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Farmers' perceptions of pollinators' importance in coffee production in Uganda

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ABSTRACT

Coffee (*Coffea canephora*) is the principal cash crop and the country's largest agricultural foreign revenue earner in Uganda. Previous surveys confirmed that coffee grown in central Uganda was largely depending on bee pollination to set fruit set. Despite its high contribution to the economics of agricultural sector in Uganda and despite its great dependency to bees for fruit set, it is not clear if small-scale farmers are aware of the importance of managing farmlandscapes for pollination services conservation to increase coffee yield. The aim of this study was to assess farmers' perceptions and knowledge of the importance of pollinators and pollination services conservation for coffee production enhancement. The main hypothesis was that small-scale coffee growers were not aware of the relevance of pollination services for coffee production. Farmers' surveys were conducted in coffee-banana farming systems in central Uganda.

It was found in this study that more than 90% of interviewed farmers were not aware of the role played by bees in coffee yield increase. Farmers were not willing to manage their lands to protect pollination services, particularly because they considered pollination service as an unsolicited "free service", or as a "public good". Farmers were not aware of the role of semi-natural habitats serving as reservoir (hiding points) for pollinators in the surrounding of coffee fields. However, they were aware of some ecosystem services delivered in the coffee-banana farming system such as planting shading trees. Only 3.3% of respondents believed that placing beehives in coffee farms could increase the yield. The study recommended the increase of the awareness of small-scale coffee growers on the importance of pollinators to increase coffee production.

It is recommended that future management of pollination services are built on improving farmers' indigenous knowledge and on adequate understanding of the ecology of the local pollinator species. There is a need to broadly scale-up best field, habitat and landscape management strategies and practices that are friendly to coffee pollinators in rural landscapes of Uganda

Keywords: Coffee Production; Ecosystem Services Delivered in Farmlands; Pollinating Services; Farmers' Perceptions of Pollinators; Pollinators Conservation; Pollinator-Friendly Farming practices; Uganda

1. INTRODUCTION

Coffee (*Coffea arabica* and *C. canephora*) is an important commercial crop. It is the second most traded global commodity by developing nations after oil [1]. Coffee is an important cash crop in Uganda because the tree crop is the principal cash crop and the country's largest agricultural foreign revenue earner [2].

At the farmer level, coffee remains an important source of income since its production accounts for over 10% of total income of the farmer [2]. At the national level, income from coffee currently contributes around 20% - 26% of Uganda's export earnings [2] In 1999, coffee exports totaled 150,000 mt (2.5 million bags of 60 kg) representing US$125.316 million in foreign exchange earnings. Exports by value for Uganda coffee is

of 398 million $USD in 2009 (Presidential press of 31 December 2010).

The improvement of coffee yield quality and quantity at farm level remains importantly an area that requires encouragement as part of national strategy to increase the production of coffee in Uganda. Thus, improvement and stability of coffee productivity are very important in the Uganda national economy. However the improvement needs the understanding of farmers' perceptions and knowledge of pollinators and pollination services for coffee production among other key production and management factors to consider. It is important to collect such information since any management and technology that can be scaled-up to improve coffee production has to be implemented by small scale growers.

There are many ecosystem services that are delivered in agricultural landscapes and pollination service is one of them. It may be difficult for farmers to invest in the conservation of ecosystem services without knowing and being convinced of their importance. Farmers can not consider managing their lands for the conservation of ecosystem services delivered by pollinator biodiversity if they are not aware or convinced of the importance of these services for their livelihoods.

In Sub-Saharan Africa and in Uganda, farmers' perceptions and awareness about the role of pollinators in coffee production remain largely un-documented. Yet, such information is necessary for developing suitable management plans to conserve agro-ecosystems and services delivered in and from these agro-ecosystems for coffee productivity stability and improvement. Information about indigenous knowledge's and perceptions of pollination services is necessary to be incorporated in the design of management strategies for increasing and maintaining pollination services for the stability of the yield of coffee and other pollinator-dependent crops and for on-farm biodiversity conservation .

Pollination is a service nature provides that is mostly taken for granted, and very little is done to improve or maintain this natural service [3]. However, pollination is an ecosystem service that is key to food security [4-6]. Pollinators are essential for many vegetable, fruit and seed based crops including coffee that are grown in Uganda and in Sub-Sahara Africa. Good agricultural environmental health is fundamental to sustainable farming [3]. For pollen-limited crops, promoting pollination services is a mean of increasing their productivity without resorting to expensive agricultural inputs such as pesticides and herbicides. Indeed, pollination services are most likely underpinning productivity in many Sub-Saharan grown crops without farmers even recognizing it [6].

Globally, the contribution of pollinators for increasing genetic diversity, adaptation, seed set or crop production, crop quality and natural regeneration of wild and cultivated crops species has been highlighted and the need to conserve pollinators has been stressed worldwide [7-11]. Yet the public' knowledge of the role of pollinators remains poorly documented or not documented at all, especially in Sub-Saharan Africa [2] including Uganda, where farmers grow crops with high degree of vulnerability to future pollinators decline [2]. Conducting an interview survey seems to be an important step in information generation for policy-makers concerned with issues related to conciliate on-farm pollinator biodiversity conservation and promotion of agriculture modernization that is aiming at increasing agriculture production and thereby increasing household annual income and employment opportunity of the farmers.

Hence, the relevance of assessing specific knowledge by farmers on pollinator importance for coffee crop yields increase, agriculture, wild biodiversity and agro-biodiversity conservation.

The understanding of farmers' perceptions of pollinator importance in coffee production can help in developing strategies to reduce on the negative attitudes and influence the change of attitudes and opinions towards the adoption of environmentally friendly farming practices by farmers.

The objective of this study was to document farmers' knowledge and perceptions of the importance of ecosystem services delivered in farmlands and of pollinators for coffee yield increase and stability. It was hypothesized that "small-scale coffee growers were not aware of coffee pollinators and perceive these as not important in coffee production because "granted by the nature". Because most managers of coffee farms (from central Uganda) are aged (50 - 70 years) male farmers, and that female farmers play a secondary role, it was therefore hypothesized that the knowledge of pollination by farmers would be linked to the gender and age of the farmer. Since most coffee growers have small land area, it was expected that the size of the coffee farm would influence the knowledge of pollination. It was also predicted that the knowledge of pollination would be linked to the level of education since in most schools in Uganda; students get to learn pollination issues. These expectations combined to various others were tested by carrying out an analysis on most probable factors explaining such knowledge among small scale coffee growers from central Uganda.

2. MATERIALS AND METHODS

2.1. Survey Area and Sites

This study survey was conducted in the banana-coffee

system of Lake Victoria Arc in central Uganda (**Figure 1**). This system is based on the production of banana (*Musa* sp.), (mainly cooking and dessert types) as the main food crop and coffee, mainly *Coffea robusta*, as the main cash crop. Food production is mainly conducted by small scale less-resourced farmers. The coffee-banana system covers the districts of Jinja, Iganga Mukono, Mityana, Luwero, Rakai, Masaka, Wakiso, Kampala, Mpigi, Mubende, Mukono, Kamuli, Mabira districts of central Uganda. The Lake Victoria Arc, central Uganda, is characterized by ferrisoils with high to medium fertility level, and receives on average 1000 - 1700 mm of rains on a bimodal pattern (rainy seasons: March-May, September-November; dry to semi-dry seasons: June-August, December-February) with 22˚C - 28˚C and 60% - 75% of temperature and relative humidity respectively. The area is characterized by the prevalence of high rains although the rainfall amounts and patterns are unpredictable.

