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Beekeeping as an alternative source of livelihood in Uganda

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DECLARATION

I, Elizabeth Ahikiriza, declare that this Master dissertation is my own original work and has never been submitted here or in another University. Acknowledgement has been made to works of other authors used accordingly. Permission for personal use and consultation purposes of this work is to be given by the author, tutor and promoters. Copyrights laws apply for any other form of use.

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ABSTRACT

Objective: This study aims at analysing beekeeping adoption process and production as an alternative source of income to households in Northern Uganda.

Methods: A cross sectional study design was used to interview 166 beekeepers and 138 non-beekeepers from the three agro-ecological zones. Collected data was analysed using descriptive statistics, binary logistic regression model, Heckman selection model and Ordinary least squares estimations.

Results: The results indicate that beekeeping was a male dominated activity and livelihood capitals such as social, human and financial capital drove farmers to diversify into beekeeping. Honey production was low compared to installed capacity of beehives. Factors such as access to market information, access to ready markets, sources of equipment, knowledge on routine apiary management practices, beekeeping experience and forage availability influenced honey production. Inadequate production knowledge and skills, pests and diseases, predominant use of informal marketing channels, poor product quality were found to be the major production and marketing constraints.

Conclusion: The study suggests that in order to improve beekeeping adoption, farmers' social capital should be empowered and this will improve access to extension services and the quality of services accessed. Farmers' social capital can be strengthened through formation of public-private partnerships to address the knowledge gaps. The major knowledge gaps to be addressed are lack of production and marketing knowledge. Furthermore farmers should be sensitised on how to integrate beekeeping in crop production and still obtain optimal production. Development partners should therefore focus on improving beekeeping productivity and marketing if beekeeping is to be used as a tool to reduce poverty at household level.

Key words: Beekeeping, Beekeepers, Adoption, honey and Livelihoods

ABBREVIATIONS AND ACRONYMS

CBO	Community Based Organisations
DRC	Democratic Republic of Congo
HH	Household
kg	Kilogramme
km	Kilometre
KTB	Kenyan Top Bar hive
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
NAADS	National Agricultural Advisory services
NGOs	Non-governmental organisations
OLS	Ordinary least square estimations
PMA	Plan for Modernisation of Agriculture
Qty.	Quantity
Tot.	Total
UEPB	Uganda Export Promotion Board
UgShs	Ugandan Shillings
UK	United Kingdom
UNADO	Uganda National Apiculture Development Organisation
USD	United States dollar
VIFs	Variance Inflation Factors

1. CHAPTER ONE: INTRODUCTION

1.1 Background

Africa's rural poor living in isolated settlements heavily depend on subsistence agriculture for their livelihoods (1-4); a process they achieve through utilization of natural resources such as land, water and biotic resources (5). Uganda has 85% of its population residing in rural areas and engaged in agriculture as a major economic activity (6). About 24% of these live below the national poverty line (7). Northern Uganda hosts the highest number of rural poor households due to the 20year civil strife. Many of these rural poor suffer from income poverty, lack of education, health, poor housing, unemployment, limited empowerment and personal insecurity (8). Because of the above poverty constraints, these communities are constantly re-organizing their livelihoods based on available natural resources to alleviate poverty. Beekeeping has been considered as one of the livelihood diversification alternatives by farmers and development actors (9). The government of Uganda, for instance through the plan for modernization of agriculture, has promoted beekeeping extension services particularly targeting the rural poor (10, 11). This program has assisted poor farmers to invest in beekeeping through group organizations.

Beekeeping's competitive advantage for on-farm integration is ascribed to the low start-up costs, labour requirements, less land, user friendly technology and dependency on traditional knowledge and skills (12-14). Additionally, it provides complementary services to other on-farm enterprises like crop pollination. Beekeeping is also an efficacious tool in rural development as bees are omnipresent and the required equipment and tools namely: hives, smokers and protective clothing are locally made. Due to all these factors plus its contribution to livelihood outcomes especially the guaranteed year-round financial protection, beekeeping is considered a vital component of poverty eradication in rural areas (15).

Beekeeping offers direct and indirect benefits to the rural people. Directly, beekeeping substantiates household income from hive product sales, provides food, safe medicines and raw materials for industries (16, 17). These income benefits have been reported to have high impact among marginalized and small income earners such as women, orphans and other vulnerable groups within the society (18). Indirectly, beekeeping contributes to water shed-management, forest conservation and crop pollination (19). In their studies, Morse and Calderone (20) and Chaplin-Kramer, Dombeck (21) found that bees are responsible for one third of food crops produced for human consumption. Honeybee pollination improves quality, quantity and market value of food crops (22). Thus honeybees are central in ensuring food security. With all the above benefits, it is believed that

beekeeping can improve living standards of the rural poor. Yet productivity and beekeeping adoption remains low among rural farmers in Uganda.

1.2 Problem statement and rationale

In spite of the existing beekeeping potential in Uganda, the opportunity remains unexploited by most of the poor due to insufficient documentation on its profitability, performance and specific contribution to a poor man's needs (9). Beekeeping is still marginal with only 10-15% of the households engaged in it (23, 24). The sub-sector is also fundamentally orthodox and subsistence in nature and the government has done little to improve it.

Additionally, there is still scant information on the monetary value of honey output which makes it more complex to estimate its contribution (25). This information is hardly available given poor documentation and record keeping by farmers and statistic institutions plus little research focus on this sector. Focus is rather accorded to other livestock enterprises and major cash crops. Furthermore, the factors underlying adoption of beekeeping in the poorest regions in Uganda are unknown. Research also shows that during adoption of agricultural technologies, the process tends to be slowed and deterred by a number of challenges (26). These may be environment specific hence the importance to understand these area specific beekeeping constraints. Moreover, if the unexploited potential of beekeeping is to be met then these constraints must be identified and addressed. Therefore, this necessitates studies to address these knowledge gaps yet adoption studies have only been done in Western Uganda with no research in other regions (9). In addition, a systematic and holistic study on livelihood assets of farmers and how these influence adoption and production in the most vulnerable Northern Uganda is still lacking. This study therefore employed the livelihood framework to predict the effects of various factors driving beekeeping adoption and production in Northern Uganda along with conditions that would motivate rural farmers to take up beekeeping. The findings from such studies are relevant to future researchers with related topics, policy makers, donor agencies and organizations involved in seeking and designing sustainable poverty reduction strategies in rural areas especially in developing countries. In addition, such findings create awareness and assist extension workers to come up with more practical solutions to address the needs of the farmers.

1.3 Objectives of the study

1.3.1 Overall objective

The overall objective of this study is to analyse the beekeeping adoption process and production among rural farmers in Northern Uganda.

1.3.2 The specific objectives are:

1. To discuss the contribution of beekeeping to rural livelihood outcomes in Uganda.
2. To determine factors influencing the adoption of beekeeping among the rural farmers in Uganda.
3. To analyse the factors influencing honey production among beekeepers in Uganda.
4. To identify the major beekeeping constraints faced by farmers in Uganda.

1.4 Structure of the dissertation

This dissertation is organised into seven chapters (Figure 1). Chapter one gives the background and presents the problem statement which served as the rationale for the need to investigate the adoption process and production of beekeeping as an alternative income source for the rural poor. Additionally, general objective and the four specific research objectives are presented in this chapter. The second chapter presents literature review structured based on the specific research objectives. The chapter also gives highlights on what other studies have done and the existing knowledge gaps that have been addressed by this dissertation. Chapter three provides more details on beekeeping in Uganda, description of the study area, research design, data collection and management. The forth chapter describes the methods of analysis and all the variables used to achieve the research objectives. Results and discussion of the findings are presented in chapter five and six respectively. Lastly, conclusion and recommendations are presented in chapter seven.

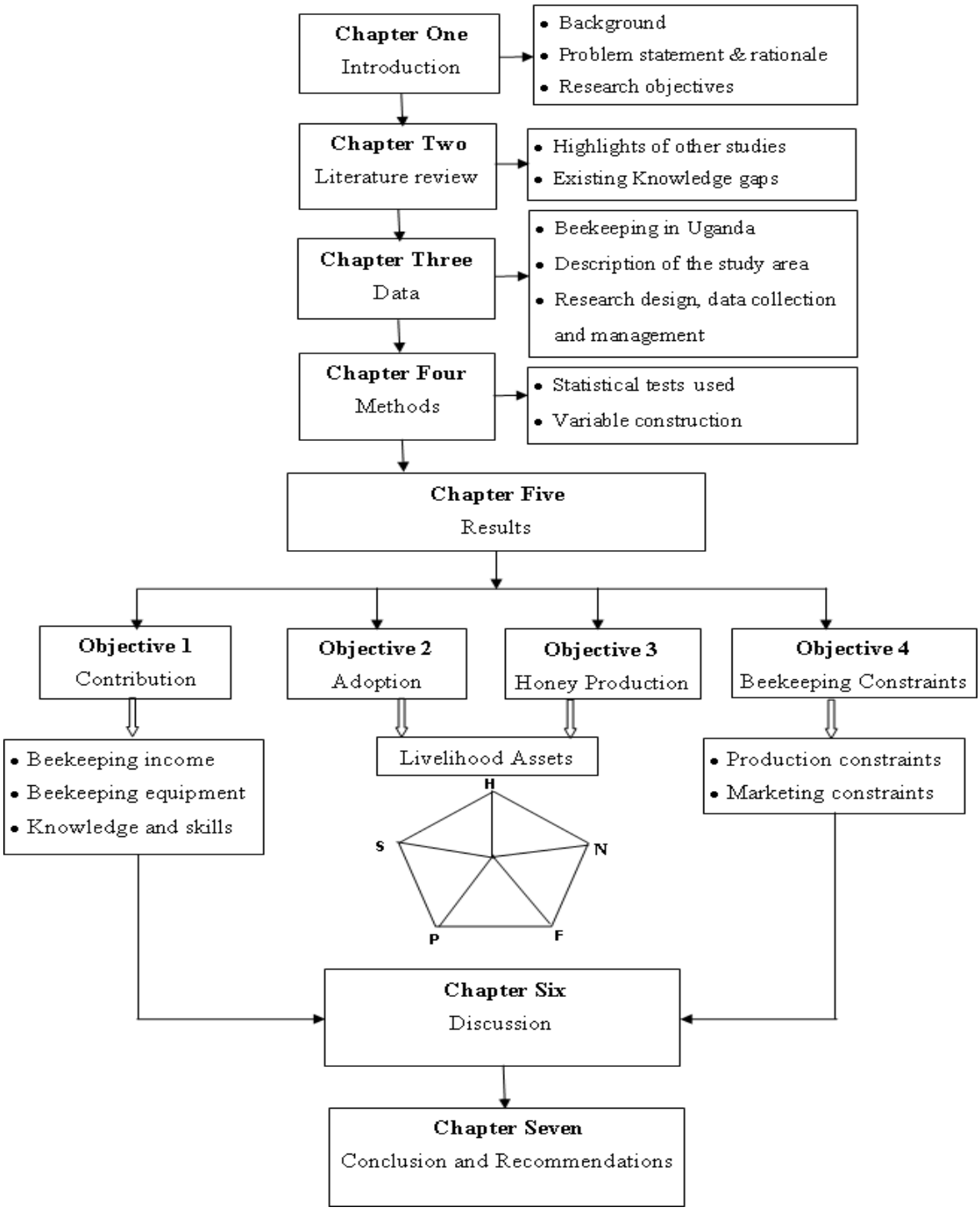

Figure 1: Outline of the dissertation

2. CHAPTER TWO: LITERATURE REVIEW

2.1 Beekeeping as a livelihood strategy and its contribution at household level

For decades, communities have depended on honeybees for food production; first through bee hunting and now beekeeping as a process of honeybee colony maintenance (27). Beekeeping entails wild colony capture and domestication in wooden boxes or cylinders made of clay or mud commonly referred to as beehives (28). Honeybees thereafter build their natural combs and maintain them. Two types of beehives exist that is fixed frame beehives (traditional) and movable frame beehives (improved) (29). Examples of fixed frame traditional hives are log, pot and basket hives (Figure 2). On the other hand, movable frame hives include langstroth, Kenya top bar and Johnson's hives (Figure 4). Under improved beekeeping, movable frame hives have been preferred over fixed comb due to difficulty in management, inspection and product harvesting from fixed comb hives (Figure 3). Following the development of these improved beehives and promotion of diverse livelihoods as a major strategy to eradicate poverty, beekeeping has gained popularity (30).

Figure 2: Traditional beehives (left a log hive and right a basket)
Source: Field photos taken during data collection.

Figure 3: Harvesting traditional beehives

Figure 4: Photographs showing improved movable hives and how they are harvested.

In order to study the contribution of beekeeping to livelihoods, a sustainable livelihood approach is used. The sustainable livelihood framework distinguishes strategies besides agricultural intensification, extensification and migration (31). According to Chambers and Conway (32), a livelihood is a set of capabilities, activities and assets; both material and social that are required for a means of living. A livelihood is said to be sustainable, only if it can cope, recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base (33). Peasant farmers are prone to shocks, trends, policy changes and various interventions that claim to enhance their farming hence require sustainable livelihoods. Figure 5 shows the components of the sustainable livelihood framework as adapted from DfID (34).

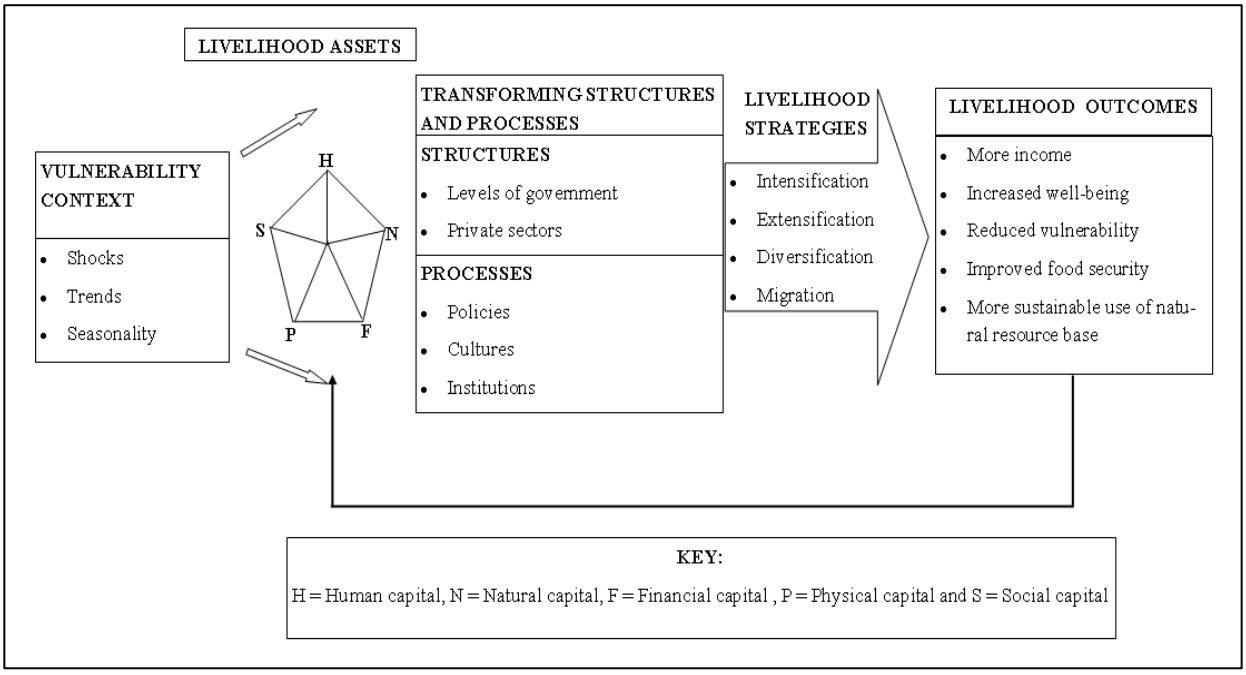

Figure 5: Sustainable livelihood framework
Source: Carney, Drinkwater (35)

Beekeeping contributes to livelihood outcomes through increasing food security more so increasing food accessibility, availability and utilization. Beekeeping enhances food accessibility through direct income generation which can be used for purchasing other nutritious foods that reduce the prevalence of protein, iodine, vitamin and iron deficiencies (36). Beekeeping has additional nutritional benefits as an extensive source of food hence its contribution to food availability. This is mainly in form of honey which is used for several other purposes in a home including being used as a sweetener. Honey contains antioxidants, minerals, vitamins, proteins and a high calorific value which present attractive ingredients that do not occur in artificial sweeteners (18). Honey is also used for brewing traditional beer in Africa primarily for cultural and religious purposes. In addition it possesses antibacterial properties that make it a well-known remedy for colds, mouth and throat irritations. Consumption of honey improves food assimilation, reduces infective intestinal problems such as constipation, duodenal ulcers and liver disturbances which increase peoples' food utilization (37). Not only is honey used to treat infections but also promotes tissue regeneration and reduces scarring even in its pure unprocessed form.

