a colony than the bigger mammals (Naomi M. Saville and Narayan Prasad Acharya, 2001).

7. Ants

Ants may infest a bee colony and feed upon larvae and honey stores. Usually ant populations are not high enough to severely damage colonies in the hills of the Nepal but in warmer climates they can damage colonies and / or cause absconding. If ants become problematic a hive may be places on a stand with the stand feet inserted into bowls of water that are not allowed to dry. So long as vegetation or other 'bridges' for ants to access the hive are removed the water if kept topped up and clean will stop ants accessing the hive (Naomi M. Saville and Narayan Prasad Acharya, 2001).

8. Lizards

In certain areas lizards can be a major predator of bees. Large lizards tend to wait near the hive entrance and prey upon foragers leaving or returning to the hive. Small lizards can occasionally be found inside hives where presumably they prey on bees. Although lizards are a relatively major predator of bees, other than killing them directly, there is no known way of controlling them. Since they only eat individual foragers, they are less problematic than bears and pine martens, which

can destroy entire apiaries within the course of a few nights (Naomi M. Saville and Narayan Prasad Acharya, 2001).

9. Insecticide poisoning

Insecticide is a very serious cause of bee mortality in the World. Whereas in some more developed countries relatively 'bee-safe' insecticides are being promoted, in developing countries it is not the case. New users of insecticide are often insufficiently informed of the toxicity of the chemicals to bees, humans and livestock. Instructions, if provided at all, are rarely in a language that users can read and sometimes Agricultural Extension workers themselves are unaware of the danger to bees. As a result of insecticide misuse bee colonies die in large numbers. An entire colony can be killed within 3 hours if feeding close to an area where insecticide is being applied. Aside from killing foraging bees in the field, nectar or pollen carrying the toxin may be carried back to the hive and fed to nurse bees and larvae such that the whole colony is destroyed.

If insecticide is to be sprayed at all in areas where bees forage or where beehives are located it should be applied at just after dark. If this is impossible, then beekeepers should be informed of the day and time of day that sprays will be applied so that they can close up hives from the dawn if that day, using wire mesh or other material which provides ventilation but keeps the bees trapped inside the hive (Naomi M. Saville and Narayan Prasad Acharya, 2001).

2.1.4. Social economic activities associated to Nyungwe National Park

Human dependence upon forests is a multifaceted phenomenon due to the fact that forests provide a diverse stream of benefits to humans (Beckley 1998 in Masozera 2002). Humans depend upon forests directly for timber, non-timber products, and recreational experience and indirectly for things such as air and water quality, biodiversity, carbon sequestration, and other ecological services (Masozera 2002). In the southern parts (Southern Province) where Nyungwe National Park is located, the main poverty-environment issue is soil erosion and soil infertility, largely due to over cultivation, use of inappropriate technology and lack of external inputs (REMA, 2006). The situation for people around Nyungwe Nyungwe National Park 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).

Sixty percent of Rwandans live below the officially established poverty level, with some of the highest poverty rates in districts bordering the Volcanoes and Nyungwe parks. Landlessness is also concentrated to a high degree in these areas. In Southern Province (Former Gikongoro), along Nyungwe's eastern border, 59% of families own less than 0.2 ha of farmland; in Western (Former Cyangugu) Province to the west of Nyungwe, 37% have less than 0.2 ha. Gikongoro also has the highest percentage of renters (19%), who are generally less likely to use soil and other conservation practices (Bush 2004). Still, it is notable that roughly 25% of all families living around Nyungwe National Park plant and maintain small woodlots on their private parcels: a significantly higher percentage than for those living around comparable Protected Areas in southwestern Uganda (Plumptre et al, 2004).

It is no surprise that people living in sectors bordering Nyungwe National Park depend on the natural forest for at least some of their subsistence needs (water, wood, bamboo, honey, medicines). In their large-scale study of Albertine Rift communities, Plumptre et al (2004) found that small, but significant minorities of those living around the Nyungwe National Park (12%) admitted entering the park illegally to cut and collect wood, bamboo, poles, or bean stakes. In a smaller, but more detailed study of community relations around Nyungwe, Masozera (2002), found that 22% of participants admitted to such illegal use. Water access is further complicated by the fact that one-third of all rural water sources in Rwanda need rehabilitation, according to the national Poverty Reduction Strategy (PRSP 2001).

This would get complicated by the fact that surrounding communities are not included in park's decision-making processes and are not permitted to access the natural resources within its boundaries.

Tourism is growing by approximately 30 per cent per year; in 2010 the park welcomed approximately 4,000 visitors. Tourists are drawn to the recently opened canopy walk, chimpanzee and colobus-tracking opportunities, hiking trails and birding. There is, however, currently no mechanism in place to monitor growth in tourism, nor is there a concerted tourism strategy for Nyungwe.

Five per cent of national tourism revenues are allocated to projects in communities near each of Rwanda's three national parks: Volcanoes, Nyungwe and Akagera. Funding is divided among the parks (Volcanoes receives 40 per cent, Nyungwe 30 per cent and Akagera 30 per cent), and is then distributed to communities in the districts surrounding each park. Funding typically goes to support housing and education projects, mainly in those communities that pose the biggest threat to the park.

The main challenges to the continued protection of Nyungwe's ecosystems and biodiversity are population pressures, high rates of poverty, a high reliance on natural resources for livelihoods in the communities surrounding the park, forest fires (fires in 1997 consumed 5 to 8 per cent of the park), hunting pressures (particularly for large mammals), pressures from artisanal and industrial mining, and deforestation for firewood and construction materials.

2.1.5. Conclusion

In this section of the research, types of Apis mellifera species were discussed with two races (A.m.scutelata an.m.monticola) identified to occur in the beekeeping sector in Rwanda. There are about 83,000 beekeepers with an estimated 93,000 bee colonies where most of them practice traditional beekeeping (more than 95%) and support for the sector has mainly been through community based natural resource management projects around the protected areas. The general importance of beekeeping including the implication of honeybees in the conservation of both agricultural crops and natural vegetation was discussed. This section has also documented major challenges to beekeeping development including bee colony loss due to several factors.