The study zone belong to the Lake Victoria phytochorion, with shrubs of *Acacia* spp, legume trees, melliferous plant species, *Papyrus* and palms ranging from 2 to 15 m high dominating the remnant secondary vegetation. Several food and cash crops are grown, mainly cassava (*Manihot esculentum* L.), Sweetpotato, (*Ipomoea batatus*, L.), maize (*Zea mays*), beans (*Phaseolus vulgarus* L.), groundnut (*Arachis hypogea* L.); tomato (*Lycopersicon esculentum*), watermelon (*Citrullus lanatus*), pumpkin (*Cucurbita moschata*), cucumber (*Cucumis sativus*), melon (*Cucumis melo*); chilies (*Capsicum* spp.); and several other fruits, vegetables and horticultural crops (cabbage, onion etc., egg plants, sim-sim, etc.). The majority of these crops are grown in small-scale monoculture and or polyculture fields that are integrated into the coffee-banana agroforest production systems where coffee and banana are the heading corps. Coffee is the cash crop of economic importance at national level, mainly produced in this region, while banana is the main staple food crop [2]. However, some large monocultures and Estates of industrial crops (tea, sugar, and coffee)

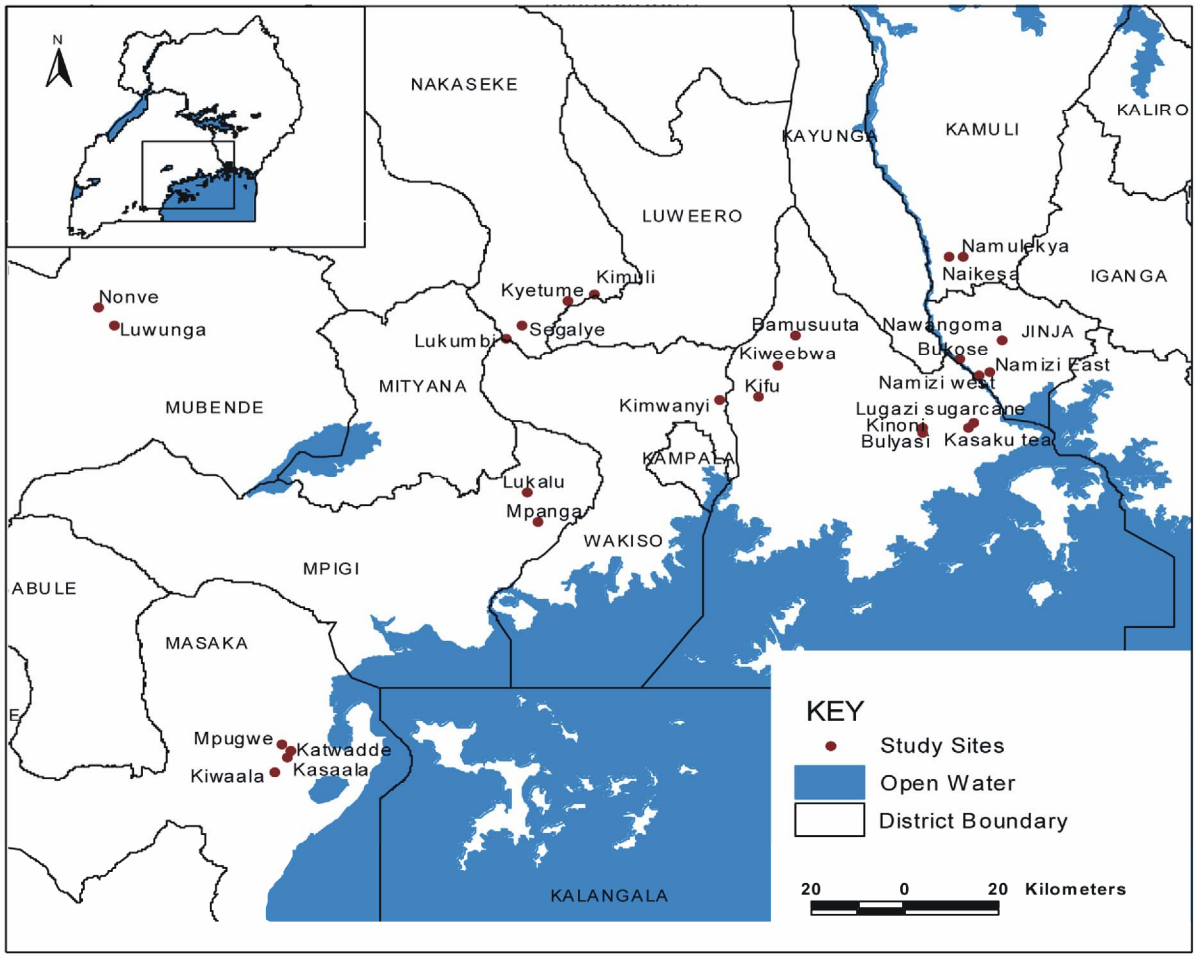

Figure 1. Location of sites (per district) in which the survey on farmers' perceptions of pollinator importance to coffee production was conducted in the coffee-banana farming systems area around Lake Victoria in Uganda.

are found in the study zone. Traditional agroforestry systems with multipurpose tree species such as avocado (*Persea americana*), papaya (*Carica papaya*), mango (*Mangifera indica* L.), jackfruit, citrus trees, anonas (*Annona* spp.). These tree species are maintained in simple and complex traditional agroforestry systems, indicating the diversity of farming systems in the landscapes. *Lantana camara* L., an invasive species, and several tropical flowering plant species are often found on farmlands and in home gardens.

Rural central Uganda is mosaic landscape where "islands" of natural habitats (forest fragments, forest fallows, forest reserves, wetlands) are found scattered within agricultural matrices dominated by linear and nolinear features of semi-natural habitats (fallows, hedgerows, grasslands, cattle pastures) that are displayed as field boundaries of the diversity of small-scale fields.

Compared to other regions (districts) of Uganda, the area is also characterized by high demographic pressure, limited access to arable lands, continuous cultivation and over-exploited lands. Central Uganda is characterized by different population densities from two main tribes (Baganda and Basoga): very high (400 - 500 pers/km^2), high (200 - 400 pers/km^2), medium (100 - 200 pers/km^2) and low (50 - 100 pers/km^2). The region has benefited much with some of the interventions (agricultural technologies dissemination) deployed by PMA (Plan for modernization of agriculture) actors and partners interested in socio-economic transformation and sustainable development of agricultural sector in Uganda.

Different study sites were intentionally selected based on assumptive criteria of drivers that may potentially be responsible for differences in knowledge of pollinator communities by local people across different localities found within the study zone. A total of 26 sites (**Figure 1**) was selected to represent a range of habitats types of varying degrees of anthropogenic disturbances, and management intensities (**Figure 1**) These included human population densities; farm management practices, cultivation intensities (traditional small-scale farms versus large and intensely managed plantations or estates); natural and semi-natural habitats, gradient of vegetation complexity and structures (strata) found within and between agricultural fields. Two to four sites (1 km^2 each site) were selected per district. The different surveys conducted were grouped into clusters using human population density as a surrogate measure of agricultural intensity [2]

2.2. Surveys on Farmers' Knowledge Ecosystem Services, Pollination Services, Pollinators and Their Importance in Coffee Production

Interviews started with group discussions with local coffee farmers selected from all the administrative units of the study area. The group discussions were followed by detailed household interviews. For these interviews, a stratified random sample of coffee growers was selected involving about 17% of the village coffee growers in the study area.

A total of 120 farmers (60 males and 60 females) were interviewed from 26 study sites (**Figure 1**) to document their knowledge of valuable ecosystem services delivered in coffee-banana farming system and to document their knowledge and perception of coffee pollinators and their importance to coffee production. In each study site, 4 farmers (two males and two females) engaged in coffee growing and productions were selected for the interviews. Interviews were conducted as recommended [12-14]. Interviews were conducted during coffee blooming seasons (June-August 2007 and November 2007 to March 2008). The farmers were randomly selected from the study sites selected per district using lists of coffee farmers obtained from local council chairpersons.