Apart from enhancing food security, beekeeping provides employment especially in areas where there is population pressure on the land (38). This helps households manage economic shocks hence reducing vulnerability among these households (39). In marginal areas with infertile land for agricultural production like the Kenya Masai communities, beekeeping was the fifth major livelihood diversification strategy to support their pastoral farming systems (40).

Apiculture also accelerates the accumulation of savings as a result of increased income. Beekeeping increases cash flows because it supplements the household income especially during the dry seasons when on-farm income is low. Hive products may be harvested two to three times a year especially at consumption peak times, for instance, when school fees has to be paid (23). Some bee products such as beeswax and propolis have long shelf lives which enable them to be stored for a long period as a form of saving and sold when need arises. Additionally, the ease of asset recovery and accumulation among beekeepers in case of insecurity was reported by Enzama (41). This makes beekeeping a very important safety and cargo net.

Beekeeping is said to improve well-being of the beekeepers through increasing the number of tools, equipment and access to basic infrastructure for instance access to roads and markets (39). Some of the tools and equipment owned to enhance beekeeping production include bee suits, smokers, beehives and other tools used in apiary management. During beekeeping production, farmers acquire new knowledge and skills particularly those related to beekeeping (42). This may be acquired from

organised trainings or as a result of cumulative experience in beekeeping. These skills enhance beekeepers capabilities. In addition, beekeeping gives an opportunity to farmers to network with other members in the communities. This is mainly through group formation that eases access to extension services (43).

Indirectly, beekeeping improves peoples' quality of life through facilitation of sustainable natural resource management. For instance, it enhances pollination which is very important for production of most seed, cash and food crops and promoting biodiversity (22, 44). Pollination of agricultural crops is an important agro-technical measure that increases productivity of seeds, fruits and vegetables. Some crops such as rapeseed even require supplementary pollination that is achieved by placing one to two beehives per hectare. It is also known that the closer the hives are to the bloomed field, the greater the pollination effect which expedites production. Although the exact contribution of pollination to yield is hard to measure precisely, it is likely to be much higher than the value of honey, wax and royal jelly (5, 45).

In spite of thorough discussions on the contribution of beekeeping in many countries including some African countries, no study previously used the sustainable livelihood framework in their explanation. Additionally, as far as known to me, no study has been done in Uganda to determine beekeeping contribution to the rural livelihoods.

2.2 Adoption of beekeeping as an economic activity

Adoption is taken as a variable representing behavioural changes that farmers undergo when accepting new ideas and innovations in agriculture. Behavioural change refers to "desirable change in knowledge, understanding and ability to apply technological information, changes in feeling behaviour such as changes in interest, attitudes, aspirations, values and changes in overt abilities and skills" (46). According to Feder, Just (47) adoption is classified into two types namely: individual and aggregate adoption based on coverage. Individual adoption refers to the farmer's decisions to integrate a new technology into the production process whereas aggregate adoption is the process of diffusion of a new technology within a region or population. In this dissertation I focused on individual adoption. Based on the adoption cycle, most farmers do not adopt agricultural activities/technologies immediately as they get to know about them. Different farmers adopt agricultural technologies at different times and these adopters can be grouped into three categories according to Diederen, Van Meijl (48):

- *Innovators* are the first farmers in their area to use a certain technology. In the case of beekeeping these are the farmers that adopted the activity before anyone else.

- *Early adopters* referring to the farmers who indicate to belong to the first quarter of adopters of a certain innovation, relative to the full range of potential adopters.
- *Late adopters* are those farmers who adopted an innovation, but did not belong to the first quarter of potential users.

There are factors that influence the general adoption process or determinants of farmers' uptake of the innovation/technology and there are those that determine the speed of diffusion of the technology. However, it is very difficult to discuss them separately in this section as very little has been done on determining adoption in the early stages but rather focus on the completed diffusion cycle (49). In this master dissertation, no differentiation was made.

Beekeeping adoption at household level like any other adoption process is determined by several factors that do not influence the process individually but these factors tend to interact with each other. First, Mujuni, Natukunda (9) reported phobia for bees as the main factor affecting beekeeping business in Western Uganda. African honeybees have high levels of defensive behaviour hence tend to sting everything that crosses their boundaries as their defensive mechanism (50).

Capital endowments such as human, social, natural and financial capitals have been reported to drive agricultural technologies (51). Beekeeping as an on-farm enterprise is also driven by the same capital endowments although there were limited studies on the drivers of beekeeping adoption particularly in the geographic region of study. Available literature suggests that human capital influencing adoption of beekeeping includes access to related knowledge, education levels of the farmers, labour availability on the farm, farmer trainings and age of the farmer. In the study of Mujuni, Natukunda (9) most of the beekeepers had attained formal education with 43% having achieved secondary and 18% tertiary education. This showed that educated farmers were more likely to adopt beekeeping since education stimulates their acceptance of new technologies. Education level of the farmers was found relevant and positively influenced adoption of beekeeping too. This was attributed to increased knowledge, access to related information such as the right time for harvesting and improved understanding of the related best management technologies (52-54).

Age and trainee occupation positively influenced adoption decision of beekeeping training attendance (55). Most farmers that attend these trainings are amongst the younger people (35 years and below) that have formal education and are predominantly from rural backgrounds with agriculture as their main occupation. Such trainings are usually organized by NGOs and government programs which

increasingly influence farmers' knowledge about various practices of beekeeping and its adoption (41).

Social capital that influences adoption of beekeeping encompasses access to extension services, formation of associations and cooperatives. All these increase farmers' bargaining power and their access to markets. Additionally, availability of information and knowledge about the related skills required for bee farming are vital in the beekeeping adoption process. The sources of information that positively influenced adoption process comprised of fellow farmers, meetings, media and extension officers (56). However, the appropriateness, accuracy and effective dissemination of this information must be highly considered. Edillon (57) found that organizational membership and extension service coverage also significantly and positively influenced adoption of agricultural technologies. Though social capital plays a crucial role in beekeeping adoption, it was reported to be highly influenced by programs and policies in place.

The main natural capital influencing adoption is land where the amount of land owned, quality of land and the presence of land investments are considered during adoption process. Farm size was found to have ambiguous relationship with adoption rates of most agricultural technologies depending on the characteristics of the technology and the institutional setting (47). However, farm size was not yet found to be significantly related with adoption of apiculture (9).

According to other studies, financial assets that significantly influence adoption of beekeeping are farmers' income, savings, access to credit, farm structures and access to beekeeping equipment/tools (39). Access to credit eases the production and marketing processes by facilitating the purchase of tools, equipment, packaging materials and transport to the market. Lack of start-up capital to buy beehives and other tools negatively influences adoption by prospective beekeepers (9). Hence, farmers' incomes and access to credit significantly affect the uptake of such technologies. On the contrary, Chuma, Mushuku (5) reported that financial assets were not essential for beekeeping at subsistence level in Zimbabwe. Although, these factors have been reported to influence adoption of beekeeping, their influence may vary across communities and agro-ecological zones yet their influence on adoption of beekeeping in the Northern region in Uganda had not been previously studied.

2.3 Factors influencing honey production in beekeeping

Factors that influence production in beekeeping differ from those influencing its adoption and a number of them have been pinpointed by different studies across the globe. For instance for a study in

Ethiopia, Bekele (58) reported access to extension services such as market information and beekeeping training as the most crucial factor influencing production of honey and other bee products. His findings showed that farmers that were frequently contacted by the extension agents produced higher quantities of bee products with better quality than those that did not. In addition, farmers that had received beekeeping training were more likely to use improved beekeeping equipment and produce more honey than their counterparts.

Several studies reported beekeeping equipment such as the number and type of beehives, ownership of protective clothing, hand gloves, knives and baiting materials to influence honey yield (59-61). On average, beekeepers produced 8-15kg/hive and 20-30kg/hive from traditional and modern beehives respectively (60). However, varying yield within farmers using similar hive types was reported and attributed to differences in certain apiary management practices. Routine management practices such as hive inspection, pests and disease control and provision of water were the major practices that influenced colony performance and honey yields (62).

Apart from the above mentioned factors, environmental factors such as bee forage availability and weather conditions influence honey yield (58, 63, 64). Though bee forage quality and availability are vital in honey production, these seem to continuously reduce over years due to changes in agricultural practices (65, 66). These changes include the increased use of fertilizers that has reduced rotation of legumes in cropping systems and extensive use of herbicides that reduces weeds within the crops and at crop edges. Similarly, increased use of pesticides, reduced extensive grazing and harvesting of alfalfa before blooming to maximize protein content significantly reduce bee forage available for pollen and nectar collection by bees (67).

Weather conditions not only influence the availability of forage plants but they also affect the average daily brood production, length of worker life and individual productivity of workers that were identified as the three primary factors that interact together to influence the amount of honey produced (68). Given that weather conditions vary from place to place, the geographic location of the farmer was also found to influence honey yields (69).

Whereas those studies examined the above as the factors influencing honey production, there were no previous studies conducted in Uganda. Additionally, the effects of the source of beekeeping equipment and market availability on honey yield were not explored by any of the studies.

2.4 The major beekeeping constraints

Existing literature has emphasised the importance of biological (ecological), technical, trade and institutional constraints in beekeeping (45). The major ecological and biological constraints previously focused on were inadequate bee forage, limited land for expansion, pesticide poisoning, predators, pests, diseases and death of the colony (44, 60, 70, 71). Like all organisms have been subjected to infestation and attack from natural enemies, Honey bees are not any exception and are attacked by pests, predators and parasites. These frequently lead to absconding and poor production (72). Pests are easier to address since they can easily be identified, have immediate effects and their solutions are often known to beekeepers. Studies such as that conducted by Mahaman, Harizanis (73) reported toads, wasps, mice, braula, beetles, wax moth, ants, birds, lizards and insect eating mammals as the main pests to honeybees. Besides pests and parasites, diseases were also a major concern in beekeeping and more so those affecting the brood because they quickly weaken the colony (64, 74). American foul brood, European foul brood, chalk brood and sac brood are the most common examples of brood diseases.

Technical constraints highlighted in previous studies were lack of knowledge on suitable management methods of tropical bee races and species, lack of skilled trainers and training opportunities, lack of dissemination of new research information especially that related to disease control and inadequate beekeeping equipment (45). There is a consensus in previous research that the major technical constraints in beekeeping production are low production knowledge/skills (60, 75). Most beekeepers lacked knowledge on the use of modern hives and how to determine the right time for harvesting (76, 77). Although beekeeping does not require high technology in practice, capacity building is required to train beekeepers on relevant management practices (78). Capacity building is usually impended by high illiteracy levels of beekeepers as reported in the study conducted by Illgner, Nel (38) in South Africa. Illiterate beekeepers are also unable to keep proper records per colony while this is vital for proper management of apiaries.

Trade/marketing constraints in beekeeping identified in Ethiopia were market inaccessibility, price fluctuations and lack of grading systems that deny beekeepers an incentive to produce good quality products (79). Additionally, the same study reported that bee products' prices widely varied based on goodwill of various buyers. Other marketing constraints reported by other studies included absence of organised market channels, transportation problems, low involvement of the private sector in market development and lack of appropriate technologies for processing and packaging bee products (80, 81). Lack of proper packaging materials was more common in rural and remote areas where recycled bottles of drinking water and whisky were used as packaging materials (82). These packaging

materials are unsuitable for marketing such products in towns, cities and export markets. This kind of packaging also undermines product presentation, quality and safety of the products (83).

The last category of beekeeping constraints are institutional constraints such as weak producer organizations, lack of resources such as trained personnel and laboratories to support the enterprise, multi-sectorial policy contradictions and conflicts within Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) (82). In addition, lack of policies to protect the industry and stress safety precautions and lack of adequate statistical information to guide the plans and operations were identified by Ministry of natural resources and tourism (84) as constraints. Availability of this information would attract and give confidence to potential investors and guide preparations of bankable beekeeping programs and projects. This would also facilitate the provision of credit to beekeepers, processors, traders and manufacturers of beekeeping equipment and products. Progressive beekeepers' associations were also found to face institutional challenges that included lack of commitment by the group members and difficulty in maintaining partnership with various agencies (85).

Other beekeeping constraints that were rather difficult to categorise included conflicts between beekeepers and their neighbours including beehive theft (9, 86). In some areas non-beekeepers demonstrated phobia for bees and did not allow beehives to be sited near their fields hence beekeepers had to look for isolated areas to keep their bees.

Although very many studies discussed challenges in the beekeeping sector, a few have been conducted in Uganda. Furthermore, those done in Uganda were conducted in other regions but not in the area of study for this thesis, had smaller sample sizes and did not categorise the constraints (9, 13). The current study intended to give a clear distinction of the major marketing and production beekeeping constraints in Uganda.

3. CHAPTER THREE: DATA

This section gives general data about beekeeping in Uganda, describes the area of study, sampling issues, the data collection and management process of the current study.

3.1 Beekeeping in Uganda

Honey is the major bee product produced by Ugandan beekeepers. Uganda's annual honey production is estimated at 100,000–200,000 metric tonnes but its position when compared to other African honey producing countries is not documented (87). The major honey producing areas are Northern and Western Uganda while the Central region is the least producing area (88). Most of the honey is organically produced by small-scale beekeepers that still use rudimentary methods of production and have failed to meet the country's domestic demand (89). Due to the unmet honey demand on the domestic market, Uganda has been importing more comb honey from Sudan and Democratic Republic of Cong (DRC) (87). Additionally, more processed honey is imported from Kenya, United Arab Emirates, Germany, Switzerland, UK and Dubia.

Although some honey is imported to meet this demand, the market is still dominated by the local brands. There are seventy two honey brands on the Ugandan market of which 71% are local brands (90). The most common local brands are Bee Natural Honey, Bushenyi Honey, East African Organic Honey, Pure Natural Honey and Pearls Pure Honey. Besides importing, Uganda exports honey to Kenya and is also among the five countries in Sub-Saharan Africa that export honey to the European Union (91). The European Union market is however, very competitive and its prices depend on the country of origin. Due to lack of quality standards in honey production, processing and marketing in Uganda, only 20% of its honey qualifies for the European market (92). Poor storage and honey adulteration are the main factors that deteriorate honey quality along the market value addition chain (93).

Certain reports have revealed that Uganda has no central market or pricing mechanism and its honey market is still largely informal (94). This makes access to ready good markets by the majority poor small-scale producers almost impossible. Market information distribution is also weak with neither efficient nor organised mechanism for its flow (95). Due to this, few beekeepers are able to sell their honey in bulk to consolidators, packers or bottlers and benefit from collective marketing. These gaps need to be addressed in order to meet the unmet honey demand in Uganda.

3.2 Description of the study area

Beekeeping data was collected from West Nile, Mid-Northern and Eastern agro-ecological zones in Northern Uganda. The three zones were selected based on their mean annual yields of honey. West Nile was classified as high producing region, Mid-Northern as moderate producing and Eastern as low producing zone (96). Figure 6 gives the map of the agro-ecological zones as adapted from Wasige (97) and Winterbottom and Eilu (98).