IV. FIELD SURVEY

4. Field survey

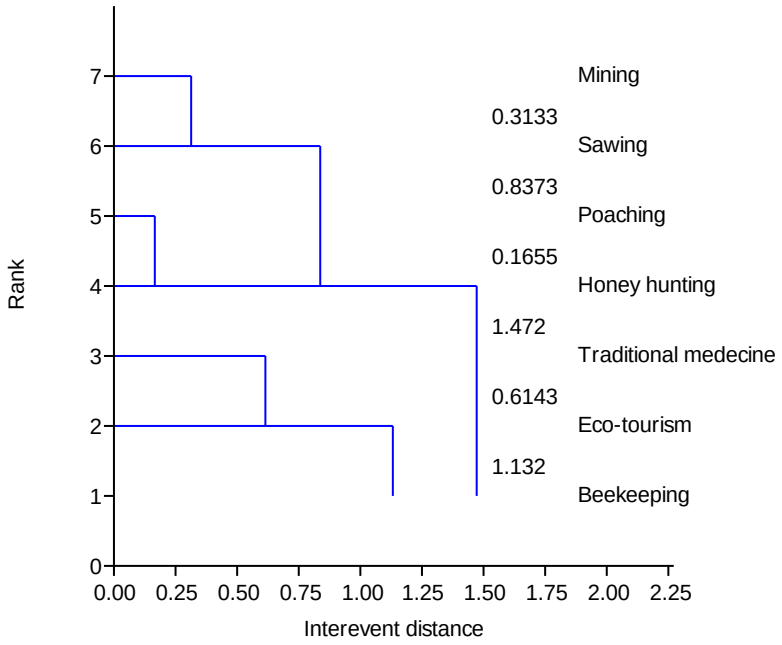
4.1. Social economic activities associated to Nyungwe National Park

Activities associeted to Nyungwe National Park are mainly beekeeping. According to information from beekeepers and conservationists in the Nyungwe landscape, before 1994, beekeeping was practiced inside the park where two forms of honey production were used i.e. honey hunting and keeping beehives within the park. These practices were sometimes the source of wildfire and associated to other illegal activities such as mining, sawing and poaching. It is this poaching that caused the extirpation of elephants and buffaloas in this park. After 1994, conservation measures were taken and those who were practicing illegal activities in the park were expelled including beekeepers. With this regard, Wildlife Conservation Society and other development partners managed to help beekeepers settling their beehives outside the park in the buffer zone and formed cooperatives.

This survey involved “Ubwiza bwa Nyungwe” cooperative union operating around Nyungwe National Park and other 2 cooperatives which are not part of the union. The union comprises 1,370 beekeepers grouped into 13 cooperatives with more than 4,000 bee colonies where more than 95% are traditional colonies. The union enjoys technical and financial supports from Wildlife Conservation Society (WCS). Other four cooperatives are supported by other development partners including Rwanda Development Board and local NGOs. Tourism activities in and around Nyungwe National Park are increasing but still at low level compared to other parks. Figures from RDB show that in 2010, the number of visits was 5,769 compared to 23,359 and 16,231 in Volcanoes and Akagera National Parks respectively.

Other activities are considered illigal and include herbalism, mining, sowing, poaching and honey hunting (Figure 1).

Figure 2: Scaling dendrogram of social economic activities associated to Nyungwe National Park



Gapusi (2007) found that the population surrounding Nyungwe National Park are more interested in honey production as an alternative income for their livelihood.

Agriculture, the main economic activity in the area, is not linked directly to Nyungwe National Park. There are many tea plantations in extension that generate income to the local population. Tea plantations serve also as a buffer zone in some parts of the park but is not favorable for beekeeping development as it is not serve as a bee flora. The remaining of the buffer zone is made mainly by Gum trees (*Eucalyptus* sp) which is a good food source to bees but not sustainable because when harvested, this would disrupt beekeeping activities. The most stepple food crops

include potatoes, sorghum, wheat, peas and maize, but the production remains insufficient, the region has been suffering from chronic food shortage.

4.2. Challenges to beekeeping development

The challenges for beekeeping in Rwanda in general and Nyungwe landscape in particular include:

4.2.1. Low returns from beekeeping

Many farmers have left beekeeping because of lack of profits and low yields and due to the amount of work and the investments that are required for hives and equipment. This low return is sometimes associated to the use of traditional hives mostly log hives and operating outside the park boundaries, poor in bee floral sources. Others have abandoned modern beekeeping because of improper management coupled with substandards equipments.

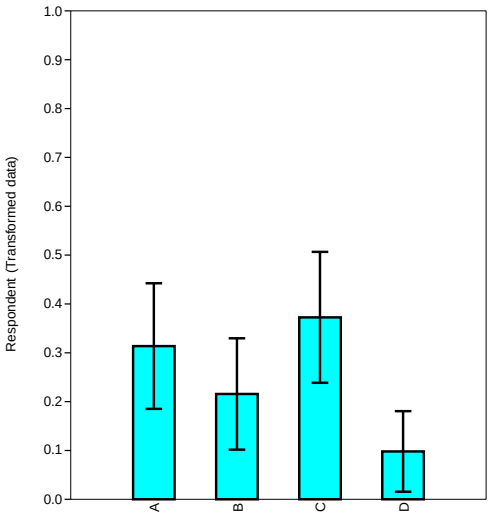
4.2.2. Poor colony management

Beekeepers around Nyungwe National Park practice mostly traditional beekeeping using traditional hives mostly log hives with very little use of modern hives such as Top bar and Langstroth types. The use of these types of hives does not ease colony management because it is almost impossible to inspect colonies inside these hives. In this kind of beekeeping, bees are left to look for their own forage, water and to provide their own security from invaders. During dearth periods, beekeepers do not provide supplements to their bees which triger starvation to bees and sometimes occasioning desertion and hence the farmer loses potential yield from such hives. This was realized in apiaries

inspected during this survey where a number of hives were unoccupied. When examined, desertion was due to several factors all associated to poor colony management. The identified factors included food shortage because in these kind of beehives, beekeepers cut combs indiscriminately, both honey and brood combs and don't leave enough food for bees during dearth periods (Figure 2). During this exercise, beekeepers are likely to kill the queen that would trigger the collapse of the whole colony.

It was proved that the colony strength is reduced and in some extent destroyed while harvesting as honeycombs are cut indiscriminately whether having honey or brood. During the exercise, the queen (the mother of the colony) has many chances to be killed as the practice is done most of the time during night hours because of the wildness of African honey bees and the use of excessive smokes that kill many worker bees and would also alter the quality of honey (P. Gallmann and H. Thomas, 2012 and Kangave Alice et *al*. 2012).