Prior to conduct formal interviews on the importance of pollinators for coffee, a questionnaire was submitted to farmers and aimed at assessing the level of appreciation and knowledge of different valuable ecosystem services delivered in the coffee-banana farming systems. There exist a number of ecosystem services delivered in rural landscapes .The pre-survey concentrated on ecosystem services that are relevant and likely to be delivered in the coffee-banana farming systems of central Uganda. Selected ecosystem services likely to be delivered in the coffee-banana farming system are presented in **Table 1.**

To assess the level of knowledge of farmers of these ecosystem services and to understand how farmers appreciate these ecosystem services for their livelihood improvement, each ecosystem service was presented to a farmer as statement relating its importance in the agro-ecosystem. The researcher provided sufficient explanation to the farmer about the role, function and importance of that ecosystem service in the agro-ecosystem. After explanation, each farmer was requested to state whether he agreed, disagreed or nether agreed/disagreed with the statement. Farmers who responded that they agreed are those believed to be aware of the value of that ecosystem service.

A formal interview followed shortly after collecting data during the preliminary interview. During the formal interview, farmers were interviewed using a pre-tested structured questionnaire. The questionnaire was filled using face to face interviews. All interviews and discussion with farmers were conducted in the main local language (Luganda) either at the farmer's home or in the coffee-banana field where such fields were within 1 km

Table 1. Type of statements on valuable ecosystem services delivered in coffee-banana farming systems in central Uganda.

No	
	Supporting services
1	Soil structure and fertility is important to be maintained to increase crops yields
2	Nutrient cycling maintains soil fertility through mediation of microorganisms (bacteria, fungi, actinomycetes) that enhance soil fertility by liberating nutrients from detrital organic matter
3	Bacteria enhance nitrogen availability through the fixation of nitrogen from the atmosphere, thus contributing to better yield of legume crops
4	Non-crop plant products (organic matter, cow dung) are keys to soil fertility since they can replenish nutrients to agricultural land during fallow periods.
5	Conservation tillage can contribute to increase soil fertility and crop yields
6	Upstream soil erosion control contribute to high crop yields
	Regulating services
7	Some insects contribute to better yields of my crops
8	Ground beetles provide dung burial services and decompose wastes thereby recycling nitrogen and contributing to enhance soil fertility.
9	Ground beetle, ladybeetles, spiders, ladybugs, mantis, syrphid flies, and wasps, and lacewings reduce crop pest, thereby contributing to better yield of your crops
10	The harvest can be reduced to nil if stingless bees, honeybees and other wild bees do not visit the flowers of crops (stimulant/vegetable/legume/fruit) they grow
11	Moths, butterflies, flies visitation to crops help to get better yield for most of crops we grow
12	Sunbirds, bats visitations to flowers of crops like coffee contribute to higher fruit set; in addition, they reduce/eat crop pests (e.g. coffee berries borers)
13	Growing in mixture many crop varieties (landraces) increases resistance of your crops to disease attacks; thereby contributing to better yields of your crops
14	Increasing a high cover of trees on farm contribute to high rainfall in my village
15	Polyculture systems contribute to the stabilization of temperature and precipitation regimes (contribute to the reduction of frequency and severity of extreme weather, droughts, floods, etc.) than monocultures in the village
16	Favorable, suitable and stable climate with sufficient rains can be obtained if we plant many trees in the village
17	Cutting or clearing all forests and semi-natural habitats around my gardens can contribute to high yield loss
18	Keeping a large amount of forested habitats help in getting clean purified water downstream (at the bottom of hill/mountains) and reduce soil erosion in the village.
19	Planting shading trees along coffee farms can contribute to increase coffee yield
20	Sun coffee yield better than shaded coffee
	Provisioning services
21	Great harvests (crop production) and food we eat can not be obtained without participation of insects, micro-organisms, birds in the production systems
	Non-marketed services
22	Aesthetic and beautiful landscapes obtained in the village through tree planting can contribute to your health and long life

from a farmer's homestead and the farmer was willing to be interviewed on site. The researcher visited every respondent's coffee field in order to verify some of their responses.

Interviews were conducted in order to collect necessary information that could help to understand the level of knowledge of farmers about pollinators and pollination mechanisms. The survey questionnaire comprised two main parts. The first section sought general socio-demographic information about respondents, including age, gender, household income, gender labour in coffee production, marital status, number of children and formal education. The second section gathered information relating to respondents' knowledge of coffee pollination and perception of the importance of pollinators to coffee yield and other crops.

Specifically, farmers were asked to i) describe their understanding of pollination, ii) identify and differentiate between wild bees, honeybees and insect pests iii) mention the role of bees and other pollinators in coffee fruit set, iv) identify nesting habitats of different wild bee species that visit coffee flowers, and v) comment on the effects of pesticides application on honeybees and other pollinators in fields. Photographs of insect pests and different kind of pollinators were presented to respondents to help in identification of different species of insects visiting coffee flowers.

2.3. Data Analysis

The survey data were encoded, entered into a spreadsheet and checked prior to analysis. Cross-tabulation with selected variables, percentages and means were undertaken using pivot table in Microsoft Excel 2003. Percentages were based on either the total number of respondents or total responses, details of which are provided in the respective text or tables. Chi-square test was

used to determine the effects of farmers' socio-demographic profiles on their knowledge and perceptions of pollinators and their roles in coffee production. Chi-square test was also used to identify significant difference in response of males and females in the agreement of statements proposed about the importance of differentiate ecosystem services delivered in farmlands. All statistical analyses (chi-square) were conducted using Minitab 15, English Version.

A logistic regression analysis was conducted to determine most important factors that could probably have influenced knowledge of pollination by farmers. Logistic regression allows one to predict a discrete outcome from a set of independent variables that may be continuous, discrete, and dichotomous, or a mix of any of these. The dependent variable in this case, the knowledge of pollination, had binary values, *i.e.*, yes or no response.

3. RESULTS

3.1. General Perception of Types of Valuable Ecosystem Services Delivered in the Coffee-Banana Farming Systems in Central Uganda

Interviewed farmers (males and females) in the sample were mostly aged (50 - 70 years). Respondents declared that farming was the main source of their income. In addition, majority of these farmers declared that their annual incomes came from coffee farming activities and that they have almost no off-farm incomes. Declared farm incomes were in general low (<US $ 1500 - 2500 per annum) but the family incomes were higher when farmers owned big land of coffee.

Various statements (**Table2**) explaining the importance of different ecosystem services delivered in farmlands were read and explained to farmers. The purpose was to identify if farmers knew or were aware of the value of these ecosystem services and if they were could to care for their preservation. In relationship to coffee pollination, ecology and management for yield increase, statements 10, 11, 12, 19 and 20 (**Table 2**) were mixed among other statements and set to identify if farmers acknowledge the value of these ecosystem services delivered in coffee-banana farming system.

When asked if they believed that "harvests can be reduced to nil if stingless bees, honeybees and other wild bees do not visit the flowers of crops they grow", 45 (75%) of males and 37 (61.7%) of female respondents disagreed with the statement number 10. However, there was no significant difference in the disagreement in rela-

Table 2. Farmers' attitudes and knowledge and awareness of important ecosystem services delivered in coffee-banana agroforestry systems. (Do you agree/disagree with the statement?: Number of farmers agreeing/disagreeing with statement). Total number of interviewed: 120 (60 females and 60 males). Significance levels of chi-square test: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$, ns = not significant, NT = not test conducted.