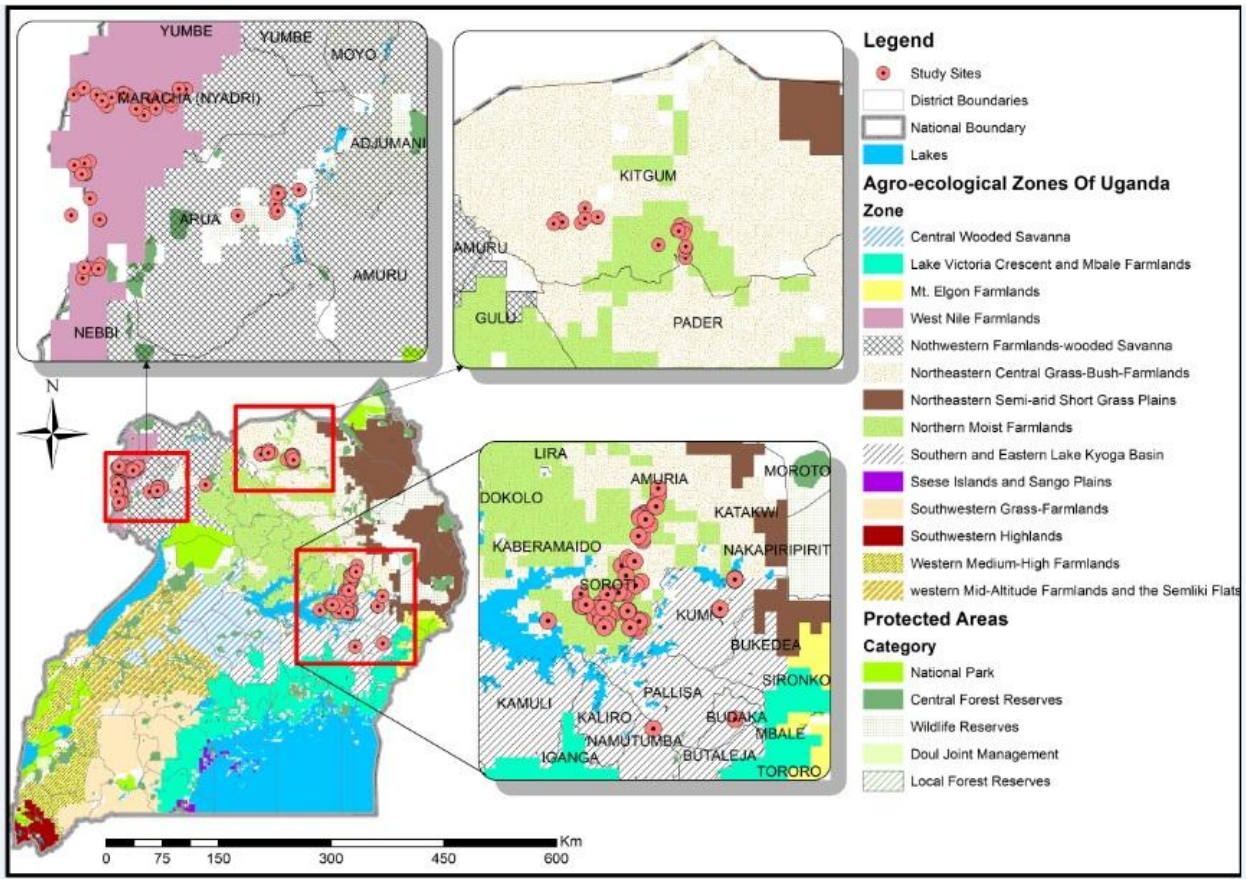

Figure 6: The map of Uganda and the location of the sampled areas

3.2.1 Geographic relief, climate and economic activities in the area of study

West Nile is situated at 1143 meters above sea level with average annual rainfall of 1250mm. It follows a bimodal rainfall pattern with a rainy season from March to May and another from July to October. It has a mean temperature of 28°C to 31°C. Dry seasons are usually experienced in June, December and February.

The region produces over 700 tonnes of honey per annum. The beekeeping sub-sector in this region is quite developed with an estimate of 6,300 farmers (88). Most of these farmers are involved in private-public partnerships which try to involve them into established value chains (41). This has enhanced

knowledge and technology on quality and quantity improvement of these beekeepers' products. Besides beekeeping, farmers in the region are also involved in other agricultural activities with crop production as their major activity. The staple crops grown are sweet potatoes and cassava, some legumes like cowpeas and beans while the major cash crop is tobacco (99). They also rear livestock where the main livestock reared are goats, poultry and cattle (100).

Data was also collected from the Kitgum district which belongs to the Mid-Northern agro-ecological zone and is situated at 1100m above sea level. It receives mean annual rainfall of 1300mm and experiences bimodal rainfall pattern with the first season from March-May and the second from July to October. The dry-hot season is from mid-March to December with mean monthly temperature range of 17^{o}C to 27^{o}C.

Kitgum has vast land and overgrown vegetation that is suitable for beekeeping (98). It produces around 9 tonnes of honey annually mainly from small-scale beekeepers that are stuck to their rudimentary methods of production such as burning of bees before harvest since they lack protective wear (101). The region has over 420 groups of small-scale beekeepers most of which lack the necessary skills needed to produce quality honey. A weak producer organisation structure also exists in this sector which has stunted the capacity of beekeepers in this region. Besides beekeeping, over 90% of the population is engaged in crop production as their major economic activity with a few others engaged in rearing livestock. The major food crops grown are sesame, upland rice, green vegetables, fruit trees (citrus and mangoes), beans, groundnuts, sorghum, maize, millet cassava, sweet potatoes, pigeon peas and sunflower. Cotton and tobacco are the major traditional cash crops while cattle, sheep, goats, pigs, chicken and fish are the livestock kept (102).

Lastly, data was obtained from the Soroti district which is located in the Eastern agro-ecological zone. It receives annual rainfall between 1100mm and 1200 mm but this is often unreliable and hence lead to droughts and floods (103). Most rain is experienced between March-May, light showers between June-August and other heavy rains between September-November. The dry season runs from December to February. It has average minimum and maximum temperatures of 18^{o}C to 30^{o}C respectively. Soroti is traversed by numerous swamps and other wetlands and has poor, shallow and light-textured soils with high sandy loam content (104, 105).

The district's exact annual honey production is not documented though most of the beekeepers in the region are organised in associations from which they receive the required training. Regardless of their organisation in associations, most beekeepers still operate on a small-scale and lack the required equipment to transit into modern beekeeping. However, they seem to produce good quality honey due

to access to training and availability of plenty of trees that provide bees with good quality nectar and pollen. Soroti is also a test bed for many agricultural development initiatives and has been zoned for citrus production under the National agricultural advisory services (NAADS). This gives it a great potential of integrating beekeeping into the fruit farms. Like other regions in the study area, a majority (78%) of the population are subsistence farmers and produce cassava, citrus, groundnuts, sorghum, finger millet, maize, green grams, sesame and soybeans as the major food crops (106). The major cash crop grown is cotton while the major animals reared are cattle, goats, sheep, poultry, pigs and a few farmers keep donkeys.

3.2 Research design and data collection

The study used secondary data that was collected by a doctoral student at the Department of Crop Protection (Faculty of Bioscience Engineering, Ghent University). The research and sampling designs of this data were given and described in the succeeding paragraphs.

The data was collected using a cross sectional research design over a period of five months (October 2014 to February 2015). The respondents included beekeepers and non-beekeepers in the three zones. To select beekeepers a list was obtained from the Ugandan national apiculture development organization (UNADO). Numbers were assigned to individuals and thereafter participants to the survey were selected randomly. Beekeeping households were 630 at the time of data collection. The study ended up with a sample of 166 beekeepers. This was lower than the 189 estimated using the Neuman (107) rule of 30% sample for a village population under 1000. This was mainly due to non-responses from some of the beekeepers initially selected as part of the sample.

In order to easily compare beekeepers with non-beekeepers, non-beekeepers from the same sub-counties as the sampled beekeepers were selected. This was done by obtaining lists of non-beekeepers adjacent to beekeepers from the respective district NAADS offices. Then using simple random sampling, individual non-beekeepers were selected from the three agro-ecological zones. A total of 138 non-beekeepers were proportionally and purposively selected for comparison with beekeepers. Table 1 presents the breakdown of the number of respondents in the different agro-ecological zones.

Table 1: Distribution of sampled respondents in the three agro-ecological zones

Agro-ecological zone	Beekeepers	Non-beekeepers	Total
Mid-Northern	38	30	68
Eastern	69	51	120
West Nile	59	57	116
Total	166	138	304

The household survey of beekeepers and non-beekeepers used a pre-tested structured questionnaire. The questionnaire was administered to the person owning beehives for beekeepers and for non-beekeepers it was administered to any adult male or female in the household. The questionnaire had six sections (Appendix 1), which covered household demographics, livelihood asset endowments and farm characteristics. The information collected referred to the time of data collection keeping in mind that this time slightly differed among respondents.

3.3 Data management

Data collected from the household survey was entered in Microsoft excel and then exported to SPSS and STATA for analysis. This data was cleaned to remove outliers during preliminary analysis. During data cleaning, three beekeepers were considered outliers and omitted based on the quantity of honey harvested and number of hives owned. Based on number of hives, two beekeepers were removed because one had 192 beehives and the other had 150 hives yet the person following them had only 75 beehives (Appendix 2). Then on the basis of honey produced, the respondent who said he produced 250kg of honey was removed as his immediate follower's production was reported at 100kg. This left the data set with a total of 301 respondents composed of 138 non-beekeepers and 163 beekeepers but rather more representative. Further analysis was done to achieve the proposed research objectives.

4. CHAPTER FOUR: METHODS

This section explains the details of how the research objectives were achieved, all the statistical tests and variables used in analysis of the data collected.

4.1 Methods of analysis

First, with the use of descriptive statistics the socio-economic characteristics of the interviewed farmers were established. Then characteristics of the beekeepers were identified using comparative statistics in order to distinguish them from other farmers in the community. Similarly, the first and forth objectives of the current study namely: to determine the contribution of beekeeping to rural livelihoods and to identify the major beekeeping constraints respectively, were achieved by generating descriptive and comparative statistics. The descriptive and comparative statistics used were minimum, mean and maximum values, standard deviations, frequencies, percentages, Chi-square values and t-statistics. Independent sample t-test (Levene's test of equal variance) was used to compare the means of the continuous variables while Chi-square test was used to analyse the binary and categorical variables.

The second objective on adoption was answered by first generating percentages of the various reasons for keeping and not keeping bees by beekeepers and non-beekeepers respectively. Binary logistic regression and probit models were proposed for further analysis. Binary logistic and probit models are normally recommended for dichotomous dependent variables which distinguishes these two models from linear regression model (108). The two models are also commonly used in adoption studies (47, 109). Though other models such as simple correlation and linear probability function can be used to predict adoption behaviours of farmers, these were not used because they have limitations (110, 111). For instance their t-ratios exhibit heteroscedasticity, non-normality and their estimated probabilities may be greater than one or less than zero since they assume probability to linearly increase with the level of independent variables. Probit and logistic models are based on a cumulative distribution form. Besides their ability to relate the choice probability *Pi* to the explanatory variables while keeping the probability in the range of 0-1, the logistic model is also easier to work with (112). A binary logistic regression model follows a logistic distribution function and specifies a functional relation between the probability of adoption and the predictor variables (113, 114).

A binary logistic regression estimates the probability that a characteristic is present given the values of explanatory variables. The model also uses maximum likelihood estimation.

Y= response variable (in this case beekeeper)

Y_i = 1 if the respondent is a beekeeper

Y_i = 0 if the respondent is not a beekeeper

X = (X_1, X_2, ..., X_n) is a set of explanatory variables which can be discrete, continuous, or a combination. x_i is the observed value of the explanatory variables for respondent *i*.

The logistic distribution for beekeeping can be specified as Gujarati (115) :

$$\boldsymbol{Pi} = \frac{\mathbf{1}}{\mathbf{1}+\boldsymbol{e}^{-\boldsymbol{z}\boldsymbol{i}}} \qquad \textbf{(1)}$$

Where, *Pi* is the probability beekeeping adoption for the i^{th} farmer, *e* is the base of natural logarithms, z_i is the function of a vector of explanatory variables which is underlying an unobservable index for the i^{th} farmer. If *Zi* exceeds the threshold level (Z*), the farmer is taken as an adopter. Otherwise he is a non-adopter if *Zi* is below the threshold value and can be expressed as,

$$\boldsymbol{Zi} = \boldsymbol{\alpha} + \sum \boldsymbol{\beta i X i} \qquad \textbf{(2)}$$

Where α = intercept, βi = vector of the unknown slope of coefficients and X_1, X_2 …X_n represents explanatory variables. The logit model assumes that the underlying stimulus index (*Zi*) is a random variable which predicts the probability of beekeeping adoption. The slope reveals how the log-odds of beekeeping adoption change as independent variables change. Therefore, if *Pi* is the probability of adopting beekeeping, then the probability of not adopting is *1-Pi*.

From Equation 2, we get the odds ratio that defines the probability of adoption relative to non-adoption. The logit model is then obtained by taking the logarithm of Equation (2) as follows:

$$\boldsymbol{Li} = \boldsymbol{Ln}\left(\frac{\boldsymbol{Pi}}{\mathbf{1}-\boldsymbol{Pi}}\right) = \boldsymbol{Ln}\left(\boldsymbol{e}^{\boldsymbol{\beta}_0}\boldsymbol{X}_{\boldsymbol{ji}}\right) = \boldsymbol{Zi} = \boldsymbol{\beta}_0 + \sum_{\boldsymbol{j}=\mathbf{1}}^{\boldsymbol{n}} \boldsymbol{\beta}_{\boldsymbol{j}}\, \boldsymbol{X}_{\boldsymbol{ji}} \qquad \textbf{(3)}$$

Li is the log of the odds ratio in favor of beekeeping adoption. *Li* is linear in both Xj, and the parameters. If the stochastic disturbance term (u_i) is introduced, the logit model becomes:

$$\boldsymbol{Zi} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1\boldsymbol{X}_1 + \boldsymbol{\beta}_2\boldsymbol{X}_2 + \cdots + \boldsymbol{\beta}_n\boldsymbol{X}_{ni} + \boldsymbol{u}_i \qquad \textbf{(4)}$$

Using the binary response on whether a farmer is a beekeeper[1] or not as the dependent variable, logistic regression models were run.

Four binary logistic models were run with different specifications to explore the determinants of beekeeping (Table 13). The first model contained human capital variables, the second model combined financial and natural capital variables while the third model contained variables used to measure social capital of the farmer. The forth model combined all variables in the first three models. A probit (first step of Heckman selection model) containing all the variables included in the final binary logistic regression model was also run to ensure robustness and correct for selection bias if

[1] *Beekeeper in this study refers to a farmer owning beehives.*

any. In addition, all these models were rerun using the dataset containing outliers to make a comparison with results from the non-representative dataset (Appendix 3). Marginal effects of all independent variables were generated and reported with their significance levels. The determinants that entered into these models were those found in literature but also those that were found to stand out in descriptive analysis.

The study went ahead to classify adopters into innovators, early and late adopters based on beekeeping experience measured in years. The innovators consisted of adopters that had been beekeepers for eight and above years, early adopters for four to seven years and late adopters were those that had been beekeepers for less than four years. Then Chi-square and one-way ANOVA tests were used to determine if there existed significant differences among the three groups. Furthermore, a post hoc test was used to determine which groups significantly differed in terms of continuous variables used in one-way ANOVA test.

The third objective of the study is to analyse factors influencing honey production. This was achieved by the use of an Ordinary least squares estimation (OLS), because the dependent variable (quantity of honey harvested per year) was a continuous variable. The OLS assumptions were tested to ensure that the obtained results were efficient and unbiased. Using the visual test and the Breush pagan test, heteroscedasticity was tested. In addition, multicollinearity was checked for by generating the correlation coefficients of the independent variables. Similarly, linearity and normality of the standard errors assumptions were tested by generating a scatter and QQ plots respectively.

Because an endogeneity problem was suspected, a Heckman selection model was used to correct it in case it existed (116-118). The Heckman model takes into account the problem of non-random selection and endogenous variables generated by latent variables crossing their thresholds (116, 119, 120). In this study, this model ensured that differences between beekeepers and non-beekeepers reflected the differences in capital endowments and farm characteristics not the unique impact of participation itself (121). The first equation of Heckman model predicted the probability of a farmer adopting beekeeping using a probit maximum likelihood function on both beekeepers and non-beekeepers. The second equation was an OLS estimation equation of quantity of honey harvested per year. The inverse mills ratio term as an added variable was used to reveal whether there was selection bias. A significant mill's ratio (lambda) would mean sample selection biases were present and had been corrected. The results generated from Heckman selection model were compared with those generated from the OLS estimation. Lastly, the two models were rerun using the data set that

contained outliers and the results were compared with those obtained by using the representative data set to see if the outliers had major effects on the model output (Appendix 3).