Figure 3: A barchart of the methods that beekeepers use during honey harvesting around Nyungwe National Park



A: Cut combs with only honey; B: Cut combs with both honey and brood; C: Cut combs indiscriminately; D: Killing bees before collecting honey

4.2.3. Bee Predators

4.2.3.1. Man

People can cause a lot of damage to hives and are usually considered the worst enemy of bees. Honey hunters and thieves destroy countless bee colonies and hives. Children often antagonize bees by throwing stones at beehives, which often results in people and livestock being stung. Human predation is a serious challenges for beekeeping development around Nyungwe National Park. It is practiced mainly by Batwa communities living in the vicinity of the park. They destroy colonies in the search of honey and cause huge losses to beekeepers. This finding is supported by reports that indicate that man is the most significant predator to honeybees in Africa followed by honeybudgers (Crane 1990).

4.2.3.2. Chimpanzes

Chimpanzes were also reported predating on bee colonies in the search of honey and brood. They enter the apiary, open hives and eat honey and brood while destroying all combs they find in the hives.

4.2.3.3. Birds (Honeyguide and bee eaters)

These birds were also reported predating on outgoing and incoming worker bees from hives. Some birds sit on the hive and eat worker bees coming out. Honey guides eat bees and bee brood. Honey guides on the other hand lead other predators to the hive.

4.2.3.4. Ants

Ants go for bees, brood and honey during any season or when the hives smell of honey. They were reported to challenging beekeepers around Nyungwe National Park.

4.2.3.5. Honey budger (Mellivora capensis)

This small mammal was cited by beekeepers to cause damage to their bee colonies. This information is not verified as during the field work, it was not sighted and it is sometimes confused by locals with mangoose. This animal breaks into hives to eat honey and brood.

4.2.4. Bee pests

4.2.4.1. Wax Moth (greater and lesser)

This moth looks like the moth that eats grain and destroys woolen clothes. It lays eggs in the hive and the larvae looks like a worm or maggot. Both the larvae and adult feed on the combs. The greater moth's larvae feed on the brown combs and destroy the wax. It burrows through the combs and leaves a white web or mesh in a long line in the comb. The lesser moth tends to attack processed wax. Wax moth is not a major problem to beekeeping development in the region because beekeepers still practice traditional beekeeping while these insects attack honeycombs in modern hives type Langstroth. It was not reported in Kitabi apiary made mostly by log hives but was found in Rangiro apiary in Langstroth hives.

Figure 4: Wax moth larva and combs destroyed by wax moth in in Rangiro apiary.

4.2.4.2. Hive beetles

Beetles enters hives through gaps and cracks but also through large entrance holes. The large black beetle feeds on brood and is most numerous during the rains. Others with distinct markings feed on small amounts of honey and pollen. The smaller hive beetles lay eggs in pollen

cells, which can be turned into a stinking mess by the maggots within a few days. They were not reported in Kitabi apiary but was found in Rangiro apiary.

Figure 5: A hive beetle in Rangiro apiary

4.2.4.3. Bee louse or bee fly (Braula coeca)

The bee louse, *Braula coeca* Nitzsch is a common pest in colonies around Nyungwe National Park. It is a wingless fly that lives as a commensalist in western honey bee, *Apis mellifera* Linnaeus, colonies. The fly is presumed to be harmless to its host, though this point is debatable as in some countries bee louse control is recommended. Because no true economic damage can be attributed to the fly, it probably poses a minimal threat to the beekeeping industry. It is seen on the backs of the bee but causes negligible damage to the colony. Regular smokes in the hive would control them.

Figure 6: A bee louse (Photo: Internet)

4.2.5. Bee diseases

4.2.5.1. Paralysis

This disease was reported by beekeepers around Nyungwe National Park. It is caused by viruses in adult honeybees.

Paralysis is a symptom of adult honey bees and is usually associated with viruses. Two different viruses, chronic bee paralysis virus and acute bee paralysis virus, have been isolated from paralytic bees. Other suspected causes of paralysis include pollen and nectar from plants such as buttercup, rhododendron, laurel, and some species of basswood; pollen deficiencies during brood rearing in the early spring; and consumption of fermented stored pollen.

Symptoms of the disease are the inability to fly, as well as uncoordinated and trembling movements of the body. Affected bees are usually found on top of the frames. In severe cases, large numbers of crawling bees are seen on the hive floor and in front of the hive. Death follows within days. The infected bees may be molested by the other bees and become hairless. The symptoms of paralysis are similar to those of Nosema and poisoning by pesticides.

4.2.5.2. Diarrhea

Diarrhea or Dysentery or Nosema in honey bees was reported by beekeepers around Nyungwe National Park. No definite diagnosis is possible without microscopic examination. The only outward signs of Nosema are a weakening of a colony or failure to build up normally when conditions are favorable. However, in severe cases the diseased bees will soil the hive, inside and at the entrance. Bees may be seen crawling out of the hive with abdomens slightly swollen. Heavily infected bees may give the impression of being clumsy and lethargic.

Although definite diagnosis of Nosema is only possible with microscope examination, there is a method which beekeepers can put to use with a little practice. The last abdominal segment (with the sting) of an adult bee is grasped with a fine pair of forceps and the gut pulled out. In healthy bees the midgut is brownish-yellow or mustard coloured, and its constrictions or rings are clearly seen. In bees that are heavily infected with *nosema*, the midgut is white and somewhat swollen, obscuring the constrictions.

4.3. Other challenges to beekeeping

4.3.1. Absconding

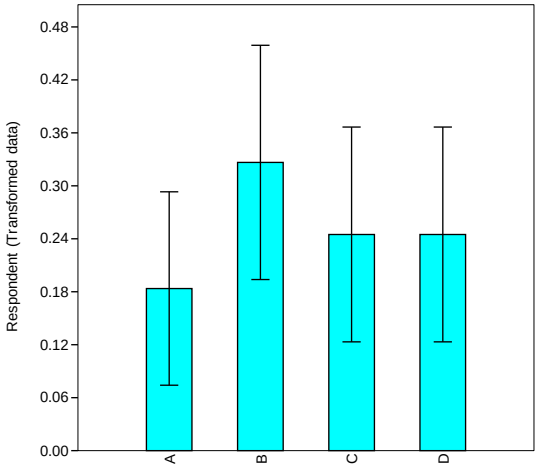
Beekeepers around Nyungwe National Park faces absconding problems in their apiaries. Reasons for absconding can be the lack of water, exhaustion of food stores, overheating, fire, thwarted swarming, deterioration of the nesting site and continuous pest attack (Sakagami, 1960; Smith, 1960; Fletcher, 1975, 1976; Seeley et al., 1982; Ruttner, 1988; Mutsaers, 1994; Hepburn and Radloff, 1998; Dyer, 2000).