Number of statements on types of ecosystem services	DS = Disagree			AG = Agree			NAD = Neither Agree/Disagree			Dominant perception (% of farmers)		
	Male	Female	(χ^2-test) Ch-Sq	Male	Female	(χ^2-test) Ch-Sq	Male	Female	(χ^2-test) Ch-Sq	Male	Female	(χ^2-test) Ch-Sq
Supporting services												
1	19	10	2.79 ns	40	49	0.91 ns	1	1	0.00 ns	AG (66.7)	AG (81.7)	1.51 ns
2	5	8	0.69 ns	5	7	0.34 ns	40	45	0.29 ns	NAD (66.7)	NAD (75.0)	0.49 ns
3	10	12	0.18 ns	15	3	8.11 ns	35	45	1.25 ns	NAD (58.3)	NAD (75.0)	2.07 ns
4	0	0	NT	45	50	0.36 ns	15	10	1.00 ns	AG (75.0)	AG (91.0)	1.53 ns
5	0	0	NT	6	0	6.11 **	54	60	0.32 ns	NAD (90.0)	NAD (100.0)	0.52 ns
6	40	45	0.29 ns	5	10	1.66 ns	15	5	5.00 **	DA (66.7)	DA (75.0)	0.49 ns
Regulating services												
7	2	4	0.66 ns	1	5	2.66 ns	47	51	0.16 ns	NAD (78.3)	NAD (85.0)	0.27 ns
8	12	10	0.18 ns	28	34	0.58 ns	20	16	0.46 *	AG (46.7)	AG (56.7)	0.98 ns
9	19	10	2.79 ns	11	45	20.65 ***	30	5	17.87 ***	AG (75.0)	NAD (50.0)	5.14*
10	45	37	0.78 ns	10	13	0.39 ns	5	10	1.66 ns	DS (75.0)	DS (61.7)	1.23 ns
11	25	5	3.31 **	5	10	1.66 ns	30	45	3.11 ns	NAD (75.0)	NAD (50.0)	5.41 *
12	35	40	0.33 ns	5	13	3.56 **	20	7	6.35 ns	DS (58.3)	DS (66.7)	0.56 ns
13	10	4	2.5 ns	15	46	15.75 ***	35	1	32.11 ***	AG (76.7)	NAD (58.3)	2.46 ns
14	2	4	0.66 ns	35	56	4.85 **	17	0	17.0 ***	AG (93.3)	AG (58.3)	8.76 **
15	10	4	2.57 ns	34	26	1.05 ns	16	30	4.26 *	AG (56.7)	NAD (50.0)	0.41 ns
16	4	0	4.12 *	45	55	1.00 ns	10	5	1.66 ns	AG (41.7)	AG (91.7)	18.75**
17	2	43	37.5 **	3	17	9.87 ***	25	0	25.0 ***	NAD (66.7)	NAD (75.0)	0.49 ns
18	12	5	2.89 ns	40	55	2.37 ns	18	0	18.00 ***	AG (58.3)	AG (91.7)	7.45**
19	7	3	1.69 ns	53	49	1.98 ns	0	8	14.1 **	AG (83.3)	AG (81.7)	3.31 ns
20	30	35	1.98 ns	7	13	0.38 ns	23	12	3.46 ns	DS (50.0)	DS (58.3)	0.65 ns
Provisioning services												
21	5	5	0.00 ns	10	15	1.00 ns	45	40	0.29 ns	NAD (75.0)	NAD (66.7)	0.49 ns
Non-marketed services												
22	0	0	NT	40	34	0.48 ns	20	26	0.78 s	AG (66.7)	AG (56.7)	0.84 ns

tionship to gender (χ^2-test, $P > 0.05$). This result indicated that the majority of respondents did not perceive the contribution of wild bees, stingless bees and honeybees in boosting their crop harvests including coffee. In other words, farmers were not aware of the value of ecosystem services delivered by bees to their crops. Only few farmers were aware of the key role played by pollination services for coffee. As indicated in **Table 2**, most respondents hold the view that the presence or absence of stingless bees on coffee flowers has no impact on coffee fruit set and yield. Not only that farmers did not know the role of bees but the role played by other pollinators (moths, butterflies, flies) to help crops getting better yields for most of crops they grow remain largely unknown . In fact 75% of males and 50% of female respondents neither agreed nor disagreed with statement number 11, meaning that they were not sure or certain, probably the information was new to them.

Similarly, most farmers (58.3% of males and 66.7% of females respondents) disagreed equally (χ^2-test, $P > 0.05$) with the statement number 12 (**Table 2**) indicating that "sunbirds and bats visitations to flowers of crops like coffee could lead to higher fruit set of coffee through reduction by eating crop pests (*e.g.* coffee berries borers) and through pollination of coffee flowers".

When asked if "planting shading trees along coffee farms could contribute to increased coffee yield", 53 (83.3%) of males and 49 (81.7%) of females respondents agreed with the statement 19 although there was no significant difference related to the gender (χ^2-test, $P > 0.05$). However, there was a significant difference (χ^2-test = 14.1, $P < 0.001$) between men and women who neither agreed/disagreed that planting shading trees along coffee farms could contribute to increase coffee yields.

"Coffee being a male crop" in central Uganda, some 8 female farmers were not sure of if shading of coffee trees could increase coffee yield, whereas most men agreed that shading can increase coffee yield in the proportion of 10 to 35%. When asked if sun coffee could yield better than shade coffee, most (50%) males and females (58.3%) disagreed with the statement 20 (**Table 2**), meaning that they believed that shading coffee could lead to better yield better than sun coffee (**Table 2**).

3.2. Farmers Perceptions of Importance of Pollinators for Coffee

Up to 70% of farmers did not understand what pollination meant (**Table 3**). The proportion (%) of respondents who did not know what attract massively insects (bees) to coffee blossoms flowers was high but statistically ($P > 0.05$) similar between men (72%) and women (73%).

Farmers were unable to separate and distinguish honeybees from all other bee species and pest species. Around 25% of respondents knew honeybees and stingless bees. Women (33.3%) had higher understanding (χ^2-test, 1df = 5.6, $P < 0.05$) of honeybees and stingless bees than did men (16.7%). Only 8.2% of men could recognize that among the different kinds of insects presented to them were pollinators or natural enemies. In addition, women knew honey as the only benefit from honeybees **(Table 3)**. Up to 41% of the respondents perceived that these insects (flower-visitor insects shown to them) are just there and will always bee there. The majority of respondents (35.8%) were not aware of any ecological services performed by insects in their gardens. Almost (35%) of respondents stated that the majority of these insects presented to them were pests or just playing with coffee flowers but actually not harmful or beneficial to coffee (**Table 3**).

According to farmers, pollination service is "un-solicited" services or a "free service" or a "public good". Small-scale farmers do not feel the need for managing their farms for the provision of a "public good"

The majority (90%) of the respondents were not aware of the role played by pollinators in coffee yield and production (**Table 3**) although a high number of bee species visited coffee flowers during blooming seasons (**Table 3**). Hence, they did not perceive that coffee needs bees to produce. Significantly higher percentage of men (50%) than percentage of females (11.7%) perceived that bees were not important for coffee fruit set (χ^2-test, 1df = 23.8, $P < 0.0001$). Most farmers (65%) believed that coffee can still produce even if the flowers were not visited by bees.

Most of the respondents (75%) did not know where wild bees constructed their nests. Farmers had no idea of the role of semi-natural habitats as reservoir for pollinators in the surrounding of coffee fields. All respondents knew the importance of pesticides in pest/weed management, although some of them frequently said they had no means to buy them. For those who could afford buying these pesticides, 95% of them were not aware if pesticides could kill bees including honeybees (**Table 3**). When asked if they believed that placing hives in coffee gardens could increase coffee fruit set and yield, only 3.3% of respondents believed that hives in coffee farms could increase coffee yield; majority of the respondents believed that beehives have no impact on yield of coffee and other crops they grow (**Table 3).**

3.3. Factors Determining Knowledge of Pollination by Farmers

During discussion with farmers, compared to females, male respondents frequently offered an explanation and

Table 3. General knowledge and perception of farmers about the role of pollinators (bees) In coffee pollination and yield increase.