4.2 Variable construction

For objective one, the variables that are used to generate descriptive and comparative statistics are the production quantities of all the bee products, their unit prices, use and income contribution to the households. The prices and income from the different bee products are continuous variables reported in Ugandan Shillings (UgShs) but were converted into US dollars (USD) using the exchange rate at the time of data collection (1USD =UgShs2700). The quantities of bee products are also continuous variables but measured in kilograms. In addition, the details of all the beekeeping equipment owned by beekeepers were compiled listing their prices and sources from which they had been obtained. The equipment is measured by recording the number of equipment a beekeeper owned and the sources are binary responses (1= yes if the beekeeper obtained equipment from a particular source and 0= No if the beekeeper did not obtain the equipment from that source). Then variables measuring group membership of the beekeepers were compared with those for non-beekeepers. These included membership to savings, burial, farmer, marketing or beekeeping groups; access to any form of extension services, the form of extension services accessed and source of extension services. All these had binary responses (1= yes and 0= No). Table 2 shows the description of knowledge and skills measured related to beekeeping. These are all binary variables with 1= yes if the beekeeper possessed that skill and 0 =No if the beekeeper did not possess the skill.

Table 2: Description of beekeeping related knowledge

Knowledge/skill	Description of the knowledge, whether the beekeeper had knowledge on:
Capturing swarms	Catching swarms
Hive siting	Selecting sites for beehives
Pest and disease control	Controlling pests and diseases
Understanding the colony calendar	Understanding the colony calendar
Local hive construction	Constructing local hives
Honey harvesting	Harvesting honey
Inspection of hives	Inspecting beehives
Feeding of bees	Feeding bees
Colony multiplication and splitting	Colony multiplication and splitting
Process other products	Processing other bee products apart from honey (beeswax and propolis)

Table 3 shows the variables that were used as independent variables to predict factors influencing beekeeping adoption (objective 2).

Table 3: Definition of independent variables in the binary logistic regression and first step of the Heckman selection model

Variable (s)	Description of the variable (s)	Type of measure (s)	Type of response(s)
X_1= Age	Age of the farmer	Continuous in years	(12 - 91)
X_2= Gender	Gender of the farmer	Dummy	(1= Male, 0= Female)
X_3= HH size	The number of people living in the household	Numeric	(1-30 members)
X_4= Primary education	Whether the farmer had primary education level as the maximum level of education	Dummy	(1= Yes, 0 =No)
X_5= Secondary/tertiary	Whether the farmer had received secondary/ post-secondary education	Dummy	(1 =Yes, 0=N0)
X_6=Tot. annual income	Total annual income received by the household	Continuous in USD	(51.85- 8890.37)
X_7= Land acres	The total land owned by the household	Numeric in acres	(1-200)
X_8= Farmer group	Whether the farmer belonged to a farmer group	Dummy	(1= Yes, 0= No)
X_9= Access to extension services	Whether the farmer received any form of extension services	Dummy	(1= Yes, 0 = No)
X_{10}=NGOs	Whether the farmer accessed extension services through NGOs	Dummy	(1= Yes, 0=No)
X_{11}= Government	Whether the farmer accessed extension services through the government	Dummy	(1= Yes, 0= No)
X_{12}= Distance to market	The distance to the nearest market	Numeric in kilometres (km)	(0 - 40)
X_{13}= Eastern Zone	Whether a farmer belonged to the Eastern agro-ecological zone	Dummy	(1= Yes, 0 =No)
X_{14}= Mid-Northern Zone	Whether the farmer belonged to the Mid-Northern agro-ecological zone	Dummy	(1= Yes,0= No)

For the third objective, the factors hypothesized to influence honey production tested in the OLS estimation and Heckman selection model (second equation) were market access measured by having fellow community members as the main buyers (1: yes), access to market information (1: yes), access to extension services, having knowledge on apiary management practices, availability of bee forage, amount of non-farm income (USD), beekeeping experience of the adopter (years) and the source of beekeeping equipment.

There are quite a number of variables measuring access to market. These variables included the mode of transport used to reach the market, who bought the honey from beekeepers, the distance to the nearest markets and whether poor roads was one of the main challenges faced by the beekeeper. The study selected the variable concerning "*who bought honey from the beekeepers"* to measure access to ready markets. This was considered the most appropriate measurement given that it was the variable that varied among individual beekeepers. The distance to the market was not used because generally all beekeepers lived far away from the markets. Additionally, the variable of poor roads was not used in the model because this was to a larger extent influenced by public decisions rather than individuals' decisions. Since the roads among other factors were likely to influence the mode of transport, this variable was also not found appropriate to be used as measurement for ready market accessibility.

The management practices used in the models were hive inspection and pest and disease control because they were found in literature and were not correlated to beekeeping experience. Availability of forage was measured based on whether the beekeeper grew citrus on his farm or not. The sources of beekeeping equipment were also included in the model because the study wanted to know whether there would be a difference in production between farmers who acquired beekeeping equipment with their own effort and those that were given freely by the NGOs and other sources. Among the equipment, beehives and bee suits were used because they were the most important production assets owned by beekeepers. In addition, log beehives were used because they were the major hive type owned by adopters. On the other hand, gumboots were not included in these models even when they were owned by a bigger proportion of adopters because they are not solely owned for carrying out beekeeping activities. Therefore, it would be less accurate to associate ownership of gumboots with the quantity of honey produced. With a combination of all the listed variables, the determinants of honey production by the adopters were established.

5. CHAPTER FIVE: RESULTS

In this chapter results are structured based on the study objectives which focused on; a) characteristics of beekeepers, b) contribution of beekeeping to rural livelihoods, c) factors influencing adoption of beekeeping, d) factors influencing honey production and e) the major beekeeping constraints.

5.1 Description of the farming households

The aim of this section is to describe the general characteristics of farmers in the study area based on their socio-demographic features in order to understand the study population.

Findings revealed that most farming households in Northern Uganda were male headed (94%). In addition, about 41.4% of the farmers had not received any formal education, only 34.2% had at least attained primary education, while the others (24.4%) had secondary or tertiary education. In this region, three different land tenure systems were observed, those that owned land under freehold were the majority (85.7%) followed by communal land ownership (14%) with a few renting (0.3%) land for farming. In relation to distance, most of these farming households lived far from the markets with an average distance of 6.5km from the nearest markets (Table 4). The average annual household income[2] was 727.3 USD equating to 1.99 USD household daily income. Their average household size was ten members.

Table 4: General characteristics of farming households

Characteristic	Mean±SE	Minimum	Maximum	Standard deviation
Age of the farmer (years)	43.8 ±0.9	12.0	91.0	15.0
Land acres (acres)	9.3± 0.8	1.0	200.0	14.0
Total land allocated for crop production (acres)	6.3±0.3	1.0	50.0	4.8
Total land allocated to livestock production (acres)	2.3±0.2	0.5	34.0	3.4
Distance to market (km)	6.5±0.5	0.2	40.0	6.6
Total annual income (USD)	727.0±55.4	51.9	8890.4	959.9
Total annual crop production income (USD)	350.0±43.9	4.4	8888.9	724.2
Total annual livestock production income (USD)	297.4±35.0	13.0	3555.6	494.6
Total annual non-farm Income (USD)	79.8±59.6	0.9	7296.3	708.0
No. of HH members	10.4±0. 2	1.0	30.0	4.9

n = 301 1 USD =UgShs 2700 at the time of data collection HH = Household

[2] *Annual household income does not include own consumption.*

Some households had diversified income generating activities mainly diversifying in on-farm (78.4%) and non-farm activities (33%). Further analysis showed that crop production contributed the highest proportion (48%) to the household income, followed by livestock (41%) and non-farm activities (11%). The major crops grown were cassava (found on 90.4% of the farms), sorghum (77%), groundnuts (74%), sweet potatoes (71.1%) and millet (70.4%). The major animals reared were poultry (found on 98.4% of the farms), cattle (73.4%), goats (69.4%), pigs (23.7%) and sheep (22%). While the non-farm activities engaged in by these households were retail businesses (kiosk, motor cycle riding, tailoring and motor cycle riding), bricklaying, charcoal burning and civil services (Figure 7).

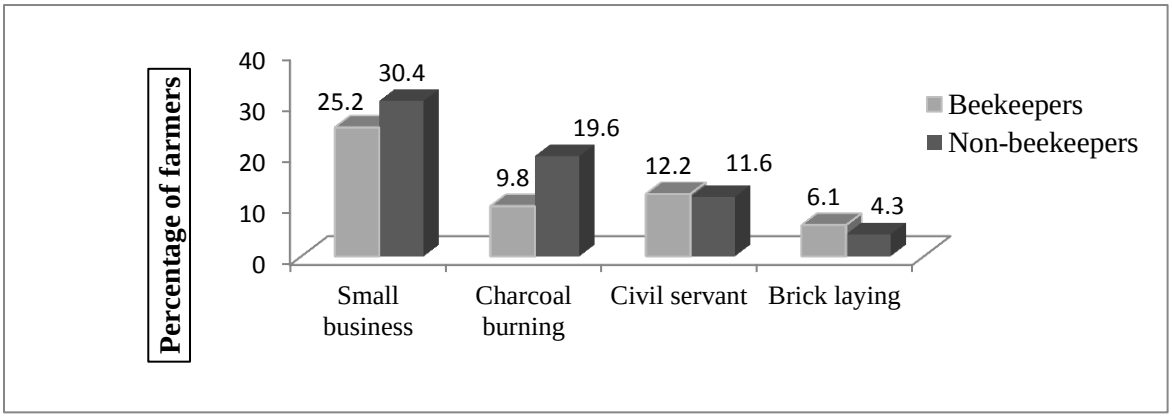

Figure 7: Major non-farm income sources of households in the three agro-ecological zones

Reasons for diversification were consumption needs, income demands, access to knowledge about the enterprise and market availability for the products to diversify their income generating activities (Figure 8).

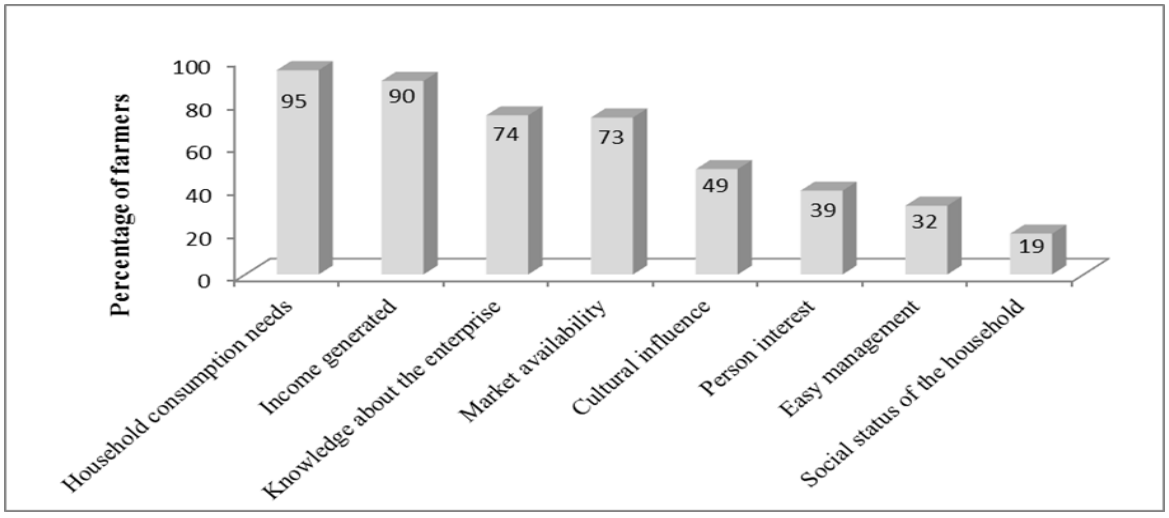

Figure 8: Farmers' engagement in different farm enterprise

In sum, these results revealed that the farming households interviewed were generally poor, had large households, low education levels and were highly dependent on crop production for survival even though their farm activities were diversified. Diversification of these activities was mainly driven by their consumption needs and income demands.

5.1.2 Characteristics of the beekeepers

Table 5 presents demographic characteristics of beekeepers in relation to non-beekeepers. Beekeeping was a male dominated enterprise practiced by the uneducated farmers that highly depended on on-farm incomes for their survival. Both groups did not differ in land ownership.

Table 5: Demographic characteristics of beekeeping households in comparison with non-beekeeping households in the study area

Characteristics of the farmers	Beekeepers (n= 163) (% yes)	Non-beekeepers (n= 138) (% yes)	Chi-square value	P-value
Gender of the farmer				
Males	78.3	62.3	9.373	0.002***
Females	21.7	37.7		
Education				
No formal education	59.6	19.6		
Primary education	36.1	31.9	90.479	0.000***
Secondary education	3.6	39.1		
Tertiary education	0.6	9.4		
Household head				
Male headed	94.0	94.2	0.933	0.933
Female headed	5.8	5.8		
Marital status				
Single	9.0	2.9		
Married	86.1	96.4	10.037	0.018**
Divorced	2.4	0.7		
Widowed	2.4	0		
Land ownership				
Freehold	83.7	88.4		0.382
Do not own land	0.6	0.0	1.926	
Communal land	15.7	11.6		
Main income sources				
On farm income source	85.5	71.0	9.604	0.008****
Non-farm income source	7.2	13.8		

*Proportions were compared using Chi-square, *** refers to significant at 1% level and **= significant at 5% level*

Beekeepers and non-beekeepers did not differ in average age (Table 6). Distance to the nearest markets was 5.4km longer for the beekeepers than the non-beekeepers a difference that was statistically significant at ($p<0.01$). Beekeepers also allocated more 0.78 acres of land to livestock production than non-beekeepers. Furthermore, beekeepers reared more small ruminants than their counterparts. They also earned 255 USD less household income per year compared to the non-

beekeepers suggesting they were poorer with more household revenue emanating from crops than livestock. On the other hand, non-beekeepers earned more income from non-farm sources than beekeepers.

Table 6: Comparison of the beekeepers and the non-beekeepers using Independent sample t- test

Farmer attribute (s)	Beekeepers (n=163) Mean	Non-beekeepers (n=138) Mean	t-statistic
Age of the farmer	44.9 (15.6)	42.8 (14.5)	1.18
Land acres (acres)	9.2 (16.4)	9.4 (10.3)	-0.16
Total land allocated to crop production (acres)	5.5 (6.5)	5.2 (10.0)	0.47
Total land allocated to livestock production (acres)	2.3 (4.2)	1.5 (1.4)	1.90*
Distance to market (Km)	6.3 (7.4)	0.9 (2.5)	8.23***
No. of cattle reared	4.7 (0.8)	4.7 (5.4)	-0.04
No. of goats reared	5.0 (5.2)	3.9 (4.7)	1.84*
No. of sheep reared	1.6 (4.8)	0.6 (1.9)	2.49**
Total annual income (USD)	615.5 (946.1)	870.5 (961.2)	-2.32**
Total annual income from crop production (USD)	382.0 (919.7)	245.0 (229.6)	1.71*
Total annual income from livestock production (USD)	88.1 (124.5)	324.7 (592.2)	-5.03***
Total annual income from non-farm sources (USD)	98.8 (21.8)	320.0 (734.3)	-3.69***
HH size	10.5 (5.1)	10.3 (4.6)	0.31

*Standard deviations between brackets (), *** refers to significant at 1% level, ** =significant at 5% level and *=significant at 10% level. 1USD = Ugshs 2700 at the time of data collection, HH= Household, No. = number*

5.2 Economic contribution of beekeeping to the rural households

This section intends to describe the contribution of beekeeping to livelihood outcomes of the beekeepers. The main products and their incomes are presented first, followed by beekeeping equipment, beekeepers' skills and lastly their access to extension services and group membership. Beekeeping was found to economically contribute to the wellbeing of rural households as direct income generation. Bee products also facilitated beekeepers to meet their consumption needs.

5.2.1 Bee products and their incomes

Honey (90%), beeswax (18%) and propolis 10% were the main bee products harvested by beekeepers in the region. About 49% of the honey produced was used for both sale and home consumption, while 47% was solely produced for sale and only 4% purely for home consumption. Farmers that harvested beeswax either sold it as pure wax (13%) or with honey as comb honey (71%) while others threw it way (16%).

Most beekeepers (90%), concentrated on the production of honey as the main bee product though it had the least market price. As the main hive product, honey contributed 75% to the total income derived from bee products, beeswax (24%) and propolis contributed only 1.3%. Though propolis was rarely produced by the beekeepers, it had the highest unit price followed by beeswax and then honey (Table 7). Beekeeping generally contributed a small proportion (7%) to the annual household income of beekeepers and 49% to their annual livestock income.