African subspecies do not experience a winter and may forage virtually all the year round (Schneider and Blyther, 1988; Schneider and McNally, 1992). However, food availability in tropical Africa is often temporally and spatially unpredictable, owing to unpredictable rain patterns (Griffiths, 1976; Sinclair, 1983; Rinderer, 1988). As a result, African races frequently respond to unfavorable periods by undergoing "seasonal absconding" or migration, which consists of a colony abandoning a nest site, presumably to move into an area of greater resource abundance (Fletcher, 1978; 1991; Winston et al., 1979; Schneider, 1990 a; McNally and Schneider 1992).

4.3.2. Poor harvesting methods

Rudimentary harvesting methods, for example, using too much smoke or burning the hives leads to destruction of the bee colonies as well as to contamination of the honey harvest. Majority of beekeepers harvest honey by cutting combs indiscriminately; Very few cut combs having only honey or combs with both honey and brood where while some few others kill bees to access honey. These conducts regarding honey harvesting have a negative impact on the colony and honey quality one way or another. This poor hervesting method is sometimes accompaned by visiting the beehive more than once during honey flow season while it is recommended to visit the hive once per honey flow season. These combined practices are the main causes of aggressiveness and absconding behaviors of african honeybees (Figure 6).

Figure 7: Barchart of period of harvesting



A-Weekly B-Twice a month C-Monthly D-Once a season

4.3.3. Quality control challenges

Due to limited availability and improper use of harvesting equipment, honey becomes susceptible to contamination and adulteration. The resulting low quality honey cannot enter the formal market chain, but ends up in the informal markets.

4.3.4. Pesticide kill

During this investigation, mass bee killing was observed in Muganza apiary. Pesticides poisoning were suspected for the mass killing.

Figure 8: Mass death of honeybees in Muganza apiary

Pesticide poisoning of honey bees can be a serious problem for beekeepers, especially near areas of intensive agricultural crop production or when serious pest outbreaks warrant increased pesticide applications. Pesticides can have lethal or sublethal impacts on bees.

Some pesticides necessary in crop production are toxic to honey bees. Colonies may be completely destroyed by a pesticide, but more commonly only field bees are killed. Large numbers of dead bees (sometimes piled) around the outside of the colony are characteristic of a pesticide kill. Sublethal pesticide kills are difficult to diagnosis. Colonies exposed to pesticides that do not kill bees outright may be more susceptible to disease, have difficulty replacing aging queens, and/or be less productive.

4.4. Honeybees and biodiversity conservation

Honey bees play an important role in the creation and conservation of biodiversity. They played an important role in the evolution of many plant species of Nyungwe landscape. When people are aware about the valuable contribution of bees to the life of humans, they will respect bees and try to protect them, their habitat and forage area as much as possible. Beekeeping projects are therefore an ideal tool to raise awareness about the value of forests and engage people in conscious protection, conservation and sustainable resource management. Beekeeping could also be used to deal with the issue of property rights over natural areas, an issue that has been proven to be essential in the sustainable use of natural resources. . In this regard, beekeepers in the Kitabi region informed to have reported to Nyungwe National Park managers, 10 tree cutters for charcoal and sowing, 2 poachers and contained 4 honey hunters who got rewareded integration in the cooperative to abandon their practices.

Although many beekeepers showed their favor toward Nyungwe National Park, a few number of respondents showed a negative attitude toward Nyungwe National Park conservation (Figure 8). This may due partly to the fact that many of them were denied any access in the park. They complained about absconding of their bees when some plants in the park are in boom. This complaint may be linked to the fact that their apiaries are located in places poor in bee forage and a little bit far from the park. Therefore, honeybees make long distances in the search of food to the forest which may be one of the cause that would trigger absconding. Other reasons may get associated to social econimic conditions of people living in the area that are made of subsistance agriculture coupled with high density of population.

Figure 9: Beekeepers' attitudes towards Nyungwe National Park conservation

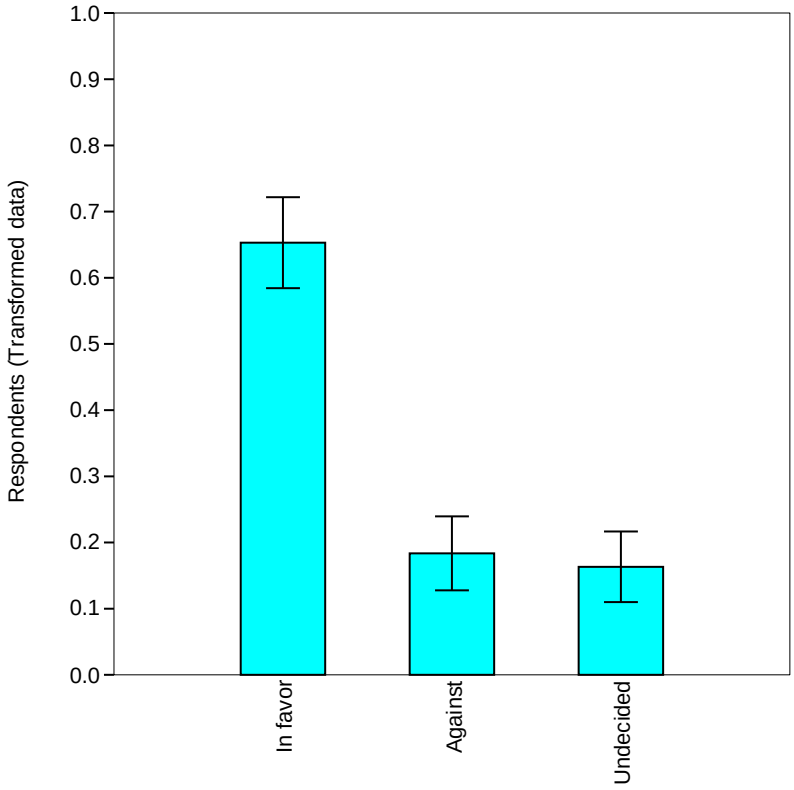


Figure 10: Rangiro apiary located approximately 1.5 Km away from Nyungwe National Park in very poor bee forage place

In the past, honey hunting, was an activity that was widely practised in Nyungwe National Park, but that was a direct threat for the bees. The activity consisted of lundering wild bee colonies. The honey hunter used fire to chase the bees away and often kill them by burning to facilitate the collection of honey. This was not only a direct threat for the bees but also for the forest as this type of fire was sometimes reported as the origin of forest fires which used to destroy large parts of the forest. These practices are still occuring even though at low level.