Gender	Number of respondents(%)						
Variables	**Males**	**% Males**	**Females**	**% Females**	**χ^2-test**	**All respondents**	**All (%)**
(A): Respondents knowledge of insect groups frequently seen visiting coffee blossoms (flowers)							
1. Apini-Meliponini	10	16.7	20	33.3	5.6 *	30	25.0
2. Ceratinini-Megachilini	0	0.0	0	0.0	NT	0	0.0
3. Anthophorini-Xylocopini	2	3.3	2	3.3	NT	4	3.3
4. Honeybee (Apini) + Pests	2	3.3	0	0.0	3.3 ns	2	1.7
5. Honey bees + non-pests	25	41.7	6	10.0	19.4 ***	31	25.8
6. Butterflies/Moths	2	3.3	9	15.0	7.4 **	11	9.2
7. Wasps/Ants	0	0.0	4	6.7	6.7 *	4	3.3
8. Flies	7	11.7	2	3.3	4.6 *	9	7.5
9.Halictini-Eucerini	0	0.0	0	0.0	NT	0	0.0
10. Thrips/Beetles	3	5.0	3	5.0	NT	6	5.0
11. Other pests	4	6.7	4	6.7	NT	8	6.7
12. Do not know	5	8.3	10	16.7	2.8 ns	15	12.5
(B): Respondents knowledge of insect group mostly damaging coffee crop and other cultivated staple plants							
1. Honeybees	0	0.0	0	0.0	NT	0	0.0
2. Butterflies	1	1.7	9	15.0	10.7 **	10	8.3
3. Wasps	15	25.0	1	1.7	20.4 ***	16	13.3
4. Flies	24	40.0	15	25.0	3.5 ns	39	32.5
5. Beetles	0	0.0	0	0.0	NT	0	0.0
6. Ants/thrips	10	16.7	20	33.3	5.6 *	30	25.0
7. Other Pests	4	6.7	0	0.0	6.7 *	4	3.3
8. Do not know	5	8.3	15	25.0	8.4 **	20	16.7
(C): Are you aware that some insects listed above as flower visitors/pests of coffee crops are beneficial (e.g. as food, predators, parasitoids, pollinate crops, or make the soil to be more fertile and productive)?							
1. None is beneficial	20	33.3	10	16.7	5.6 *	30	25.0
2. They are pests	12	20.0	30	50.0	12.9 ***	42	35.0
3. I do not know	23	38.3	20	33.3	0.4 ns	43	35.8
4. Some are beneficial	5	8.3	0	0.0	8.3 **	5	4.2
(D): What do you think attract bees/insects on your crop flowers? Do they just come play on coffee flowers?							
1. The smell of flowers	0	0.0	10	16.7	16.7***	10	8.3
2. Nectar/pollen	5	8.3	0	0.0	8.3 **	5	4.2
3. Resting/shelter	2	3.3	5	8.3	2.1 ns	7	5.8
4. Do not known	43	71.7	44	73.3	1.6 ns	87	72.5
5. Others reasons	10	16.7	1	1.7	12.3 ***	11	9.2
(F): Do you think bees and or other pollinators may play important role in coffee fruit set and yield increase?							
1. Yes it very Important	5	8.3	1	1.7	4.5 *	6	5.0
2. Not important at all	30	50.0	7	11.7	23.8 ***	37	30.8
3. They are just there	20	33.3	30	50.0	3.3 ns	50	41.7
4. Do not know	5	8.3	22	36.7	17.8***	27	22.5
(H): Knowledge of wild bee nesting sites: where do you think bees you see visiting your coffee flowers sleep?							

1. Tree branches	0	0.0	2	3.3	3.3 ns	2	1.7
2. Dead wood	0	0.0	0	0.0	NT	0	0.0
3. House walls/kraals	5	8.3	10	16.7	2.8 ns	15	12.5
4. Grounds (in the soil)	0	0.0	0	0.0	NT	0	0.0
5. Termite mounds	10	16.7	3	5.0	6.3 *	13	10.8
6. Do not known	45	75.0	45	75.0	2.2 ns	90	75.0
(G): Knowledge of effects of herbicides/insecticides: are you aware that they do killing honeybees/wild bees?							
1. Herbicides	1	1.7	0	0.0	NT	1	0.8
3 Insecticides	4	6.7	1	1.7	3.1 ns	5	4.2
3. Do not know	55	91.7	59	98.3	0.24 ns	114	95.0
(K): Do you believe that placing beehives in your field can increase your coffee yield in addition to the honey?							
1. Do not believe	45	75.0	0	0.0	75 ***	45	37.5
2. I believe	2	3.3	2	3.3	NT	4	3.3
3. Do not know	13	21.7	58	96.7	47.6 ***	71	59.2
(L): Which factor you think play a very significant role for flowers to turn into higher fruit set & coffee yield?							
1. Rains + soil fertility	20	33.3	35	58.3	6.8 **	55	45.8
2. Wind (+ "God")	1	1.7	0	0.0	NT	1	0.8
3. Coffee varieties	9	15.0	5	8.3	1.9 ns	14	11.7
4. Management	15	25.0	20	33.3	1.2 ns	35	29.2
5. Uncertain	15	25.0	0	0.0	25 ***	15	12.5

Significance levels of chi-square test: *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$, ns = not significant, NT = not test conducted

definition of the world "pollination". Because the proportion of males and females who knew how pollinators were important in crop yield increase was low and gender biased, the researcher though that such information could not be acquired in the traditional fashion of knowledge transmission. Therefore, several factors were suspected to likely contributing to pollination knowledge. Around 12 factors (**Table 4**) were selected as important drivers of such knowledge. In order to explore their effects, data was collected such as for each variable, two values could be obtained (1 = Yes, 0 = No). These factors included, age, gender, level of education, exposure to extension service etc.

Several hypotheses were therefore constructed for selecting variables to include in the model according to the objective of the study which was to determine the level of knowledge of pollination and pollination mechanisms and its importance to crop productivity among small-scale holders.

For example, education was chosen as an independent factor as it was hypothesized that people who spent much time at school are likely to be aware of what is pollination because they may have learnt it from school or they do reading or listening to radio or watch televisions. Age, gender and farming experience were also seen as likely factors influencing the knowledge of pollination. It was also assumed that knowledge of nectar/pollen collection by bees on coffee flowers could be a prerequisite to knowledge about pollination. It was also thought that respondents who had regular contact with

Table 4. Description of the respondent variables selected for logit regression as they were suspected to influence the knowledge of the farmers of pollination.

1. Age of the farmer [(1 = (>40 years); 0 = (<35 years)]
2. Number of years already spent farming coffee (1 = >15 years; 0 = < 10 years)
3. Gender of the respondent (1 = Male; 0 = Female).
4. Contact with extension services (1 = Yes; 0 = No) as potential sources of information about pollination
5. Higher capacity of differentiating honeybees from wild bee species visiting coffee flowers (1 = Yes; 0 = No)
6. Higher capability of differentiating a wild bee from a pest on a coffee flowers (1 = Yes; 0 = No)
7. Acquired basic primary and or secondary education (1 = Yes; 0 = No)
8. Mode of acquisition of the coffee field or farm (1 = planted all my coffee field myself; 0 = inherited)
9. Source of main agricultural household income (1 = coffee production, 0=other crops) for farmers who were not engaged in off-farm income generating activities
10. Engaged in farming a cash crop that require hand pollination such as *Vanilla* crop (1 = Yes, 0 = No)
11. Size of the coffee farm [1 = large (> 5 ha), 0 = small (0.1 - 2 ha)]
12. General attitude: Believing(agreeing) on the importance of maintaining a significant proportion (> 20% of total field) or protecting hedgerows/fallows/forests in the vicinity of coffee fields for yield increase [(1 = strongly agree, 0 = strongly disagree)]

extensions services could be able to know what the word pollination meant because extension workers are well trained in pollination issues and therefore assumed that they may bring such information to farmers.