Table 7: Bee products and their income contribution to the beekeeping households

Variable (s)	Mean ±SE	Minimum	Maximum	Standard deviation
Qty. of beeswax produced/ year (kg)	3.51±1.26	0.00	160.00	16.10
Qty. of honey harvested /year (kg)	13.42±1.39	0.00	100.00	17.80
Qty. of propolis produced / year (kg)	0.19±0.80	0.00	10.00	1.04
Tot. annual income obtained from all bee products (USD)	43.04 ±6.92	0.00	629.62	79.24
Tot. income obtained from beeswax (USD)	10.33±4.50	0.00	592.59	57.40
Tot. income obtained from honey (USD)	32.10±3.43	0.00	222.22	43.74
Tot. income obtained from propolis (USD)	0.58±0.34	0.00	37.03	4.28
Unit price of beeswax (USD/kg) [a]	3.01±0.36	0.55	4.44	1.13
Unit price of honey (USD/kg) [a]	2.61±0.14	0.74	9.26	1.72
Unit price of propolis (USD/kg) [a]	4.00 ±1.19	0.37	7.41	2.66

1 USD =UgShs 2700 at the time of data collection. Qty. = Quantity Tot. = total

Note: a *= mean value was calculated for only respondents that sold the respective product.*

5.2.2 Beekeeping equipment

Beekeepers owned a number of equipment used in production and processing of honey as shown in Table 8. Beehives were the major production equipment. On average beekeepers owned 21 beehives. Log hives (93%) and Kenyan Top Bar (KTB) hives (68%) were the most common types of beehives owned. Pot hives (21%) and langstroth hives (21%) were the other hive types used by the beekeepers. Pot hives and log hives were classified as traditional beehives while KTB and langstroth as improved beehives. Other production tools owned by majority of the beekeepers were: gum boots, bee suits, smokers and gloves. Processing equipment such as air tight buckets, honey strainers and honey extractors were not as common as production equipment among beekeepers.

Table 8: Summary of tools and equipment owned by beekeeping households and their prices

Equipment owned and their unit costs	Mean ±SE	Minimum	Maximum	Std. Deviation
Number of:				
Beehives (n=163)	21.00±1.22	2.00	75.00	15.60
Log hives (n=150)	14.49±1.06	1.00	70.00	12.94
Pot hives (n=35)	3.08±0.34	1.00	8.00	1.20
KTB hives (n=109)	8.71±0.81	1.00	54.00	8.44
Langstroth hives (n=34)	3.94±0.89	1.00	24.00	5.17
Pairs of gumboots (n=58)	1.30±0.07	1.00	3.00	0.59
Bee suits (n=45)	1.40±0.12	1.00	5.00	0.82
Smokers (n=41)	1.50±0.07	1.00	3.00	0.48
Pairs of gloves (n=38)	1.40±0.09	1.00	3.00	0.60
Airtight buckets (n=32)	2.10±0.33	1.00	10.00	1.84
Bee veils (n=29)	1.40±0.14	1.00	4.00	0.78
Bee brushes (n=27)	1.60±0.33	1.00	10.00	1.73
Honey strainer (n=10)	1.10±0.10	1.00	2.00	0.32
Hive tools (n=9)	1.10±0.11	1.00	2.00	0.32
Honey extractor (n=1)	1.00±0.00	1.00	1.00	0.00
Unit cost (USD) of a:				
Log beehive	3.42±0.35	1.85	11.11	2.01
Pot hive	2.03±0.19	1.85	2.22	0.26
KTB hive	36.64±7.38	3.70	92.59	27.62
Langstroth hive	43.24±8.15	27.78	166.67	33.62
Pair of gumboot pair	6.26±0.25	4.44	11.11	1.54
Bee suit	46.21±21.00	5.50	111.11	29.65
Smoker	11.44±1.79	5.55	22.20	5.41
Pair of gloves	5.00±0.36	1.11	16.67	0.46
Airtight bucket	7.84±2.58	1.48	44.40	1.11
Bee veil	16.67± 0.00	16.67	16.67	0.00
Bee brush	1.69±0.18	0.93	2.22	0.48
Honey strainer	24.07±0.75	11.11	3.70	1.50
Hive tool	3.33±2.04	1.11	7.41	3.53

1 USD =UgShs 2700 at the time of data collection. These statistics were compiled for only those beekeepers that owned the respective equipment not for the whole sample. The unit prices are compiled for only those beekeepers that purchased the beekeeping equipment themselves.

Beekeepers obtained their beekeeping equipment from different sources: namely through either own purchase, co-funding, making them locally or through donation from NGOs and government programs that were promoting beekeeping in the area (Table 9). None of the equipment was found to be obtained on credit in this study. The major sources were donation and own purchase.

The results on beekeeping equipment implied that beekeeping in the area of study was dominated by the use of traditional beehives that were majorly locally made by the beekeepers. It was also found that a few of the beekeepers owned processing equipment and those who did mostly acquired them through donations rather than own purchase.

Table 9: Sources of different beekeeping equipment

Equipment owned	Number of beekeepers	Percentage bought	Percentage donated	Percentage locally made	Percentage Co-funded
Traditional hives					
Log hives	150	25	4	70	1
Pot hives	35	41	19	0	40
Improved hives					
KTB hives	109	10	84	4	3
Langstroth hives	34	22	88	0	0
Gum boots	58	78	20	0	2
Bee suits	45	34	55	0	11
Smokers	41	34	64	0	2
Gloves	38	31	67	0	3
Airtight bucket	32	66	31	0	3
Bee veils	29	35	73	0	4
Bee brushes	27	43	53	0	4
Honey strainer	10	20	80	0	0
Hive tools	9	70	30	0	0
Honey extractor	1	0	0	0	100

5.2.3 Beekeeping knowledge and skills

The study revealed that beekeepers had knowledge in various beekeeping related activities such as hive siting (mentioned by 73% of the respondents), local beehive construction (61%), honey harvesting (52%), understanding the colony calendar (39%), feeding honey bees (33%), capturing of swarms (27%), processing of other hive products (24%), pests and diseases control (20%), inspection of beehives (12%) and colony multiplication and splitting (8%).

Furthermore, beekeepers had varying experience in beekeeping. A large part had 4-7years; some had more experience and others less. A small part were newcomers with one or less than one year of experience while only 3% had more than ten years of experience. Correlations between beekeeping experience and knowledge on related activities are reported in Table 10. The knowledge on processing of other hive products such as beeswax and propolis, feeding honey bees, understanding the colony calendar, capturing of swarms, harvesting honey and local hive construction increased with the years of experience.

Fewer of the farmers with beekeeping experience below four years had knowledge on these practices compared to their counterparts. More farmers with over four years of experience had knowledge on local hive construction, hive siting, feeding bees and processing of others hive products than those with less than four years of beekeeping experience. A significantly bigger percentage of the farmers with over 8 years of beekeeping experience had knowledge on harvesting honey and understanding the colony calendar than the other two groups. While the number of beekeepers that had obtained

knowledge on the above practices differed significantly among the three groups, those that had obtained knowledge on pests and disease control, colony multiplication and splitting and inspection of hives did not. It needs to be noted that only few beekeepers had knowledge on such practices across all the three categories.

Table 10: Knowledge of beekeeping that was dependent on the experience in the activity

Type of knowledge (1= yes)	≥8 years (% yes)	4-7 years (% yes)	<4 years (% yes)	Chi-square value
Capturing swarms	45.2	26.0	17.3	10.68**
Hive siting	81.0	80.0	60.0	8.83**
Pest and disease control	21.4	24.0	14.7	1.87
Understanding the colony calender	57.1	46.0	22.7	13.71**
Local hive construction	83.0	80.0	33.3	40.04**
Honey harvesting	71.4	54.0	37.3	12.80**
Inspection of hives	16.6	10.0	10.7	1.18
Feeding of bees	47.6	38.0	20.0	10.43**
Colony multiplication & splitting	7.1	12.0	5.3	1.89
Process other products	31.0	36.0	12.0	11.00**

*** refers to significant at 5%*

5.2.4 Beekeepers' access to extension services and group membership

Beekeepers had more access to extension services compared to non-beekeepers, a difference that was significant at $p<0.05$ (Table 11). More beekeepers also had access to management training, training on product processing and access to inputs as compared to non-beekeepers. The results also showed that beekeepers' main sources of knowledge were fellow beekeepers, extension agents and to a lesser extent radios, newspapers, parents and relatives. Trial and error (repeated experience) was also mentioned as a source of knowledge.

Table 11: Beekeepers access to different extension services

Extension service accessibility (Access to :)	Beekeepers (% yes) n= 166	Non-beekeepers (%yes) n= 138	Chi-square value
Any form of extension services	97.0	69.6	43.46**
Training on management	88.0	31.1	103.30**
Training on product processing	58.4	37.7	13.00**
Routine extension agent visits	46.4	37.0	2.74
Inputs	87.4	46.4	58.88**
Marketing information	59.0	63.1	0.51

******** *refers to significant at 5% level*

Note: For the beekeepers, extension services related to beekeeping were used for comparison while access to extension services on general agriculture was used for non-beekeepers.

The study further reveals differences in sources of extension services between beekeepers and non-beekeepers. The main sources of extension services to beekeepers were NGOs and government (Table 12). Some of the beekeepers also received these services from fellow farmers, media channels, private consultation and community based services. Significantly more beekeepers accessed extension services through NGOs compared to non-beekeepers. More of the non-beekeepers received their extension services from the government (mentioned by 59% of the respondents), fellow farmers (51%) and media channels.

Table 12: Different sources of extension services

Source of extension services	Beekeepers (% yes)	Non-beekeepers (% yes)	Chi-square value
NGOs	55.06	1.45	132.05**
Government	51.81	74.64	16.70**
Private consultation and community based services	14.45	59.42	67.70**
Fellow farmers	28.92	51.45	16.06**
Media channels	6.63	18.84	10.51**

*** = Significant at 5% level*

5.3 Reasons for keeping bees and not keeping bees

Table 13 gives an overview of the reasons beekeepers indicated as important towards engaging in beekeeping and factors expressed by non-beekeepers that could convince them to keep bees. Prospects of high income from hive products, motivation from fellow farmers, personal interest and access to beekeeping management information majorly drove farmers to diversify into beekeeping. Non-beekeepers were deterred from beekeeping by limited knowledge about the enterprise (mentioned by 62% of the respondents), fear of bees because of their defensive behaviour (59%), lack of capital to buy the equipment (31%), limited space (24%), lack of interest (23%), fear that the enterprise would not break even (16%) and lack of awareness about the market for the hive products

(15%). Non-beekeepers also reported high expected income from hive products, access to beekeeping management training and access to capital as the major motivations that would encourage them to keep bees although 9% reported no interest in beekeeping at all.

Table 13: Factors that drive farmers to engage in beekeeping

Pull factors that attracted beekeepers into the activity	**Share of beekeepers (%yes) (n=163)**
Prospects of high income from hive products	59.0
Fellow farmers keeping bees	50.6
Personal interest	50.0
Access to beekeeping management information	35.5
Parents	12.7
NGOs and government	11.4
Factors that would encourage non-beekeepers to engage in beekeeping	**Share non-beekeepers (%yes) (n=138)**
High income expected to be generated from hive products	63.8
Access to training on beekeeping management	60.9
Access to capital to buy beekeeping equipment	52.9
Reduced bee aggressiveness	44.9
Access to enough land	20.3
Awareness on the market availability	19.6
Security for the hive products so as not to be stolen from the site	16.7
Time availability to manage hives and to attend meetings	10.1
Not interested at all	8.7

5.3.1 Factors likely to influence beekeeping adoption

Table 14 presents the models that were used to ascertain variables influencing the probability of adopting beekeeping. Several specifications were tested. Statistical tests revealed the absence of multicollinearity among the independent variables. This was performed by generating their correlation coefficients and there was no significant correlation found between any of the independent variables. In addition their variance inflation factors (VIFs) were generated and were all less than 10 which is the threshold. Furthermore, absence of heteroscedasticity was confirmed using the visual test. The distribution of the error terms was also checked and results showed that the error terms were non-normally distributed. However, normal distribution of these error terms was assumed because of the relatively large sample size. Therefore the results from these models are efficient and reliable.

Human capital measured by education level and gender of the farmers significantly influenced adoption of beekeeping. The results indicated that male farmers were 13% more likely to adopt beekeeping than female farmers. Primary, secondary and tertiary education levels significantly but negatively influenced beekeeping adoption. This meant that educated farmers were less likely to become adopters as opposed to those that had not received formal education. All these variables were significant at 1% significance level.

Similarly, social assets measured by access to extension services, source of the extension services and being a member of a farmer group had significant influence on adoption of beekeeping. Access to extension services increased the likelihood of adopting beekeeping. Being a member of a farmer group also increased the likelihood of adopting beekeeping by 5%. The statistical results also showed that farmers that accessed extension services through NGOs were 24% more likely to participate in beekeeping while those accessing them through the government were 9% less likely to adopt.

Lastly, financial assets in terms of distance to the nearest markets also significantly influenced adoption of beekeeping. Farmers living far from the markets were 2% more likely to adopt as compared to those located nearer to the markets. This showed that the likelihood of adoption increased with increase in remoteness. While all these factors significantly influenced the likelihood of adoption, the results show several other factors that are known to influence adoption but had no significant influence in the current study. These included the age of the farmer, amount of land owned by the household, household size and the total annual household income.

Much as human, social and financial assets were found to be important factors influencing beekeeping adoption, social capital was found to play the biggest role in this process compared to the other two assets. Natural capital measured by amount of land owned by the household was found not to influence beekeeping adoption. Less educated farmers living far from markets who got information and support from NGOs seemed to be targeted for beekeeping adoption. This could be linked to the fact that the poor living in isolated areas are the main focus when promoting poverty reduction programmes.

Table 14: Estimation results of logistic regression and probit model with adoption (0, 1) as the dependent variable (Marginal effects are reported (n=301)

Variable (s)	Model1	Model 2	Model 3	Model 4	Probit model
Age of the farmer (years)	0.000			0.000	0.000
	(0.001)			(0.001)	(0.001)
Gender (1: man)	0.165			0.130	0.131
	(0.490)***			(0.037)***	(0.033)***
Primary education (1:yes)	-0.190			-0.083	-0.084
	(0.046)***			(0.033)***	(0.030)***
Secondary and tertiary education	-0.632			-0.200	-0.199
(1:yes)	(0.048)***			(0.045)***	(0.044)***
HH size (number)	0.002			0.001	0.000
	(0.005)			(0.003)	(0.003)
Distance to market (km)			0.080	0.024	0.025
			(0.006)***	(0.004)***	(0.004)***
Land acres			-0.000	-0.000	-0.000
			(0.003)	(0.001)	(0.002)
Tot. annual income (USD)			0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)
Member of any farmer group (1:yes)		0.195		0.054	0.057
		(0.048)***		(0.035)	(0.036)
Access to extension services (1:yes)		0.219		0.150	0.159
		(0.052)***		(0.046)***	(0.047)***
Government (1:yes)		-0.017		-0.087	-0.086
		(0.034)***		(0.032)***	(0.033)***
NGOs (1:yes)		0.494		0.241	0.230
		(0.065)***		(0.046)***	(0.038)***
Eastern zone(1:yes)				-0.031	-0.023
				(0.039)	(0.039)
Mid-Northern zone (1:yes)				-0.001	0.004
				(0.040)	(0.041)
Constant	0.145	0.000	0.009	0.001	0.000
	(0.558)	(0.674)	(0.257)	(1.617)	(0.824)
Pseudo R^2 (prob>chi2 = 0.000)				0.725	0.725

*Tot. = total, HH = Household, ***refers to significant at 1% level and standard errors are between brackets ()*

5.3.2 Classification of beekeepers based on the adoption cycle

Next, the study focused on the differential patterns of adoption. The study revealed that majority of the beekeepers were late adopters (n = 75), followed by early adopters (n = 50) and then innovators (n = 42). These groups significantly differed from each other in terms of low education levels where more of the late adopters (69%) had not received formal education as compared to the other two groups (Table 15). Generally, very few of the adopters had attained secondary or tertiary levels of education. Higher proportions of innovators and early adopters accessed extension services through NGOs compared to the late adopters. However, the percentages of those who belonged to farmer groups, had access to at least one of the extension services and those that accessed extension services through the government did not significantly differ across the innovators, early and late adopters.