4.5. Conclusion

Beekeeping is the most social economic activity associated directly to Nyungwe National Park although it is practiced outside the park boundaries in an area dominated by Gum trees. Other activities identified include herbalism, mining, sowing, poaching and honey hunting. The beekeeping activity is dominated by traditional beekeeping and this represent a challenge that results in low return to beekeepers. This practice is associated to poor colony management because hive inspection in those kind of hives is almost impossible. Predators dominated by man as well as pests (Wax moth, hive beetle and bee louse) and diseases (Paralysis and Diarrhea) usually associated to hign absconding behavior and pestcide kill were also found to hamper beekeeping development in the Nyungwe landscape. But beekeeping was found to support conservation effort to the landscape due to the fact that honeybees are important pollinators but also to beekeepers who maneged to contain illigal activities and therefore contributed to the protection of the forest and its resources. Majority of beekeepers were in favor of Nyungwe National Park conservation Vs a small number of them against its conservation.

V. SWOT ANALYSIS

5. SWOT Analysis

5.1. Strengths

5.1.1. Indigenous knowledge

Beekeeping has been practiced since very long time hence there is rich indigenous knowledge and skills among beekeepers in the Nyungwe area and these should be easily developed through trainings.

5.1.2. The potential of hive products

Honey is the most known hive product from honeybees. But there are other bee products of economic importance such as pollen (a good source of proteins), propolis (medecinal value), royal jelly, bee wax, swarms, etc. Honey from Nyungwe landscape is of high quality because most of the honey comes from forested areas free from any contaminant and different natural bee forages. Prices of honey and bee wax are good compared to neighboring countries and the market is not yet saturated because the supply does not meet the demand.

5.1.3. Social resources

The beekeeping sector in the Nyungwe landscape is supported by different development actors including international organizations such as Wildlife Conservation Society, national institutions such as Rwanda Development Board_Nyungwe National Park and local NGOs such as Associaton pour la Conservation de la Nature au Rwanda.

5.1.4. The potential of large swathee of bee forage

Nyungwe landscape has good climate (Mountan rain forest), which is full of diverse flowering plants, ideal for production of pure organic honey for export to niche market and fair trade market. The landscape constitutes therefore a potential for beekeeping development because of its mix of natural vegetation that would provide bee forage all year round.

5.2. Weaknesses

5.2.1. Quality control of hive products

Honey produced in tropical areas, a place where Nyungwe National Park is located has a high content of HydroMethylFrufrol (HMF) because of tropical temperatures. HMF would increase in honey produced in the Nyungwe landscape because of lack of appropriate technologies while processing it.

5.2.2. Limited knowledge and low inputs by the government

Generally Rwanda lacks qualified professionals in the apiculture sector and this is a challenge to beekeeping development. The government invests very low inputs compared to other agricultural programs. There are no proper research and development regarding beekeeping in Rwanda. In addition, beekeepers in the Nyungwe landscape possess limited knowledge in beekeeping and mostly indegenous knowledge and therefore lack basic techniques of modern beekeeping such as queen rearing and colony multiplication.

5.2.3. other weakenesses in the beekeeping sector

- The beekeeping industry is fragmented.
- African honey bee has an aggressive and absconding behavior and there are no program to rear honeybees of less aggressive and absconding behavior.
- There are limited financial means.

5.3. Opportunities

5.3.1. Favorable government policy regarding entrepreneurship and beekeeping development

The government of Rwanda has published in the Official Gazette n° 27 the law n° 25/2013 of 10/05/2013 determining the organization and functioning of beekeeping in Rwanda (Official Gazette, 2013). In 2007, It has elaborated a national strategy on beekeeping.

5.3.2. Viable market

There are prenty of opportunities for hive products. Apart from honey which is consumed at all level in the rwandan society, other bee hive products such as propolis, beeswax, royal jelly, pollen and bee venom as well as live bees are not well explored and would be an opportunity for both local, regional and international market. In addition, recently the European Union has certified the Rwandan honey for export in Euro zone.

5.3.3. Threats

- There is a high risk from other honey producers bringing pests and diseases into Rwanda and these would reach Nyungwe landscape.
- There is a lack of understanding within stakeholders on the pest and disease risk associated with bees.
- There is a risk of *Varroa* mite detected in Rubona (Southern of Rwanda) recently and *Varroa destructor* occuring in neighboring countries of Uganda, Tanzania and Kenya.
- Donor dependency sector

VI. COST BENEFIT ANALYSI

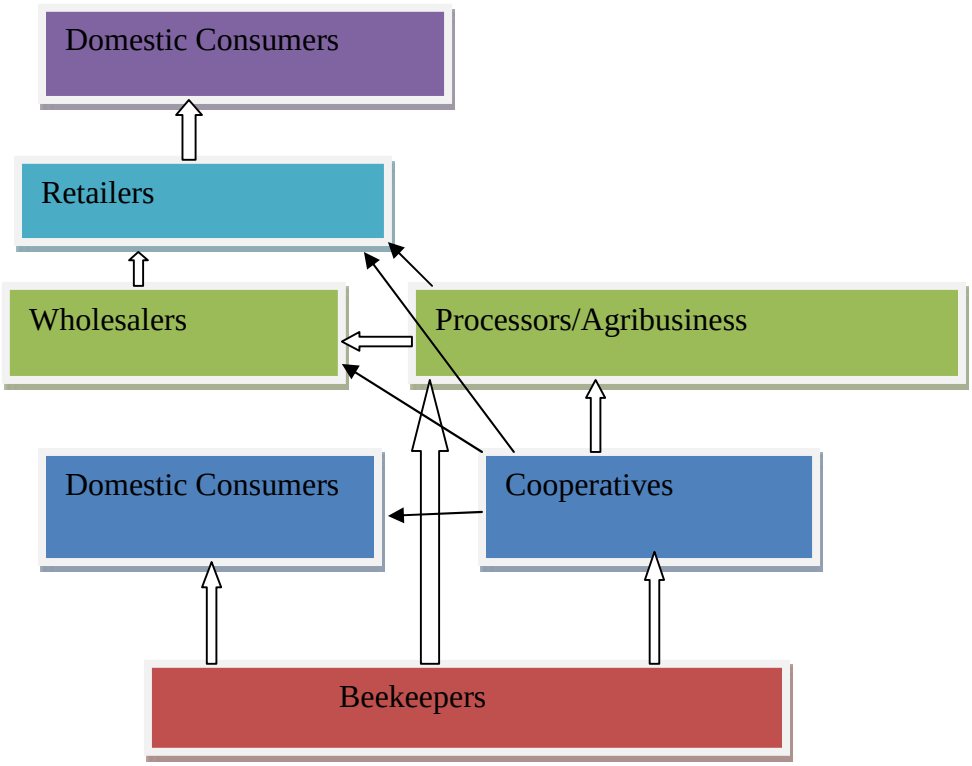
6. Cost benefit analysis

6.1. Introduction

There are many products a beekeeper can sell. It is therefore important to consider costs as well as benefits. Beekeepers around Nyungwe National Park produce honey and beewax for sell and in some extent for home use purposes. Other products i.e. pollen, propolis, royal jelly, bee venom and live bees are not well known and therefore less exploited. Log hives are commonly used but Langstroth and Top bar are rarely seen.