Vanilla is a cash crop that is well cultivated in central Uganda, and it involves hand pollination. No farmer is aware that small megachild bees do pollinating *Vanilla* crop in coffee-banana farming system in Uganda. Therefore, farmers who grew *Vanilla* were likely to know what pollination was because they are always involved in hand pollination business. The number of years already spent farming coffee was judged to be an important factor since farmers who grow coffee tend to have or seek for general information about coffee growing and productivity maintenance over times. These farmers regularly visit the national agricultural research institutes of Uganda (NARO) where scientists are likely to be able to communicate to them the word pollination.
The mode of acquisition of the farm was judged to be important since farmers who inherited coffee fields had different knowledge of the coffee productivity enhancement from those who planted their coffee fields themselves. For example, farmers who made their own plantations are also those who planted coffee colonel varieties that they personally went to buy from agricultural research institutes that are involved in breeding of coffee for higher yield and resistance to diseases. Also farmers who earned more cash from coffee sales were suspected to have general knowledge of pollination compared to those who do not consider coffee farming as a lucrative business. It was also considered that believing that maintaining a significant proportion (>20% of total field) or protecting natural and semi-natural habitats (hedgerows, fallows, forests, etc.) in the vicinity of coffee fields can contribute to coffee yield increase was an important factor to influence knowledge of pollination and care about pollination services.

The above listed (**Table 4**) variables were tested for their significant effects under multiple logistic regression models in Minitab15 English version. Significant factors ($P < 0.05$) likely influencing knowledge of pollination by interviewed small scale coffee growers are presented in **Table 5.**

It would be expected that respondents who were aged (50 - 70 years) or those who had acquired basic education (primary and or secondary education) to be more likely to know the world pollination. Surprisingly, respondents who had past several years (>15 years) growing coffee and those who established themselves their coffee plantations or and those who had regular contact with extension services were statistically ($P < 0.01$) likely to explain what pollination meant (**Table 5**). These findings confirmed the fact that extension services were well equipped with pollination information such as they could be able to pass it to farmers. Advocating for management of pollination services for crop productivity enhancement should preferably be addressed by taking into consideration the contribution of extension services. Also extension services should target aged (50 - 70 years), educated and adult farmers when delivering key messages related to pollination services conservation for coffee productivity enhancement.

The above listed (described) variables were tested for their significant effects under multiple logistic.

4. DISCUSSION

4.1. Perceptions of Value of Ecosystem Services Delivered in Farmlands

In this study a difference in environmental attitudes between males and female respondents was observed. Respondents showed a high degree of awareness and

Table 5. Binary logistic multiple regression showing the relationship between the knowledge of pollination (two values for the response: 1 = farmers with some vague information, 2 = farmers with no information at all of what pollination means) versus (regressed on) on various 12 factors (predictors) listed in **Table 4**.

Logit regression values of factors determining respondents knowledge of coffee pollination in central Uganda				
Predictors	Coef	SE Coef	Z	*P*
Constant	–4.68429	0.751583	–6.23	0.000
1. Age of the farmer	1.27765	0.761506	1.68	0.093
2. Gender of the respondent	0.0000	0.0000		
3 .Years of coffee farming	1.92975	0.713664	2.70	**0.007**
4 .Regular contact with extension services	3.20043	0.826989	3.87	**0.000**
5. Differentiating honeybees from wild bees	0.0000	0.0000		
6. Differentiating a wild bee from a pest	0.0000	0.0000		
7. Acquired basic primary and or secondary education	0.0000	0.0000		
8. Mode of acquisition of the coffee field	2.52434	0.606878	4.16	**0.000**
9. Source of household income	0.0000	0.0000		
10. Growing cash crop requiring hand pollination	0.0000	0.0000		
11. Size of the coffee farm	0.0000	0.0000		
12. Maintaining semi-natural habitats in vicinity of fields	0.0000	0.0000		
Log-Likelihood = – 52.417; G = 116.748, df = 4, *P*-Value = 0.000, $R^2 = 0.56$				

sensitivity regarding to some ecosystem services delivered in the coffee-banana farming systems. The majority of the respondents felt and agreed that some ecosystem services and functions were important in their crop production systems.

Compared to males, female respondents showed the acceptance of soil fertility restoration concept as a basic component of coffee production enhancement in central Uganda. Regarding male respondents' attitude about micro-organism services, 70% agreed micro-organisms had no positive effects on soil fertility. Few male respondents knew exactly the role played by micro-organisms in soil fertility replenishment, even when they exactly knew the details of agroforstry trees in increasing soil fertility. The lack of awareness of the role played by micro-organisms by males may due to the fact that such knowledge was not transmitted to them by their grand parents. Most indigenous knowledge bout soil is acquired traditionally or by experience. This observation (low knowledge of the role played by micro-organisms in soil fertility) indicated the need for more training and exposure of farmers on technical aspects related on soil fertility enhancement.

In this study, it was observed that farmers had a favorable attitude towards increasing on-farm trees cover based on indigenous trees. Farmers also recognized the need for planting trees to provide shade to coffee. A greater majority of the respondents agreed that shading coffee can increase coffee yield although males had a positive attitude of shading regime compared to female respondents. While majority of males farmers acknowledge the value of shading trees for coffee yield increase, female farmers were of opinions that growing shading trees along aside coffee plantations does not necessarily increase coffee yield at all. On the contrast, males had a contemporary view of shading coffee, they valued the shading regime of increasing coffee yield and associated crops since they agreed that shade contributed to increase coffee yield by at least 10% - 35% [2]. Therefore, planting shading trees alongside coffee plantations had positive attitudes about the value of the service for coffee.

Female respondents further strongly agreed that both planting trees and maintaining high fertility of soils could increase significantly coffee yield. The difference between males and females in the effects of shading regimes on coffee crop yield increase may be due to the gender segregation in labour for different activities related to coffee farm management. Coffee is generally a "male crop." Women are mainly involved in coffee berry harvests and coffee seed drying. Hence women have little time to invest and understand factors that may help in boosting coffee.

The implication of these observations (difference in knowledge of the effect of shading regime on coffee yield) is that policy makers and extension services agents should put more emphasis on the importance of shading coffee to increase the yield. It is important that extension services raise the level of knowledge of both males and females about the different tree species to be planted to provide shade to coffee and associated crops. Shade contribute to the increment of coffee yield by favoring several other factors directly involved in yield increase such as attracting a diverse and rich bee fauna. Also, it has been evidenced that coffee plantations grown under good shading regime attract efficient pollinator species. Most social bees (stingless bees) forage better and deliver pollination services to coffee trees located in farms with at least 10% to 50% shade cover [2].

It this study, a variety of beliefs about value of different pollination services delivered in farmlands among male and female respondents was observed. For example, male participants had strong agreement regarding the importance of rain (not pollination) in coffee production boosting. Most respondents disagreed that pollinators were important for coffee fruit set and yield increase, although young farmers remained neutral about this issue. This observation for strengthening information delivery by extension services about which crops rely on pollinators to set fruit seeds and what to do to maintain pollinators nearby fields.

Regarding the contribution of birds and bats to coffee pollination, it was observed in this study that most respondents disagreed that these seed dispersal agents would enhance and contribute to coffee fruit set. Farmers perceived that sunbirds and bats were of no value for coffee production in Uganda. However, most farmers agreed that honey bees could contribute to coffee yield. The lack of knowledge of role played by bats and birds in pollination was expected since farmers have no interests in observing the benefits these animals bring on farms. In most cases, birds are perceived by farmers as crop pests in Uganda. The lack of knowledge of the beneficial services from bats and bats calls for increasing education of farmers about identification, management and conservation of seed dispersal agents and related ecosystem services agents (agro-ecosystem engineers)

To summarize, rainfalls, soil fertility and shading regimes were hereby identified as accepted by most farmers as key concepts in natural resources management for coffee production boosting although other factors may be important such as pollination. Such observation and attitudes of farmers are normal in the tropics. In fact, the tropical environmental of Sub-Saharan Africa, most farmers present significant differences in economic, so-

cial and environmental attitudes ([2] and such situation has implication in the management of environmental services for crop yield stability, income generation and livelihood improvements. Policy makers and extension services need to develop strategies to increase the knowledge among farmers of the role and value of different ecosystem services in crop productivity enhancement including coffee.