Table 15: Binary variables showing differences among the three groups of adopters

Variable (s)	Innovators (% yes)	Early adopters (% yes)	Late adopters (% yes)	Chi-square value
Farmer had no formal education (1:yes)	42.0	53.8	69.3	8.89**
Secondary/tertiary education (1:yes)	4.7	7.7	4.0	0.88
Access to extension services (1:yes)	95.8	96.1	96.0	0.04
Farmer group (1:yes)	90.7	96.2	90.7	1.53
NGOs (1:yes)	81.4	75.0	46.7	18.18**
Government (1 :yes)	62.8	48.1	48.0	2.80

*** = Significant at 5% level*

Note: Innovators have over 8 years of beekeeping experience, early adopters 4-7 years and late adopters less than 4 years.

A one-way ANOVA revealed that adopters' characteristics such as age, distance to the nearest markets, total number of beehives owned, annual honey income together with total annual income obtained from all the bee products were significantly different across the three groups of adopters (Table 16). However, these groups did not differ in terms of household size, total land owned and total annual household income.

Table 16: Comparison of the household and farm characteristics of beekeepers according to adoption type (One-way ANOVA test)

Variable (s)	Innovators	Early adopters	Late adopters	P-value
Age (years)	47.1 (2.4)	49.5 (2.3)	40.5 (1.5)	0.003***
HH size (numbers)	11.1 (0.7)	10.3 (0.8)	10.1 (0.6)	0.539
Land acres (acres)	12.3 (4.5)	8.2 (0.8)	8.6 (1.1)	0.396
Tot. annual income (USD)	610.7 (66.9)	711.6 (169.1)	590.2 (112.5)	0.771
Distance to market (Km)	9.7 (1.8)	6.1 (0.8)	4.2 (0.3)	0.000***
Tot. honey income (USD)	56.5 (8.1)	45.8 (2.3)	13.8 (2.3)	0.000***
Tot. annual income bee products (USD)	68.4 (10.1)	70.9 (17.6)	13.9 (2.3)	0.000***
Qty. harvested per year (kg)	21.5 (2.8)	21.7 (5.7)	7.0 (1.3)	0.001***
Tot. no. of hives owned (numbers)	31.7 (2.4)	24.3 (2.4)	15.5 (1.6)	0.001***

*Tot. = total, Qty= quantity, no. = number, *** =1% significance level, Standard errors between brackets* ( ) and *1USD = 2700 Uganda shillings at the time of data collection.*

Note: Innovators have over 8 years of beekeeping experience, early adopters 4-7 years and late adopters less than 4 years.

Post hoc analysis revealed that most of the significant differences existed between late adopters and innovators, a few significant differences existed between early and late adopters. Early adopters were on average nine years older than the late adopters, a difference that was significant at 1%. They were also older than innovators.

Innovators lived in more remote areas than late adopters as reflected by the distance to the nearest markets that differed by 5.4km between the two groups. Late adopters on average owned significantly less number of beehives, harvested less honey per year, had less income generated from honey per year and less income generated from bee products than innovators (Table 17). Results further showed that late adopters had 16 beehives less than innovators, harvested 15kg of honey less than that harvested by the innovators and obtained 61.38 USD less from their bee products as compared to the innovators. Late adopters also differed from early adopters in terms of income generated from honey, sum of income generated from all bee products and quantity of honey harvested. These differences were: 32.01 USD, 57 USD and 15kg respectively.

In sum, innovators had more beehives, produced slightly less honey but obtained more income from honey than the early and late adopters. However, the early adopters obtained more income from the bee products which shows that the amount of income derived from beekeeping seemed independent of the number of hives owned but more dependent on the type of bee products harvested.

Table 17: Results of post hoc test showing differences in household and farm variables between adoption groups

Variable (s)	Innovators	Early adopters	Late adopters
Age (years)	47.05[a,b](2.34)	49.48[a](2.31)	40.48[b](1.54)
Distance to the market (km)	9.65[a] (1.80)	6.07[a,b](0.81)	4.21[b](0.33)
Tot. honey income (USD)	56.49[a](8.07)	45.82[a](2.33)	13.81[b](2.33)
Tot. annual income from bee products (USD)	68.37[a](10.05)	70.89[a](17.59)	13.90[b](2.33)
Qty. of honey harvested per year (kg)	21.53[a](2.74)	21.68[a](5.6)	6.99[b](1.28)
Tot. no. of beehives owned (numbers)	31.72[a] (2.36)	24.27[a,b](2.37)	15.45[b](1.57)

Qty. = quantity, Tot. = Total, no. = number, Different letters (a-b) indicate significantly different mean values using ANOVA and post hoc tests. Standard errors are between brackets ()
Note: Innovators have over 8 years of beekeeping experience, early adopters 4-7 years and late adopters less than 4 years.

5.4 Factors influencing the amount of honey produced by the adopters

As mentioned above there is a large variability in the amount of honey produced between the adoption groups. Table 18 gives the results of the two models (OLS and Heckman selection model) that were used to analyse the determinants of honey produced. The results of the first step of Heckman selection model (probit) are presented in Table 14.

Statistical tests revealed that there was no potential problem of multicollinearity that would cause the OLS estimation to be inefficient. This was tested using the correlation coefficients of the independent variables and generating their variance inflation factors (VIFs) and the tolerances. There was no significant correlation between the explanatory variable, all the VIFs were below 10 which is the threshold and the tolerances were greater than 0.2. Furthermore, normality of the error terms was checked and results showed that these error terms were non-normally distributed but normal distribution was assumed because of relatively large sample size. The assumption of linearity for OLS estimation was also tested using the scatter plot and found not to be violated. On the other hand, endogeneity was suspected because some of the relevant variables that explain honey production had not been included in the model and this would cause the OLS estimation to be inefficient. Furthermore, non-random selection bias was also suspected among beekeepers. This is due to the fact that beekeepers might have kept bees because of their unobservable characteristics. The Heckman selection model was hence used to correct for the endogeneity and selection bias if any. The Heckman inverse mills ratio (lambda) however ruled out the problem of selection bias and presence of endogenous variables since it was not significant (p=0.336). In addition, Heckman selection model and OLS estimation showed similar results which implied robustness.

Factors found to significantly influence honey production in the absence of selection bias during beekeeping adoption were access to market information, access to ready markets, source of beekeeping equipment, apiary management practices, availability of bee forage and beekeeping experience.

The results show that beekeepers that had access to market information on average produced 4kg more than those that did not *ceteris peribus*. In addition, lack of access to ready markets measured by selling products to fellow community members reduced the amount of honey produced by 6.5kg on average. The adopters that did not have access to ready markets sold their products to the fellow members of the community and hence did not have an incentive to increase their production.

Source of beekeeping equipment measured by whether the beekeeper purchased his/her own log hives was found to influence honey production. The results showed that beekeepers that purchased log hives on average produced 12kg more than those that did not *ceteris peribus*. Apiary management practices measured by whether the beekeeper had knowledge on inspection of beehives or not also had significant influence on honey production. A beekeeper that had this knowledge produced approximately 6kg of honey more than those that did not have the knowledge. Additionally, a one year increase in beekeeping experience increased honey production by 7kg. Therefore adopters with longer beekeeping experience produced higher amounts of honey per year than the new comers.

Furthermore, bee forage availability measured by the presence of citrus on the farm significantly and negatively influenced honey production. The results showed that the farmers who grew citrus would produce 7 kg of honey less than those who did not grow them. On the other hand, the study found no significant effect of the amount of non-farm household income on the amount of honey production though this had a negative relationship.

Table 18: Determinants of quantity of honey produced (dependent variable = Amount of honey produced per year and n = 301)

Variable(s)	OLS Coefficients	Heckman selection model (Second step) Marginal effects
Number of years in beekeeping (years)	6.72 (1.15)***	7.01 (1.15)***
Citrus (1:yes)	-7.19 (2.60)***	-7.23 (2.50)***
Total non-farm income received (USD)	-3.83e-008 (0.00)	-1.99e-007 (0.00)
Log hives bought (1:yes)	12.48 (3.14)***	12.74 (3.03)***
Bee suit bought (1:yes)	2.95 (4.16)	2.94 (4.00)
Hive inspection (1:yes)	5.88 (3.75)*	6.02 (3.62)*
Pests and disease control (1:yes)	0.43 (3.13)	0.71 (3.03)
Access to extension services	1.82 (7.24)	3.66 (7.22)
Access to market information (1= yes)	4.52 (2.63)*	4.34 (2.54)*
Fellow community members buyers(1:yes)	-6.49 (2.68)**	-6.65 (2.60)**
(Constant)	0.14 (8.44)	
Mills ratio (lambda)		0.336(3.44)
R^2	0.35	
Pseudo R^2 (prob>chi2 = 0.000)		0.725

*For Heckman model, wald chi2 (10) = 77.33, *** refers to Significant at 1% level, **=Significant at 5% level and * =significant at 10% level, Standard errors are between brackets ().*

5.5 The major beekeeping constraints mentioned by the adopters

Now that the factors influencing adoption and honey production are known, attention is given to constraints which may explain why some beekeepers produced more than others. The study revealed that beekeepers were affected by production and marketing constraints. Limited knowledge on production skills, pests and diseases, poor beekeeping group management, low hive colonization and bush fires were mentioned as the major production constraints. These were mentioned by more than half of the beekeepers (Figure 9). The other marketing constraints were mentioned by a few of the beekeepers.

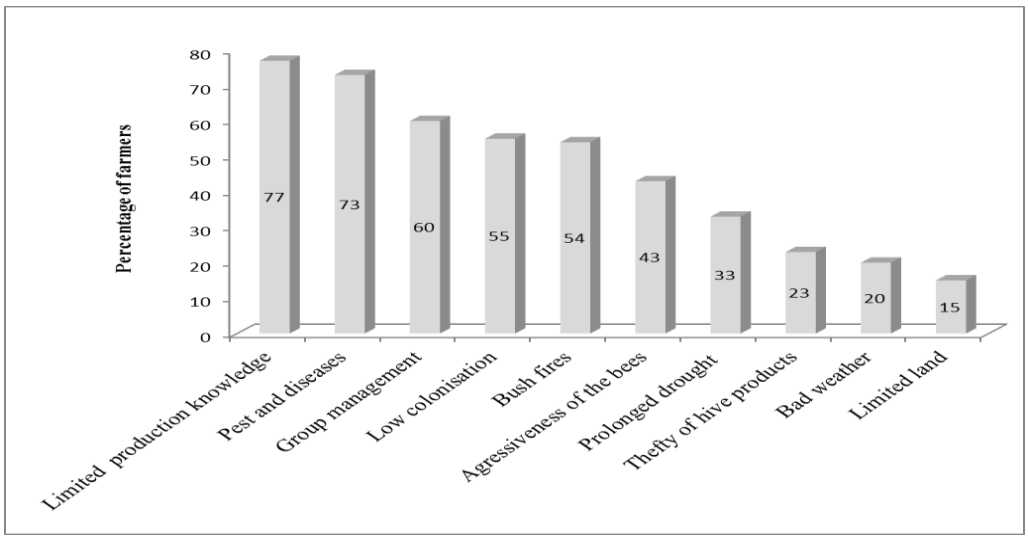

Figure 9: Production constraints of beekeeping

Meanwhile the major marketing constraints were poor quality of the hive products, being cheated by middlemen, long distances to markets, poor roads and lack of proper packaging materials (Figure 10). Low prices, limited market, low demand for hive products and products getting damaged during their transportation to the market were other marketing challenges.

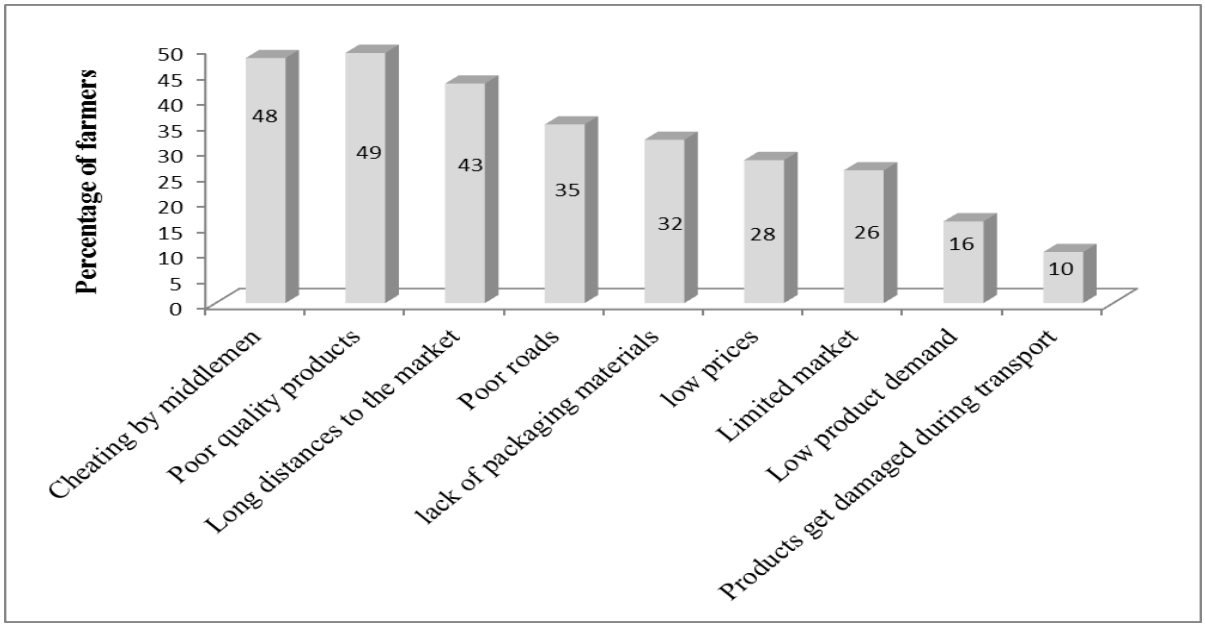

Figure 10: Marketing constraints in beekeeping

Given that most beekeepers lived further from the markets, they had to transport their products to the market. Foot (mentioned by 36% of the respondents), motorcycles (11%), and vehicles (10%) were the three main means of transporting bee products to the market. Some of the farmers (42%) entirely sold their products from home hence did not require transport means. The main buyers of the hive products were middlemen (mentioned by 54% of the respondents), fellow community members (50%), processing companies (30%) and others like co-operatives (9%), shop dealers and people with medical problems (8%). The chief places where these products were sold from included farmers' homes (60%), nearest markets (49%), schools and hospitals (39%), village ceremonies (15%) and agricultural shows (8%).

Farmers that sold to co-operatives received 4.27 USD on average as their unit price of honey while those who mainly sold to fellow community members received 3.20 USD. Additionally, those that mainly sold to co-operatives had an average honey income per annum of 43.76 USD while those that sold to their fellow community members had 36.11 USD as their annual honey income.

These results highlighted that a substantial number of the adopters sold their bee products through informal marketing channels and received low prices because they lived far from markets, were not organised in cooperatives, had poor roads and did not have proper means of transport.

6. CHAPTER SIX: DISCUSSION

This study aimed at analysing beekeeping adoption and production process in Northern Uganda. Data was collected from three agro-ecological zones in the region. Most households in Northern Uganda had diversified farm activities, a typical characteristic of rural poor households as explained by Deininger and Okidi (122). The rural poor diversify their activities so as to supplement their income from subsistence farming because they have limited risk bearing capacity. In line with Barrett, Reardon (123), this study found that diversification by rural households into beekeeping is driven by the desire to meet their economic and consumption needs. Furthermore, the results indicate that the level of awareness about the enterprise and market availability play a big role during the selection of diversification enterprises. This finding was in agreement with Dimara and Skuras (124) who reported that lack of producer information especially regarding profitability of improved practices hinders peoples' participation in certain activities.