Information received during field works indicates that an unkown quantity of honey is sold at household level for consumption, traditional liqual making and traditional medecin. There is a honey collection center at Kitabi which also process honey using not advanced technologies in honey processing. Two companies (MIG and Api Business Development Company Ltd) are enganged in the honey value chain at domestic level. There is a small wholesaler at Kitabi belonging to Ubwiza bwa Nyungwe Cooperative union. Honey is sold to by-passers mainly travellers going or coming from Rusizi town and tourists. A considerable quantity of honey reaches supermatkets in Kigali city and other major town especially Huye and Muhanga towns.

Figure 11: Honey value chain in Nyungwe landscape



6.2. Cost-benefit analysis of interventions

Cost benefit analysis of two interventions involving two types of hives: one on transitional hives (Tob bar) and one on modern hives (Langstroth) were analysed during this feasibility study. There are approximately 1,493 beekeepers in the Nyungwe landscape that would participate in this interventions. More than 99% of them practice traditional beekeeping.

6.2.1. Current situation ("without" intervention scenario of traditional beekeeping)

Inflows

The beekeeper's income comes from the sales of the beekeeper's annual honey output whenever it is consumed or sold to the market. The following farm-gate prices have been used to calculate the base-case scenario: 2,000 Frw/kg for honey. In this scenario, the average yield from a traditional beehive has been established at the level of 6 kg/year of honey (regardless the type of honey). Nyungwe landscape accounts 1,493 beekeepers with approximately 4 traditional beehives per beekeeper's household. Domestic consumption of honey has been averaged at 5 kg/household/year according to information collected during the field survey. Therefore, out of 24 kg/per household produced, 5 kg is consumed at household level. The estimated yearly loss due to pests (humans, ants, chimps and other pests) is approximately 3 kg per year, leaving the beekeeper's household with 16 kg of honey to sell. This brings to 23,888 kgs of honey sold annually from Nyungwe landscape.

Expenditures (Input and Operating Costs)

The totals for required expenditures were mainly gathered during field interviews.

Table 1: Expenditures in the "without" intervention scenario of traditional beekeeping.

Expenditures	*Cost in Frw*
Traditional beehives (4)	1,000
Bee colonies (4)	0
Beehive maintenance (10%)	0
Bee-colony replacement due to pest attack or absconding	0
Beehive replacement due to pest attack	0
Labor	1,000
Rental value of land	0

Expenditures above are for the first year in nominal terms. Values would change, and additional costs would be included for beehive maintenance, bee-colony replacement, and beehive replacement in the later years of the project.

Assumptions

The honey yield from the traditional beehive will not increase, nor will the prices of inputs (beehives, bee colonies). It is also assumed that the wage rate will not increase, resulting in a 0 percent growth rate.

6.2.2. Intervention 1: Introduction of four transitional Beehives (Top bar) per Beekeeper's Household

The base-case scenario in this intervention is the same as in the "without" intervention scenario described above. This intervention is to replace traditional beehives with transitional beehives (Top bar).

In the proposed intervention, the total cost of buying a transitional beehives with four bee colonies is 50,000 Frw. The base-case scenario's farm-gate prices for honey were used to analyze this intervention: 2,000 Frw/kg for honey.

Income

It is expected that the total amount of honey produced per beekeeper's household starting in the second year of the intervention would increase from 24kg (as in the base-case scenario) to 84 kg/year because the yearly average of a Top bar hive is 15 kg of honey. The total annual honey yield from the four traditional beehives will stay at 24 kg, but the additional honey production from the four transitional beehives will reach a total of 60 kg. The total yearly honey loss due to pests will remain the same as in the without scenario (3 kg/year). It is assumed that annual household consumption of honey (5 kg) will not increase with the higher levels of honey production, so the beekeeper's household will end up with 76 kg of honey available for sale. This will bring to 113,468 kgs of honey sold annually from Nyungwe landscape.

Table 2: *Expenditures*

Expenditures	***Cost in Frw***
Traditional beehives (4)	1,000
Bee colonies (4)	0
Transitional beehives (4)	50,000
Bee colonies for transitional beehives (4)	0
Beehive maintenance for traditional beehives (10%)	0
Beehive maintenance for transitional beehives (10%)	0
Bee-colony replacement due to pest attack or absconding	0
Beehive replacement due to pest attack	0
Labor	1,000
Rental value of land	0
Queen excluder (4)	24,000
Feeders (4)	12,000
Queen catcher	3,000
Balance (20 Kg)	60,000
Container (200L)	50,000
Strainer	15,000
Hive tool	3,000
Brush	3,000
Bee suit	25,000
Food supplement (sugar) for honeybees (20 kgs)	20,000
Smoker	15,000

Expenditures above are for the first year in nominal terms. Values would change, and additional costs would be included for beehive maintenance, bee-colony replacement, and beehive replacement in the later years of the project. This requires trainings but are not included because it will be provided free of charge.

Assumptions

The honey yield from the traditional beehive will not increase, nor will the price of inputs (beehives, bee colonies). It is also assumed that the wage rate will not increase, resulting in a 0 percent growth rate. Additionally, beekeepers will be conditioned to sell their output to SDS Ltd (beekeeping equipment and training providers) for further processing

6.2.3. Intervention 2: Introduction of four modern beehives (Langstroth) per Beekeeper's Household

The base-case scenario in this intervention is the same as in the "without" intervention scenario described above. This intervention is to replace traditional beehives with modern beehives (Langstroth).

In the proposed intervention, the total cost of buying a modern beehives with four bee colonies is 100,000 Frw per colonized colony. The base-case scenario's farm-gate prices for honey were used to analyze this intervention: 2,000 Frw/kg for honey.

Income

It is expected that the total amount of honey produced per beekeeper's household starting in the second year of the intervention would increase from 24kg (as in the base-case scenario) to 144 kg/year because the

yearly average of a modern hive is 30 kg of honey. The total annual honey yield from the four traditional beehives will stay at 24 kg, but the additional honey production from the four modern beehives will reach a total of 120 kg. The total yearly honey loss due to pests will remain the same as in the without scenario (3 kg/year). It is assumed that annual household consumption of honey (5 kg) will not increase with the higher levels of honey production, so the beekeeper's household will end up with 136 kg of honey available for sale. This will bring to 203,048 kgs of honey sold annually from Nyungwe landscape.