4.2. Farmers' Knowledge of Pollinators' Importance for Coffee Yield Increase

In this study, it was hypothesized that small scale coffee growers were not aware of the importance of pollinators for coffee production.

The results confirmed the hypothesis. In fact it was observed that more than 90% of small-scale farmers were not aware of the value of pollination services to coffee and to other crops they grow. Similar observations were highlighted by Kasina *et al.* [15] who observed that most farmers in Kakamega region (Western Kenya) were not aware of the importance of pollination for crop production.

Findings from the surveys highlighted the fact that many farmers lump pollinators together with others insect pests, and do not explicitly manage their farms to conserve them, although pollinators substantially contribute to coffee yield increase at no direct cost to the farmer.

Knowledge of the role of pollinators in coffee production remains poor in central Uganda. Farmers have very limited knowledge on pollination and pollinators; they often take pollinators for granted. Most farmers said "these insects are just there, they are part of creation and nature but they do not need to do something to protect them because these insects will always be there". Farmers said they did not need to care about these small insects seen visiting coffee flowers, because they think these small insects are just there resting but they are not harmful neither beneficial to coffee flowers. Most farmers believed that the presence or absence of these insects on coffee flowers does not stop coffee to set fruit. Also farmers believe that coffee fruit set depends largely on shade, fertility and moisture levels and on control of pests and diseases. Farmers who sprayed herbicides to control weeds did not believe that herbicides had negative impact on bees. Previous studies highlighted the fact that small scale farmers (average yield: 600 - 2400 kg/ha/year) growing coffee (shading regime: 10% - 70%) with a moderated plant density (450 - 1567 trees/ha) used on average 3 to 10 liters of herbicides ha/year [2]. This amount is a high compared to what is recommended (0.5 to 1.5 ha/year in Uganda) and it is index to predict at which level pollinators are exposed to herbicides in central Uganda, particularly in regions where farmers are interested in using herbicides to control weeds instead of hand-weeding [2]. The reason for which some farmers preferred using herbicide that hand-hoe weeding were not known but probably this could be attributed to the type of extension services they receive .

The major contingent of coffee flower pollinators belonged to the Apoidea group. Other prominent floral visitors comprise species of Diptera, Lepidoptera and Coleoptera. Neither the dependent nor the famous floral visitors are well known by small-scale coffee growers. In fact, coffee is reliant to wild bees but farmers are not aware of the role played by these wild bees. Similarly, butterflies are observed flying within coffee trees but farmers believe they are doing nothing (harmful or beneficial) to coffee flowers. In fact respondents indicated that honeybee was a frequent visitor of coffee; they were also able to identify and recognize butterflies as vagrant species in the field; however, no farmer could identify how beneficial butterflies may be for coffee in central Uganda. In contrast, farmers know some butterfly species as pests of some crop species like *Ipomoea batatus*. This finding suggest that efforts should be but in place by extension services to educate small-scale farmers to appreciate and know different pollinating agents of their important crops like coffee. Extension services should work hard to increase appreciation of the beneficial aspects of some on-farm based animals like butterflies to increase the involvement and commitment of farmers in the conservation of on-farm biodiversity for livelihood improvements in rural areas.

Farmers were not capable of distinguishing different stingless bee species that occur in their area. Farmers were also not aware that stingless bees played significant role for coffee to produce higher and quality yields. The only bee species that was recognized by farmers was honeybee although majority of farmers perceived that honeybees were just there but their presence or absence could not influence coffee fruit set. Some farmers believed that honeybees collect nectar from coffee but they are not involved in coffee reproduction process.

Field observations and surveys indicated that the overall basic knowledge by farmers of eusocial bees (*A. mellifera*, *Hypotrigona gribodoi* and *Axestotrigona ferruginea*) that occur in coffee fields was mainly related to their continued utilization for honey (from honeybees and stingless bees) and other hive products. Cultural value (in terms of utility) plays a significant role in folk knowledge of Apoidea communities by farmers. For example, in Brazil, Mexico, Costa Rica, Panama, Ghana, Kenya, *etc* farmers know different bee species in the Meliponini group [9]. They also know nesting sites (and structures) of different meliponini bees. Some have developed advanced traditional methods for rearing these

species for the production of honey. Hence, meliponiculture [16] as a lucrative activity for farmers need to be promoted worldwide based on indigenous knowledge of local communities not only for providing income from sale of hive products (honey) but also as a reliable source of pollination of crops such as coffee, particularly in over-cultivated regions where nesting sites have been degraded in disfavor of establishment of wild ground nesting bee communities that are important crop pollinators in the tropics.

Knowledge of pollination is expected from most farmers of central Uganda. However, it seems that the knowledge does not depend on the level of education and more particularly on the age. Central Uganda is inhabited by people of "Baganda" ethnic group. In Uganda, the level of knowledge of pollination seems to be associated with the tribe and the agro-ecological zone. While Baganda people have little knowledge of pollination (probably because they live on relatively fertile land where most of crops can yield with less inputs), human communities living in most other ecological zones of Uganda have a good knowledge of pollination. In fact, during a study conducted in western part of Uganda (Munyuli 2011, unpublished data), it was realized that communities (Bakiga, Bafumbira and Batwa) living in the mountainous region bordering Bwindi Impenetrable forest and Mgahinga Gorilla forest national parks were aware of the value pollinators. Most farmers interviewed from that region new how to manage their lands to care for pollinators (wild and managed bees). Farmers from that region had 5 to 15 beehives each while in central Uganda few farmers (<20% - 30%) own beehives. Beekeeping is not a common farming practice in central Uganda whereas in western part of the region, it is one of the lucrative activities providing income to farmers. Hence, knowledge of pollination by bees is advanced in west part of the country.

Additionally Baganda people were incapable of differentiating bees from other insects. Batwa people had local names for different species of stingless bees [17]. Different stingless bee species (Ebihura in batwa language) have distinct names according to Batwa nomenclature: Maranga (*Hypotrigoa gribodoi*), Obwiza (*Meliponula ferruginea*), Obugashu (*Meliponula bocandei*), Obuzagali (*Meliponula lendliana*) and Obuganza (*Plebeina hildebandti*). It was there after assumed that the high level of knowledge pollinator species and pollination by human communities from western part of Uganda may be linked to the fact that their agricultural systems is largely depending on inputs including pollination and fertilizers. Overall, the increase in level of knowledge of pollination by farmers seems following a gradient from the edge of Lake Victoria to Western part of the country.

5. CONCLUSIONS

Differences in perceptions and knowledge of pollination constitute a major obstacle in farmer–researcher cooperation and collaboration which is necessary for sustainable management of pollination services in rural farmlands.

The aim of this study was to understand knowledge and perceptions of the importance of pollinators and pollination services in coffee production. Farmers' perceptions were investigated in order to harness their knowledge in the participatory development of conservation strategies of pollination services. Perception of pollination involved both in scientific and spiritual conceptual frameworks were identified. Findings indicated that farmers' awareness of pollinator importance in coffee yield increase was extremely low and gender biased with males having high knowledge than females.

One of the greatest challenges for the conservation of Apoidea fauna in farmlands of central Uganda is the great ignorance of the role played by bees in crop production enhancement including coffee. Ironically, small scale farmers in central Uganda are involved in all activities related to the destruction and conservation of natural resources. Obviously, farmers can play significant role in the conservation of bees if they are made aware of the importance of bees to the improvement of their livelihood and sustainability of their agricultural systems.