6.1 Predictors of beekeeping adoption

Human capital influenced beekeeping adoption. The current study found that male farmers were more likely to adopt beekeeping compared to female farmers holding other factors constant. This concurs with some other studies where beekeeping was reported to be a male dominated activity (93, 125). Male's dominance in beekeeping may be linked to several possible explanations such as women's household labour demands, predominant use of traditional hives and aggressive behaviour of the bees (11, 126). The aggressive behaviour of African honey bees leaves early morning and late evening hours as the only convenient times for carrying out routine apiary management activities such as hive inspection and harvesting yet this is the time when women are busy with other house chores. In addition, most Ugandan cultures forbid women from climbing trees and this could be one of the reasons why women rarely participate in beekeeping especially when traditional hives are used. Traditional hives tend to be hanged very high in trees and this makes it complicated for women to carryout management practices without climbing. Females also have limited access to tools and equipment and are less likely to receive extension services (127-129). Thus they lack the technical know-how and means to adopt improved technologies which may in turn influence their capacity to take on activities like beekeeping.

Another important finding was that non-educated farmers were more likely to adopt beekeeping than those that had received formal education *ceteris peribus*. This may be explained by the fact that educated farmers tend to concentrate more on non-farm income sources to supplement their household income. Another possible explanation for large participation by the less educated may be that beekeeping projects targeted the poorest and low educated farmers as a poverty reduction

intervention. However, this finding is contrary to Mwangi, Kihurani (130) who reported that farmers with primary education were more likely to adopt than the illiterate ones while no significant relationship between secondary and tertiary education level with adoption of new agricultural technologies was found.

Social capital provided the largest set of significant variables that had a positive relationship with adoption. For instance, access to extension services increased the likelihood of adopting beekeeping. This was in agreement with Knowler and Bradshaw (56) who found knowledge acquisition as a key driver of adoption. The results also showed that farmers that had membership in farmer groups were more likely to adopt beekeeping. This could be linked to the assumption that farmers in farmer groups can easily access inputs required for the start. In line with these findings, Edillon (57) found that organizational membership and extension service coverage significantly increased adoption of agricultural technologies in the Philippines.

Sources of extension services also significantly influenced adoption. The farmers that accessed extension services through NGOs were more likely to adopt beekeeping. This might be linked to the fact that NGOs tend to focus more on the poorer people while offering their services in poverty eradication programs. Most farmers in Sub-Saharan Africa that benefit from government programs are usually the more wealthy farmers. Furthermore, Anandajayasekeram (131) reported that government uses top-down approach in providing extension services and lacks commitment as reflected by their failure to allocate sufficient funds to run extension programs. The same study reported that some government extension agents used their positions to extract rents from farmers which discouraged the farmers from participating in government aided programs. Putting all this together, their services are usually less efficient than those provided by NGOs and Community Based Organisations (CBOs). NGOs and CBOs use the interactive system and are often more committed. Most public extension services have also been condemned for lacking relevant technologies, motivation and accountability to their clients which makes their services ineffective (132).

Financial assets also influenced adoption of beekeeping. Access to infrastructure measured by distance to the nearest markets had a negative relationship with beekeeping adoption. Much as it would be thought that farmers living nearer to markets would adopt easily, this study found that the likelihood of adopting beekeeping increased with the increase in distance to the nearest markets *ceteris peribus*. This could be linked to the defensive behaviour of bees which cause beekeeping to only be favourably done in remote and isolated areas such as forests (50).

6.2 Honey production determinants and beekeeping barriers

The honey production seemed to be rather variable across the farmers. The major factors affecting production of honey in the study area are: access to market information, access to ready markets, source of beekeeping equipment, beekeeping experience and forage availability.

Beekeepers with access to market information were found to produce significantly more honey than those that did not have access to this information which was in agreement with the study done in Ethiopia (58). In addition, access to ready markets was reported as an important determinant of the amount of honey produced in the current study. Lack of access to ready market which caused beekeepers to sell their honey to fellow community members as the main buyers reduced honey production by about 7kg. This was in line with Abebe (133) who reported that an efficient and integrated market with good performance is very crucial for stimulating farmers to increase their output. Reduced production might be explained by lack of incentive to produce since the beekeepers are not certain of who will buy their produce in case of no access to ready markets.

Another interesting finding was that the source of the beekeeping equipment significantly influenced production. Farmers that bought their equipment were found to produce 12kg more than those that obtained equipment through donation. This might be linked to the fact that those that purchase the equipment tend to value it more than when it is freely given to them and are highly committed to honey production. In line with this, Reardon, Kelly (134) reported that a policy priority that would be used to increase agricultural productivity in Africa during the 21st century would be helping farmers find ways to earn income to pay for agricultural inputs and equipment instead of giving them hand-outs.

Routine apiary management practices such as hive inspection significantly and positively influenced honey production, a finding that is similar to that reported by Okwee-Acai, Anyanzo (62). These practices ensure proper management of hives and reduce absconding incidences. The knowledge on these management practices was obtained from different sources such as fellow beekeepers, government and NGO extension programs.

Furthermore, the longer the experience in beekeeping the adopter had, the higher the amount of honey produced holding other factors constant. A possible explanation for this may be that farmers with longer experience had mastered the process of production and could easily counteract certain challenges that the new comers would probably not be able to solve. Beekeepers with longer experience also had knowledge on most of the management practices such as hive siting, feeding bees, understanding the colony calendar and harvesting of honey. Proper management not only increases colonisation rates but also productivity. On the contrary,

Kersting and Wollni (135), reported that young farmers were more innovative and likely to produce more and good quality fruits in Thailand than the old experienced farmers.

Surprisingly, availability of forage was negatively related to honey production, a direction opposite from what was anticipated. This study found that adopters that had citrus on their farms produced 7kg less than those that did not grow citrus. This could be explained by the insecticidal activity exerted on the bees by caffeine and other related substances contained in citrus pollen (136). The toxicity from citrus caffeine is usually not a problem if it is not in synergy with the effects of pesticides. The same study reported that these synergetic effects weaken worker bees and they cannot go foraging in the field which weakens the colony leading to low honey production in the long run.

While struggling to produce optimally, beekeepers encountered several challenges. The results were in agreement with (9) who reported chief production constraints as lack of knowledge on production skills and pests and diseases. Contrary to the current study, Michael (137) reported theft and aggressive behaviour of the bees as the major constraints of beekeeping in Nigeria. The current study also revealed that being cheated by middlemen, production of poor quality products and walking long distances to look for markets were the key marketing constraints. Being cheated by middlemen could be attributed to selling of unprocessed products and lack of proper packaging materials. Value addition which translates into high prices and ability to exploit the export market was hardly explored by the beekeepers. This was probably because these beekeepers rarely owned processing equipment. As a result beekeepers were unable to produce good quality products, were given low prices by middlemen which forced them to sometimes walk for long hours searching for better prices for their products. This finding was in agreement with Ejigu, Gebey (79).

6.3 Status of beekeeping in the area of study

This study revealed that beekeeping is still contributing a very small percentage to beekeepers' average household income. This is much smaller than its estimated potential and could be linked to the neglected potential of beeswax and propolis production, marketing and production constraints and also the low amount of honey currently produced by most farmers. For instance, only 18% and 10% of the adopters harvested beeswax and propolis respectively. Yet beeswax and propolis had higher unit prices than honey. Although the contribution seemed small, it could still be of help to beekeeping households given that beekeeping was prominent in poorer households where every coin counts. This additional income can be used to buy household items, farming tools and pay school fees for the children (79). The current contribution of beekeeping could be increased through creating awareness about the production, benefits and marketing of the propolis and beeswax as well as improving production of honey through use of better hives and improved knowledge.

The study also found that most of the beekeepers had not received formal education. These findings were contrary to those of Chuma, Mushuku (5) and Matanmi, Adesiji (138) who found that 80% of the beekeepers in Nigeria had received post-secondary education. On the other hand, they were in agreement with Ndyomugyenyi, Odel (13) who also found beekeepers to have low education levels. The low levels of education might have forced beekeepers to largely depend on on-farm income since alternative sources of income are always limited for the uneducated people. Due to over dependency on on-farm income sources the beekeepers were poorer than the non-beekeepers. Since beekeeping participation is currently dominated by the poor and uneducated farmers, its promotion among educated farmers should be targeted to increase its production. If this target is achieved, then this might also translate into increased beekeeping income to households. This will prevent the activity from getting extinct as education levels of farmers increase in the future generations and also given that people choose their household activities based on their ability to satisfy their economic needs.

Beekeepers were relatively older and this was in line with the findings of Mujuni, Natukunda (9) who found most of the beekeepers to be over fifty years of age. This could be attributed to the migration of the youth to urban areas in search for white-collar jobs leaving farming for the ageing population in the rural areas. Study findings were on the other hand not in agreement with those of Michael (137) who found that most of the beekeepers were below forty years of age.

Furthermore, the study revealed that currently most beekeepers sell their honey mainly to fellow community members who offer them low prices. Co-operatives offer higher prices but very few of the beekeepers are organised in co-operatives which deny them an opportunity to explore collective marketing and increased market accessibility. This is in line with Hussein (139) who found that few beekeepers in Arabian countries were organised in beekeeping associations. If market inaccessibility problems are addressed, this could increase production because ready markets will act as a motivation.

6.4 Limitation of the study

The major limitation is the cross sectional design used. This design only gives a snapshot of the situation at a particular point in time. Therefore, no cause and effect relationships can be drawn from it. With this study design, it is also difficult to predict the behavioural changes of the farmers over time. Another limitation is that the number of women involved in beekeeping was relatively small (22%) thus assessing gender related issues was not possible in this study. The measurement of income was also challenging since most farmers did not have proper records of their cash flows and were also not very open about the topic. Recall method was mainly used to answer questions related to generated income and this is not as reliable as if they had proper records kept.

7. CHAPTER SEVEN: CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

The main aim of this study was to analyse the adoption and production process of beekeeping while overcoming the limitations of previous studies. Data were collected randomly with the aid of a structured questionnaire from 166 beekeepers and 138 non-beekeepers in Northern Uganda. Descriptive statistical tests, OLS, binary logistic regression and Heckman selection models were used to analyse the collected data. The analysis for the factors influencing beekeeping adoption and honey production was mainly based on the sustainable livelihood framework.

Study findings show that human, social and financial capitals are the key drivers of adoption of beekeeping in this setting. Social capital is however the most important of the three capitals. Social capital in terms of access to extension services, group membership and source of extension services greatly influenced beekeeping adoption rates. Other notable findings are that beekeeping is predominantly a male activity engaged in by the poor that live far away from markets and are largely dependent on crop production for their survival.

Access to market information, access to ready markets, routine apiary management practices, sources of beekeeping equipment, forage availability and beekeeping experience are the major determinants of honey production in this context. Concerning forage availability, the current study shows that much as integration of crop production in beekeeping is very important, it may also affect honey production negatively.

7.2 Recommendations

Social capital in form of access to extension services and group membership was crucial in adoption process. To increase future beekeeping adoption rates, the study recommends that development programs promoting beekeeping as a source of supplementary income to bridge the existing production and marketing knowledge gaps and also ensure that farmers are organised in groups. Private-public partnerships should be put in place to assist in bridging the gaps in extension services. These partnerships will be useful since most NGO programs are short-lived. A collaboration of the government with NGOs will increase sustainability in delivery of extension services and beekeeping related knowledge even after NGO projects have ended. The government should also put policy measures in place to reduce rent seeking behaviour of the extension workers. This will increase the number of farmers taking up beekeeping under government aided programs.

The study also recommends farmers to invest in the production of propolis and beeswax given their higher prices. This is vital if beekeeping is to be considered a poverty reduction activity.

Higher prices for the bee products could also be achieved through organising farmers into co-operatives. Subsidies should also be provided to beekeepers for production of properly packaged honey to increase market access especially the export market. These interventions will lead to a shift from the currently popular informal marketing channels of bee products to the formal ones.

To increase the current honey production, a conducive and well organised market for honey is recommended. Additionally, beekeepers should be trained on how to produce optimally even with farming systems that integrate crop production with beekeeping. With increased access to ready markets and production knowledge, future honey production will be increased.

Finally, a longitudinal research is needed to explain why most beekeepers have not exploited the production of beeswax and propolis. Yet the current study shows that these two products have higher market prices than honey. In addition, future researchers can explore how to promote beekeeping among educated farmers. This is because presently, it is mainly done by uneducated farmers.

Note: Figures 3 and 4 were accessed from: http://www.ugandahoney.com/about-uganda-honey.html

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APPENDICES

Appendix 1: Household questionnaire

This presents the parts of the questionnaire that were used for the compilation of my thesis.

Household Questionnaire

The purpose of this questionnaire is to document the socio economic characteristics of beekeeping and non-beekeeping households; perceptions, knowledge and attitudes of these households towards beekeeping; examine the current livelihood options available; barriers to women participation and their major sources of income.

Introduction:

Dear respondent this is to introduce *Ms Amulen Deborah Ruth* a graduate student of Makerere University conducting research on barriers to beekeeping in your region. The information obtained from this study will be handled with respect and confidentiality. It shall be used for academic purposes; with your consent should I begin the interview?

Questionnaire No. **Locality** **GPS No:**

A. Socio-Demographic Characteristics of the Respondents fill or tick in the adjacent boxes.

Code	Attribute		Tick		Tick		Tick		Tick
A.1	Sex	**Female**		**Male**					
A.2	Age								
A.3	household head	Female		Male					
A.4	Marital Status	Single		Married		Divorced			
A.5	Household members								
A.6	Land ownership	Own land		Do not		Share land			
A.7	Land acreage								
A.8	Education level	No formal		Primary		Secondary		Tertiary	
A.9	Main income sources	On-farm		Off farm					
A.10	Years in beekeeping	**None**	<1year	2-3years		3-5years		>5years	

B. Livelihood options, land allocation and economic contribution

B.1 Does this household engage in crop farming?

Yes = ☐ **No =** ☐

B.2 If yes which crops are grown in this household? Tick in box below;

No.	Crop Code	Tick Crop Grown
1	Cassava	
2	Sorghum	
3	Millet	
4	Sweet potatoes	
5	Maize	
6	Groundnuts	
7	Beans	
8	Cowpeas	
9	Tobacco	
10	Cotton	
11	Simsim	
12	Pigeon Peas	
13	Other Crops	

B.3. Does this household keep livestock? **Yes =** ☐ **No =** ☐

B.4 If yes which livestock are reared in this household? Tick in the box below:

No.	Livestock	Tick	Number of Livestock
1	Cattle		
2	Sheep		
3	Goats		
4	Pigs		
5	Poultry		
6	Other		

B.5 Does anyone in this household engage in off-farm activities?

Yes = ☐ **No =** ☐

B.6 If yes, what are these non-farm activities? Tick and add them.

Code	Off Farm Employment	Tick
1	Small Business	
2	Civil Servant	
3	Charcoal Burning	
4	Teaching	
5	Politician	
6	Brick Laying	
7	Others	

B.7. What made you to choose the above crops and livestock? Tick and add list**.**

No.	Reasons	Tick
1	Knowledge About It	
2	Market Available	
3	Higher Income	
4	Household Consumption Needs	
5	Culture	
6	Interested	
7	Status	

B.8 Comparing crops and livestock; what uses most of your land? Fill the acres

No.	Enterprises	Acres
1	Livestock	
2	Crops	

B.9 Where does **money** for this household come from? Fill table below;

No.	Sources of Income	Frequency of Income			Amount
		Monthly	Per season	Annually	
1	Crop sales				
2	Livestock sales				
3	Off farm employment				
4	Other sources (non-farm employment)				

*fill in the frequency the farmer can remember

Reasons for not adopting Beekeeping: (Non-Beekeepers)

C.2 If you do not keep bees, what are your reasons? **If you keep bees go to C.4**

No.	Attribute	Tick
1	Limited Knowledge	
2	No Interest	
3	Fear Of Bees	
4	No Capital	
5	Limited Space For Beekeeping	
6	No Market For Products	
7	I Don't Think It Can Make Money	
8	Others	
	Total	

Factors for Attraction to Beekeeping

C.3. For Non-Beekeepers: Under what conditions would you consider starting beekeeping?