Table 3: Expenditures

Expenditures	***Cost in Frw***
Traditional beehives (4)	1,000
Bee colonies (4)	0
Transitional beehives (4)	50,000
Bee colonies for transitional beehives (4)	0
Beehive maintenance for traditional beehives (10%)	0
Beehive maintenance for transitional beehives (10%)	0
Bee-colony replacement due to pest attack or absconding	0
Beehive replacement due to pest attack	0
Labor	1,000
Rental value of land	0
Queen excluder (4)	24,000
Feeders (4)	12,000
Queen catcher	3,000

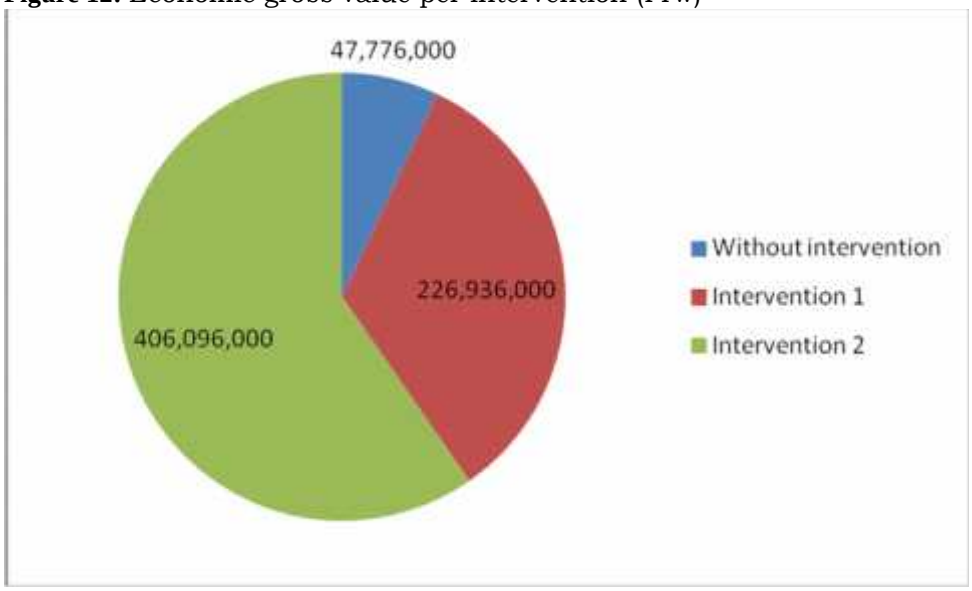
Balance (20 Kg)	60,000
Container (200L)	50,000
Strainer	15,000
Hive tool	3,000
Brush	3,000
Bee suit	25,000
Food supplement (sugar) for honeybees (20 kgs)	20,000
Smoker	15,000
Honey extractor	600,000
Comb foundation machine	600,000

Expenditures above are for the first year in nominal terms. Values would change, and additional costs would be included for beehive maintenance, bee-colony replacement, and beehive replacement in the later years of the project. This requires trainings but are not included because it will be provided free of charge.

6.3. Economic Analysis

The proposed Interventions 1 and 2 were designed to improve the quality and quantity of the supply of honey and other bee products, which would in turn facilitate developments in the Nyungwe landscape beekeeping sector domestically and in terms of potential exports.

Figure 12: Economic gross value per intervention (Frw)



As the graph show, there is a huge difference in terms of gross benefit between traditional beekeeping and the proposed interventions. These values would change positively because only one product (honey) is considered here. Other products of much more value than honey are not discussed in these scenarios. The highest level of yearly gross profit is observed in the case of Intervention 2.

6.4. Conclusion

Based on the analysis of the two proposed interventions in contrast to tradition beekeeping around Nyungwe National Park, intervention 2 (modern beekeeping) is the most appealing choice because it will provide the highest results in terms of financial and economic feasibility. The other proposed intervention will also yield positive results a considerable quantity of beewax, but honey production will be much lower than that of intervention 2.

VII. GAPS ANALYSIS

7. Gap analysis

7.1. Presentation of Beekeeping development around Nyungwe National Park

The beekeeping sector around Nyungwe National Park is mainly traditional as it is in other places in Rwanda. Activities are carried out outside the park. The current characterisitics of the beekeeping industry around Nyungwe National Park are summarized below:

- Apoximately 99% of beekeeping in the area is traditional. The modern beekeeping involves langstroth hive types and very few beekeepers in the Kitabi region have introduced Top bar hives (only 4 were identified during this study).
- Beekeepers in the region are grouped in cooperatives. 13 cooperatives form a union "Ubwiza bwa Nyungwe" with 1,370 members and over 4,000 beehives. Other 4 cooperatives with 123 members are not part of the union.

7.2. Current gaps associated to beekeeping development around Nyungwe National Park

Beekeeping in the Nyungwe landscape has not fully succeeded in exploiting its natural capacity for honey production, nor has it been able to fully benefit from its comparative advantage in the honey sector. Several factors have contributed to keep honey production from reaching its full market potential:

- Outdated technologies for honey and other by-products production, which includes traditional beehives which result in low quantity and poor quality of honey produced: Currently, most of the honey produced in Nyungwe landscape comes from traditional beehives. At national level, statistics show that as of 2012, beekeepers were numbered at 83,000 with 93,000 beehives. Traditional beehives yield low quantities of honey (average 6kg/beehive/year) that is also generally low quality, because it contains brood, wax, and other impurities.

- Lack of financial resources (such as access to loans) for beekeepers to obtain modern beehives and associated equipments necessary to make beekeeping much more profitable: Beekeepers have little access to financial products that would allow them to switch from traditional beehives to improved versions. Moving to transitional and modern beehives requires an initial investment of capital that most beekeepers do not have, so they continue to produce honey using traditional methods. In addition, the support to the sector is fragmented.

- Supply-related barriers to properly managing modern beehives: The supply of tools necessary to manage modern beehives is not readily available. For instance, some beekeepers possess modern beehives (just boxes), but they lack the tools required for the proper management of these beehives (such as a smoker, queen excluder, or honey extractor).

- Lack of proper training regarding efficient management of a modern-style apiary: In general, beekeepers who do have modern beehives do not have sufficient skills or knowledge needed to properly manage them (queen rearing, colony inspection and management) and training is not readily available. Therefore, beekeepers tend to rely on ineffective extractive harvesting methods and inappropriate tools for this

type of hive. In addition, beekeepers don't provide water for apiaries located far from water points or feed their colonies with food supplements (most of the time sugar syrup) during dearth periods and these are causes of bee starvation and absconding.