African farmers are aware of insects as pests but not as important factor in the agricultural productivity. Bees are taken for granted by farmers, just like the air and the light. However, the "free pollination service" provided by "God" to human survival is irreplaceable and it will be difficult for scientists to find a technology that can replace it in the nature.

In Uganda, many people and farmers believe that if there is a yield loss, it will be attributed to anything but not to pollination deficit. However, conservation of pollinators is a key for sustainable agriculture development in Africa. Much of crops grown in Africa owe their production to bee pollination activities. African green revolution will not work without paying great attention to pollinators in the plant breeding programs (Dr Muo Kasina, Personal communication).

Findings from this study also indicated that, that more than 90% of the farmers were not aware of the role played by bees in the increase of coffee yield. As it was also observed in Kenya [12,15], small-scale farmers in central Uganda were not willing to manage their lands to protect pollinators because not only that they were ignorant, but, they also considered pollination as an unsolic-

ited "free service", or as a "public good". Most farmers considered that coffee could still produce with or without receiving visits from bees. In contrast to the views and perceptions of the farmers, pollination experiments conducted from 30 coffees showed that the economic value of pollination services delivered to coffee approximated US $ 650/ha/year on average [2]. At the national level, the total economic value of coffee produced in Uganda is on average of US$214 million from half million hectares dedicated to coffee production, and approximately 60% (US $ 149 million) of this economic value is attributable to pollination services delivered by bees to coffee in Uganda [2]. This is the evidence that coffee needed pollinators in central Uganda. Crop pollination by bees and other animals is an essential ecosystem service in Uganda. At the national scale, pollination services may have been estimated to be equivalent of >16% - 25% of the market value of agricultural production.

Few small-scale coffee growers were selected and invited to short discussions of whether bees increase coffee yield or not. As previously highlighted, majority of these farmers said they do not think bees are important for coffee fruit set. Consequently, coffee trees were selected and bagged to exclude pollinators. Farmers were asked to take care of the pollination experiments. The un-bagging process (**Plate 1**) was run in their presence during the first blooming season (July-August 2007) when farmers witnessed that bagged flowers had no fruit whereas un-bagged flowers that were regularly visited by bees did set fruits.

During experiments conducted in November-December 2007 in the same coffee fields, the researcher found that farmers were now fencing (using traditional materials and native trees) termite mounds to protect stingless bees nesting in termite mounds (**Plate 2**) be-

Plate 1. On-farm coffee pollination experiment showing un-bagged and bagged coffee branches.

Plate 2. Termite mounds being protected by farmers to favour bees pollinating crops nearby.

cause they were told during the first blooming season (July-August 2007) by the researcher that these features (termite mounds) were used as habitats by various wild bees such as meliponini bees that pollinate their crops. When the researcher was setting experiments during the second blooming period, farmers were now asking for information about wild bees, where they live and what they eat and how to protect them in order to increase coffee yield.

In this study it was found that pollination knowledge was shaped by a wide range of social, cultural, educational and individual attitudinal characteristics of respondents. It was also found that age, level of education, gender, general knowledge of importance of protecting natural and semi-natural habitats in the vicinity of coffee fields for coffee yield increase played no important role on pollination knowledge by interviewed farmers. Contrastingly, the number of years passed farming coffee or the degree of contact with extension services were identified in the logistic model as most striking factors. In other words, knowledge of pollination by farmers was likely to occur in areas where they had access to regular extension service advices. Also, farmers who inherited their plantations and those who planted themselves their plantations were likely to know the word pollination. Therefore, it was recommended that these few factors

that were identified, be taken into consideration to be successful during awareness campaigns aiming at raising farmers' knowledge of the importance of conserving pollinators for coffee yield increase.

Overall, it is important to increase the awareness of all small-scale coffee producers of the importance of conserving pollinators within the farm landscape to increase coffee production. The role of extension services was found to significantly improve respondents' knowledge of pollination, and hence the extension service institutions of Uganda should increase and be empowered. This will help in enhancing information provision to the farmers through, e.g., frequent visits, making bulletins or using other channels such as radio or television. World wide, it has been observed that extension services have a significant impact on the learning process of farmers. There is also a need for extension services to inform farmers about the diversity and management of bee-food plants in the farm-landscape. There is a need to revise and incorporate in the school curriculum new concepts such as pollination such as young people; especially those leaving in rural areas are informed about the importance of pollinators and pollination services.

Understanding farmers' perceptions and motivations is of significant importance in relation to environmental services conservation. This can allow for gaining insight into the complex systemic interactions between natural processes, management policies, and local people depending on the environmental services (or resources). Ecosystem services such as pollination service are aspect of the environment that relate closely to human livelihoods and that can be used to convince the public that biodiversity is not only wild animals that may damage their crops, but also creatures that live on their farms and that can help to sustain crop production. Further public awareness programs on ecosystem services such as pollination are highly needed While aiming at understand how farmers view the contribution of pollinators coffee yield, most farmers were saying that "either bees visit or not coffee flowers, fruit will still come provided that rains is here". The reasons behind these thinking were not given. Although farmers depend on farming incomes from coffee, the recorded opinions of most farmers were that there was no need to care for the service. However, pollination service remain critical to all farmers since pollination is directly required for most crops they grow. If the ecosystem surrounding farmlands is healthy farmers will usually receive adequate pollination. Therefore, they need to raise their awareness about the value of investing in the conservation of this vital service. It is important to make farmers to be aware of that the work of bees is irreplaceable, hence the need for them to get involved in farming practices that are important in conserving service provided by pollinators to cash crops like coffee.

Raising the awareness of bees and pollinators for coffee production is important in Uganda since the government of Uganda earn several millions per annum from exports and sales of coffee beans. Therefore, policy aiming at improving coffee yield through management and conservation of pollination services, should advocate for increase of awareness and knowledge of pollinators (their natural history, their food and habitats requirements, their activities, behaviour, interaction with crops) and their importance for crop productivity enhancement. Policy and incentives should be put in place to increase the adoption and implementation by farmers of pollinator-friendly farming practices. This call for educational campaigns to advise farmers on best farm management options for in field maintenance and increase of diversity and density of bees. For example, farmers should be informed on better moment for utilizing pesticides if they need to apply such as their application do not erode bee fauna.

There is a need to develop and disseminate (scale-up) field, habitat and landscape management strategies that are pollinator-friendly to guarantee nesting areas, floral resources availability for coffee pollinators in central Uganda. Among other pollinator-friendly farming practices is the reduction or full avoidance of the use of pesticides while managing pests during main blooming periods of coffee.

It is there recommended to small-scale coffee farmers from central Uganda to adopt and preserve at least 20% of their land uncultivated (un-cropped areas) as pollinator reservoir to make coffee production system remain ecologically and economically sound and viable on a long-term basis. There is a need for local communities to get involved in sustainable management of semi-natural and natural habitats on farm landscapes to protect pollinators. Appropriate management of un-cropped areas to encourage wild pollinators may prove to be a cost-effective means of maximizing crop yield. With land shortage, it is recommended to farmers to adopt multipurpose agroforestry systems that take into account the needs and requirements of pollinators in terms of nesting and floral resources offered by agroforestry tree species found on-farm. Forest remnant tree species and other indigenous tree species found on-farm offer several nesting opportunities to bees. Farmers should adopt farming practices that promote the ecological intensification of agricultural production rather than promoting chemical intensification of crop production. Therefore, avoiding the destruction of stamps, wooden materials and eradication of these remnant tree species in the landscape should be avoided by farmers. Instead, it is rec-

ommended to increase the area covered by on-farm trees and semi-natural habitats without jeopardizing the land productivity.

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