No.	Conditions for Beekeeping	Tick
1	Training On Beekeeping	
2	Market Availability	
3	Land (Space)	
4	Capital	
5	Advisory Support	
6	Not Interested At All	
7	Income From Bees	
8	Time Availability	
9	No Need I Am Rich	
10	Security	
11	**Others**	

C.4 For Beekeepers: If you keep bees, what attracted you to beekeeping? Tick and add if not on the list

No.	Attribute	Tick
1	My parents	
2	Training	
3	Personal interest	
4	Income	
5	NGO's	
6	Others name them	

Assessing social Networks

C.7 Group Membership: For Beekeepers and Non Beekeepers are you a member of any of the following groups

No.	Group	Tick
1	Farmers group	
2	Marketing Group	
3	Beekeepers association (for beekeepers)	
4	Burial Group	
5	Savings Group	

Assessing the Current Knowledge Level of Beekeepers

C.8 Which aspects of beekeeping do you know? Please tick and add

No.	Beekeeping Knowledge	Tick
1	Local Hive Construction	
2	Hive Sitting	
3	Capturing Swarms	
4	Pest And Disease Control	
5	Honey Harvesting And Processing	
6	Bee Forage Calendar	
7	Other Product Processing	
8	Proper Hive Inspection	
9	Colony Multiplication Techniques	
10	Feeding (Water)	

Assessing Major Sources of the Current Knowledge and Skills

C.9 Where did you get this knowledge from? Please tick and add

No.	Knowledge Source	Tick
1	Fellow Beekeeper	
2	From Relative	
3	Extension Agent	
4	Newspaper	
5	Radios	
6	Agricultural Shows	
7	Trial and Error	

Assessing Current Beekeeper Constraints

C.10 What problems do you face in beekeeping**? Choose at least 6**

No.	Challenges	Tick
1	Aggressiveness Of Bees	
2	Bush Fires	
3	Theft Of Hives And Product	
4	Drought	
5	Limited Knowledge	
6	Pest And Diseases	
7	Limited Space	
8	Limited Market For Our Products	

Push Factors for Non-beekeepers not adopting Beekeeping

C.11 For Non-beekeepers: What are your fears of beekeeping? **Choose at least 6** add any (continue to **C 13**)

No.	Challenge	Tick
1	Aggressiveness Of Bees	
2	Bush Fires	
3	Theft Of Hives And Products	
4	I Have No Knowledge	
5	Not Sure It Is Profitable	
6	No Space To Place The Beehives	

Assessing Beekeepers current Investment capacity and Sources of Equipment

C.12 which of the following beekeeping equipment do you have?

No.	Materials	Tick	How many	home made	locally made& materials purchased	Provided on credit	donated	Cost	Number of years owned
1	Log Hives								
2	KTB Hives								
3	Langstroth								
4	Bee Veil								
5	Gloves								
6	Boots								
7	Bee Overall								
8	Water Sprayer								
9	Airtight Bucket								
10	Honey Strainer								
11	Smoker								
12	Bee Brush								
13	Hive Tool								
14	Honey Extractor								

E. Extension Service Barriers

E.1:1 Do you have Access to any form of beekeeping extension services (Tick)

Yes

No

E.2: Which form of beekeeping extension services do you access? Tick and add if missing

No.	Extension services	Tick
1	Training on Management	
2	Training on Product Processing	
3	Routine Visits By Extension Agent	
4	Supply of Beehives	
5	Market Information	
	Other	

E.3: Who provides these beekeeping extension services to you? Tick

No.	Source of extension service	Tick
1	Government	
2	NGOs	
3	Private (community based)	
4	Fellow Farmers	
5	none	

F. Bee Products Produced and Marketing

F.1 Which Products do you harvest; what is the annual yield; what do you do to them? And what is the price per kg of each of the products?

No.	Products	Quantity/ year	Use		
			Home consumption	Sale	Price /kg
1	Honey				
2	Bees wax				
3	Propolis				
4	Pollen				
5	Bees				

F.4 Who buys your bee products? Tick

No.	Buyer	Tick
1	Middlemen	
2	Processing companies	
3	Beekeepers cooperatives	
4	Fellow members in community	
5	Others specify	

F.5 Which place do you sell your products from?

No.	Places	Tick
1	At Home	
2	Nearby Market	
3	Agricultural Shows	
4	Village Ceremonies	
5	Others Specify	

F.6 What is the distance in kilometres from your home to the nearby market?

……

F.7 How do you transport your products to the market?

No.	Means of Transport	tick
1	Bicycle	
2	Vehicle	
3	Foot	
4	Animal Traction	
5	Others Specify	

F.8 What constraints do you face in marketing your bee products? List them

No.	Constraints	
1	Market is Far	
2	Poor Roads	
3	Poor Weather	
4	Low Demand	
5	Product Damages	

Appendix 2: Observation distributions based on to remove outliers from the data

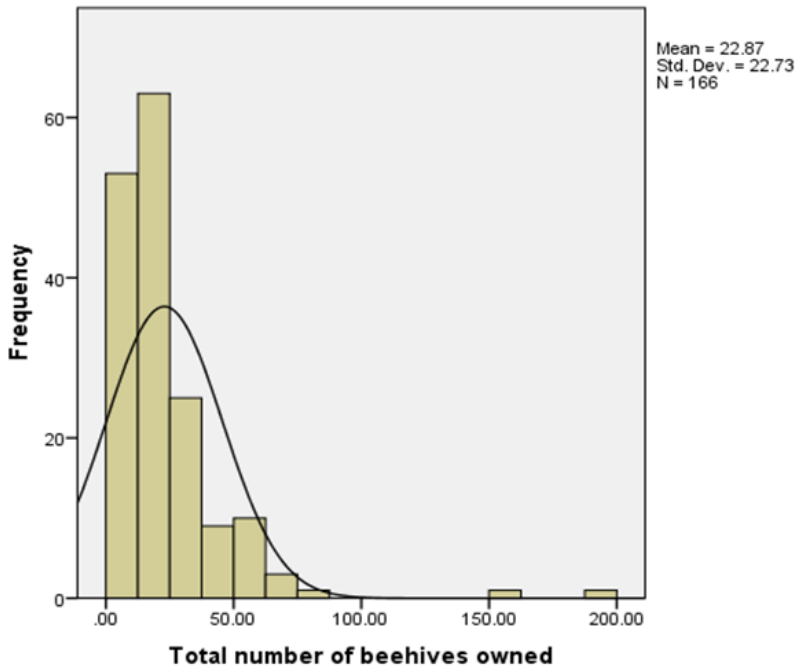

Figure A2.1: Mean distribution of number of beehives owned with outliers

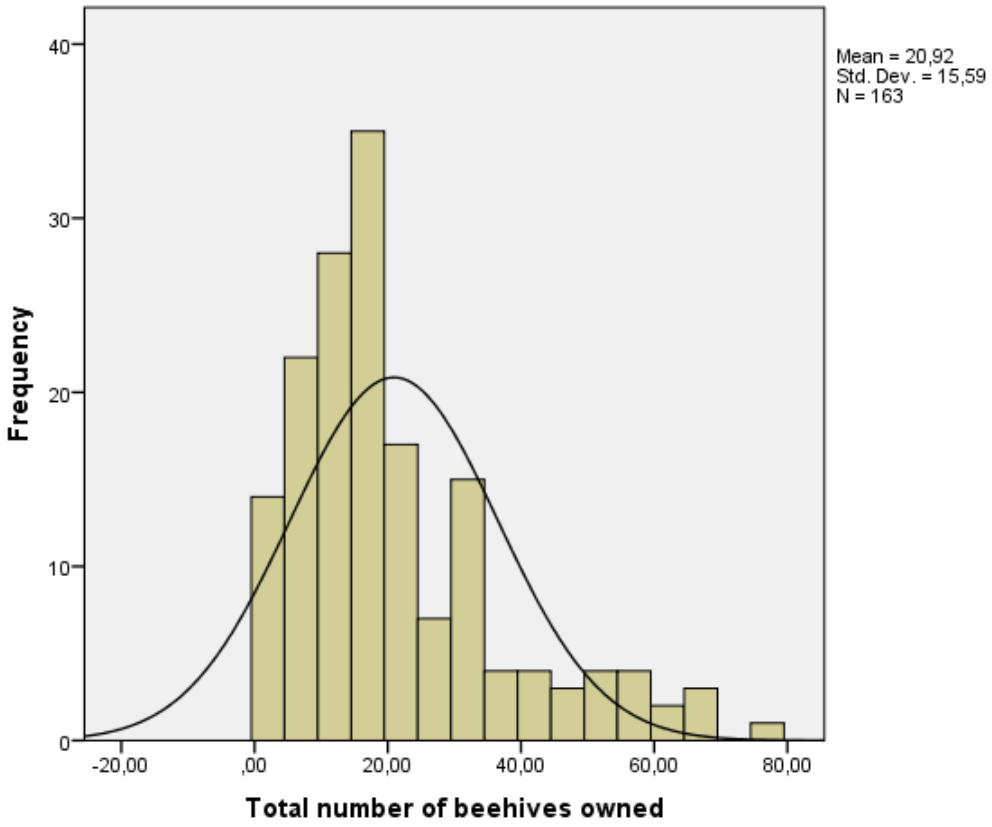

Figure A2.2: Distribution of the number of beehives owned after removing the two outliers

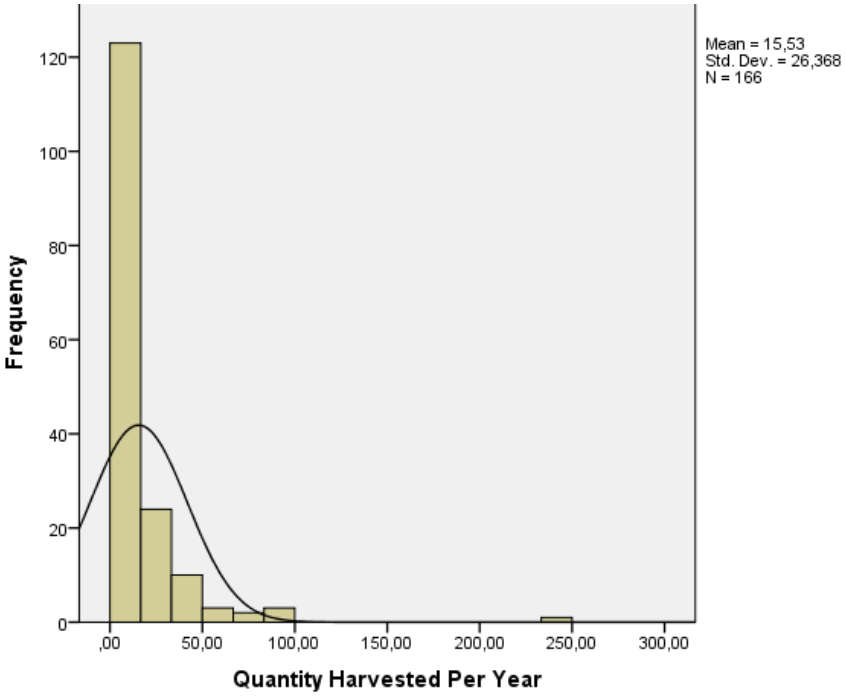

Figure A2.3: Distribution of quantity of honey produced with the outlier

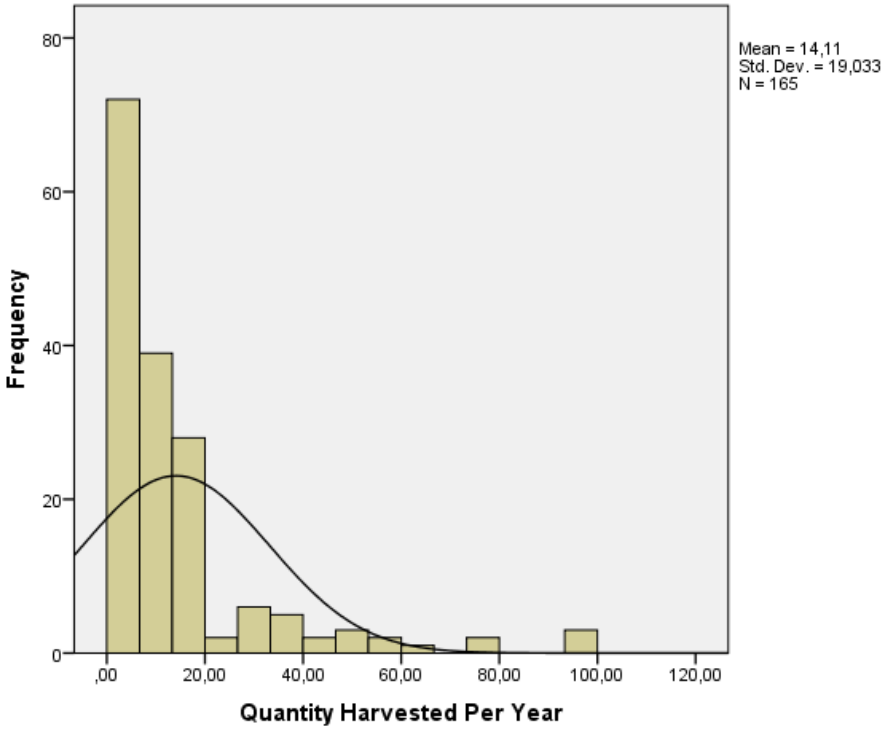

Figure A2.4: Distribution of quantity of honey harvested with one observation removed

Appendix 3: Models run with outliers included in the data

Table A3.1: Estimation results of logistic regression and probit model with adoption (0, 1) as the dependent variable (Marginal effects are reported (n=304)

Variable (s)	Model1	Model 2	Model 3	Model 4	Probit model
Age (years)	0.000			0.001	0.001
	(0.002)			(0.001)	(0.001)
Gender (1: man)	0.171			0.135	0.135
	(0.491)***			(0.034)***	(0.034)***
Primary education (1:yes)	-0.189			-0.078	-0.080
	(0.473)***			(0.029)***	(0.030)***
Secondary and tertiary education (1:yes)	-0.613			-0.204	-0.204
	(0.045)***			(0.046)***	(0.044)***
Household members (number)	0.000			0.000	0.000
	(0.005)			(0.002)	(0.002)
Land acres owned			-0.001	-0.000	-0.000
			(0.003)	(0.002)	(0.002)
Total annual household income (USD)			0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)
Member of any farmer group (1:yes)		0.198		0.060	0.063
		(0.048)***		(0.035)*	(0.036)*
Distance to market (km)			0.080	0.025	0.025
			(0.006)***	(0.004)***	(0.004)***
Access to extension services (1:yes)		0.221		0.152	0.162
		(0.053)***		(0.046)***	(0.047)***
Government (1:yes)		-0.165		-0.086	-0.086
		(0.040)***		(0.032)***	(0.033)***
NGOs (1:yes)		0.495		0.236	0.225
		(0.066)***		(0.046)***	(0.038)***
Eastern				-0.037	-0.029(0.039)
				(0.038)	
Mid-northern				-0.008	-0.002(0.041)
				(0.040)	
Constant	0.311	0.000	0.009	0.001	0.001
	(0.553)	(0.674)	(0.258)	(1.518)	(0.873)
Pseudo R^2 (prob>chi2)= 0.000				0.725	0.725

**** =significant at 1%,* =significant at 10 %, standard errors (), No. of observations = 304, for model 4 and probit model: LR chi2 (14) = 301.93*

Table A3.2: Results for the determinants of honey production among adopters with the outliers still in the dataset (n = 304)

Variable(s)	OLS	Heckman selection model (Second step)
	Coefficients	Marginal effects
Number of years in beekeeping (years)	6.84 (1.66)***	7.86 (1.65)***
Citrus(1:yes)	-10.00 (3.73)***	-10.05 (3.75)***
Total non-farm income received (USD)	9.69e-006 (0.00)***	8.41e-006 (0.00)***
Log hives bought (1:yes)	21.50 (4.35)***	22.09 (4.16)***
Bee Suit bought (1:yes)	11.40 (5.92)*	10.84 (5.63)*
Hive inspection (1:yes)	3.52 (3.75)	4.01 (5.11)
Pests and disease control (1:yes)	6.93 (4.46)	7.55 (4.28)*
Access to extension services	-3.38 (10.49)	-3.35 (10.26)
Access to Market Information (1= yes)	4.61 (3.80)	4.09 (3.63)*
Fellow community members buyers(1:yes)	-3.78 (3.85)	-4.39 (3.69)
(Constant)	0.29 (12.22)	
Mills ratio (lambda)		0.015 (4.77)**
R^2	0.35	
Pseudo R^2(prob>chi2) =0.000		0.725

**** refers to significant at 1 % level, **=significant at 5% level,*= significant at 10 % level and Standard errors are between brackets (). Number of observations = 304, for Heckman model, wald chi2 (10) = 97.26*

The results for the predictors of honey production give relatively different results with outliers included in the dataset because one of the outliers was removed based on the dependent variable for this model. Therefore the dataset with the outliers is not a typical representative of the population examined.