- Other associated obstacles: Additional barriers include a general lack of advocacy for the sub-sector. The honey sub-sector is considered "negligible" by insitutions in charge. As a result, the sub-sector has enjoyed limited support from the government. There is currently lack of continuous technical support to beekeepers. In the area of capacity development, support has been limited to one-off training. The result is the inability of beneficiaries to effectively apply training knowledge to their operations. There is also limited support in the area of honey processing. A honey processing center visited at Kitabi use rudementary technologies.

7.3. Conclusion

Key barriers to successfully expanding the honey value chain as well as other bee products in Nyungwe landscape primarily lay at the supply side of this commodity. Nyungwe honey production is insufficient in terms of quantity as well as quality. To meet the growing domestic demand as well as a likely profitable demand in the export markets, these supply-side issues need to be addressed.

VIII. GENERAL CONCLUSION

8. General conclusion

Nyungwe landscape has potentials for beekeeping development which would have a positive effect on people's livelihood improvement inhabiting the landscape, the overall economy as well as biodiversity and conservation.

Shortage of bee forage during dearth periods, honeybee pests and diseases, lack of skilled manpower and appripriate trainings to handle transitional and modern beehives, outdated technologies in honey processing and absence of policy in the apiculture sector were observed to challenging beekeeping development in the Nyungwe landscape.

Despite the challenges encountered the sub sector, the opportunities for beekeeping development in the region were the presence vast swathes of natural resources (bees and forage), the current attention of the government and development partners to develop apiculture as one of the strategies to reduce poverty in rural areas, high demand for hive products (honey) and the existance of in the area.

It was observed that upgrading avairable resources (beekeepers and their bee colonies) in the landscape by intervening using modern technologies in beekeeping (Intervention 2), results showed a gross profit of 406,096,000 Frw (U$580,137) per year.

IX. RECOMMENDATIONS

9. Recommendations

1. Beekeeping activities are practiced outside the park boundaries in places that are not suitable for large scale beekeeping. This was marked as one of the causes of bee starvation and high absconding behavior observed in apiaries visited. Given the likely successful outcomes of Intervention 2 (positive effects on the honey sector and livelihood improvement), bee forage is a pre-requisite for this intervention. It would be advised that apiaries would be settled at 0 m from the Nyungwe National Park and in some extent, relevent authorities would issue a special permit to professional beekeepers to practice beekeeping activities inside the park for more honey production and other bee products.

2. It is important however, to realize that for beekeeping to be a sustainable activity, beekeepers need to be trained on best practices. The necessary financial, extensional and technological support to fully exploit the great potential of beekeeping in the conservation Nyungwe National Park and in poverty-reduction programmes should therefore be allocated.

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XI. APPENDICES

11. Appendices

Questionnaire

Study on the value of honey bees for sustainable livelihood and biodiversity conservation: Case of Nyungwe landscape

A. Personal details

Name……
Date of visit……
Sub-location……
Village……

1. Age:

(1) Below 20
(2)20-40 years
(3) Above 40

2. Sex:

(1) Male
(2) Female

B. Social-economic activities

4. Please rank the most activities generating income around here

(1) Agriculture
Name crops
(2) Pastoralism
Name animals
(3) Business
Name business
(4) Other
Name them

5. Please rank the most common causes for the exploitation of Nyungwe landscape resources by the people around here:

6. Please rank all resources exploited by people around here beginning by the most exploited

(1) Timber
(2) Water
(3) Medicinal plants
(4) Honey
(5) Mine

C. Beekeeping activities

9. Apiaries location

a) Orchard
b) Private Garden
c) Roof garden
d) Shared garden
e) Farmland
f) Elsewhere (please specify)

10. Number of hives:

11. Do you regard beekeeping as a

a) Profession
b) Hobby
c) Somewhere in-between

12. Which best describes your view of the bees
a) Pet
b) Farm animal

13. Do you know these bee products?

a) Honey
b) Pollen
c) Beeswax
d) Propolis
e) Royal Jelly
f) Bee venom

13. Please order these aspects of beekeeping in importance for yourself.

a) Hive products
b) Pollination
c) Enjoyment
d) Farming

e) Relaxation
f) Research and Education

14. Please rank the comparative advantage in terms of economic values of the following honeybee by-products uses in your home area:

(1) Commercial
(2) Home uses

15. Do honeybees' by-products play any traditional role to the people of this region?
(1) Yes
(2) No
If yes specify……

16. Do people harvest wild honeybees' by-products around here?
(1) Yes
(2) No
If yes, rank the reasons why they harvest
(1) Products e.g. home based
(2) Sale

17. What are your feelings about this practice?
(1) Like
(2) Dislike
(3) No feeling
Others, specify……

18. What kind of hive do you own and how many?

(1) Traditional hive
(2) Top bar
(3) Langstroth

19. How do you harvest honey (methods)?

(1) Cut combs with only honey
(2) Cut combs with both honey and brood
(3) Cut combs indiscriminately
(4) Killing bees before collecting honey

20. How often do you harvest during honey flow season?

(1) Weekly
(2) Twice a Month

(3) Monthly
(4) Once a season

21. What quantity harvested per hive?

(1) Traditional hive
(2) Modern hive

22. What other bee by-products rather than honey do you harvest and how much?

(1) Pollen
(2) Wax
(3) Royal jelly
(4) Bee venom
(5) Swarms
(6) Pollination

D. Market

23. How is the demand in the market for the products?

(1) High
(2) Low

24. How is the supply of the products in the markets?

(1) High
(2) Low

25. How much do you earn out of one product per day?
(1) <1,000
(2) >1,000
Any other, specify…….

E. Conservation of biological resources

26. What is your opinion about Nyungwe landscape conservation?
(1) In favor
(2) Against
(3) Undecided
Others, specify…….

27. Are you aware of the effects of over-exploitation of biological resources here?

(1) Yes
(2) No
(3) Not sure
If yes, specify……

28. Please rank the comparative advantage that you think should be done to sustainably use biological resources here

(1) Add value to the products
(2) Control harvesting
(3) Alternative economic uses e.g. Beekeeping

H. Other activities associated with the landscape

29. Do people hunt and /or poach animals around here?
(1) Yes
(2) No
If yes, rank the reasons why they hunt and which species

30. How were the animals when you first settled here and which species?
(1) Many
(2) Few
Any other, specify……