Balancing Bees and Livestock: Pastoralist Knowledge, Perceptions and Implications for Pollinator Conservation in Rangelands, Northern Tanzania

Authors: Mpondo, Faith Thomas, Ndakidemi, Patrick A., and Treydte, Anna C.

Source: Tropical Conservation Science, 14(1)

Published By: SAGE Publishing

URL: https://doi.org/10.1177/19400829211028127

Research Article

Tropical Conservation Science
Volume 14: 1–12

DOI: 10.1177/19400829211028127
journals.sagepub.com/home/trc
SAGE

Balancing Bees and Livestock: Pastoralist Knowledge, Perceptions and Implications for Pollinator Conservation in Rangelands, Northern Tanzania

Faith Thomas Mpondo[1,2,*], Patrick A. Ndakidemi[1], and Anna C. Treydte[1,3,4]

Abstract

Insect pollinators provide numerous ecosystem services that support other living organisms. While pollinators play a large role in cropping systems, little is known about their presence and function in rangeland ecosystems, which have recently become fragmented and overexploited at an extraordinary rate. We assessed local Maasai knowledge on insect pollinators and how pollinators affect livelihood diversification in Simanjiro rangelands, Tanzania. Through questionnaires, key informant interviews, focus group discussions, and field observations, we found varied insect knowledge among Maasai herders. *Lasioglossum* of sub genus *Ipomalictus* and *Syriphidae* were the least commonly recognized pollinators as only 24%, and 7% of participants could identify them, respectively. Responses varied significantly between men and women ($F = 7.397$, $p = .007$). *Commiphora africana*, *Acacia mellifera* and *Albizia anthelmintica* were noted as most important bee forage plants while observations showed *Aspilia mossambicensis*, *Justicia debile* and *Acacia tortilis*. Most (77%) of Maasai herders showed limited ability to link pollinators and rangeland wellbeing. Beekeeping contributed to livelihood diversification for 61% of respondents, with women participating more frequently than men ($\chi^2 = 46.962$, $p = .0001$). Beekeeping was positively influenced by education level ($R = .421$, $p < .0001$) and occupation ($R = .194$, $p = .009$). Pollinator declines were attributed to climate change (47%), agriculture (37%), and habitat destruction (8%). We conclude that Maasai have limited knowledge of common pollinator groups and their roles. Community outreach and training should bridge the knowledge gap in pastoralist communities to fully realize pollinator benefits and highlight the importance of rangeland health.

Keywords

ecosystem services, livelihood diversification, pollination, bee fodder plants, indigenous knowledge, eastern Africa

The role of pollinators in the provision of ecosystem services has been recognized for centuries (Klein et al., 2007). Pollinators transfer pollen grain from anthers to stigmas of the same or different plants (Dar et al., 2017; Elisante et al., 2017), thereby increasing genetic diversity (Potts et al., 2010) and maintaining global biodiversity for both cultivated crops (Munyuli, 2011) and native plant species (Kosior et al., 2007; Munyuli, 2011; Zurbuchen et al., 2010) . About 87% of flowering plants across different ecosystems depend on pollinators (Senapathi et al., 2015). Pollinators further contribute to 75% of crop production (Klein et al., 2007). The world is endowed with diverse pollinator groups, including

[1]Department of Sustainable Agriculture, Biodiversity and Ecosystem Management, School of Life Sciences and Bioengineering, The Nelson Mandela African Institution of Science and Technology (NM-AIST), P.O. Box 447, Arusha, Tanzania
[2]Department of Biology, College of Natural and Mathematical Sciences, University of Dodoma, P.O. Box 338, Dodoma, Tanzania
[3]Department of Ecology of Tropical Agricultural Systems, Hans-Ruthenberg Institute, University of Hohenheim, Garbenstr. 13, 70599 Stuttgart, Germany
[4]Department of Physical Geography, Stockholm University, Stockholm, Sweden

Received 28 December 2020; Accepted 8 June 2021

Corresponding author:
Faith Thomas Mpondo, Nelson Mandela African Institute of Science and Technology, P.O. Box 447, Arusha, United Republic of Tanzania.
Email: thomasf@nm-aist.ac.tz

insects, birds, bats, lizards and small mammals, estimated to reach 2,00,000 species (Harmon et al., 2011). Insects represent the most significant group of the pollinators, with bees being the most crucial ones (Elisante et al., 2017; Patrí, 2014; Potts et al., 2010). However, a current rapid decline in flower-visiting insect pollinators across many ecosystems has globally raised alarm (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2016; Potts et al., 2009; 2010). Pollinators make a substantial contribution to maintain grassland biodiversity and functioning (Black et al., 2011), however, their role has been given little attention (Patrí, 2014) and most pollinators studies focused on agricultural landscapes (Allen-Wardell et al., 2016).

Conservation and management of insect pollinators require a participatory approach between authorities and local communities as most pollinators are found outside protected areas (Eardley et al., 2009) and are strongly impacted by land-use change (Potts et al., 2010; Stewart et al., 2018). Local knowledge, thus, forms an essential tool towards pollinator conservation (Berkes et al., 2000), and contributes to decision making on land use. However, in most developing countries, there is still limited information on how the local communities perceive the presence and role of pollinators (Ali et al., 2020; Munyuli, 2011). While most studies on local knowledge about pollinators in the East Africa region have focused on the assessment of crop farmers' awareness (Elisante et al., 2019; Munyuli, 2011), information from the pastoral communities is lacking.

Maasai rangelands in northern Tanzania harbor diverse livestock and wildlife (Msoffe et al., 2011), with pastoralism and agro-pastoralism as the primary sources of livelihoods. Pollinators support food production, nutrient cycling, support livestock and other wildlife, including birds within rangelands (Black et al., 2011). Pollinators further ensure reproduction in about 67% of wild plant species, and therefore promote sustainability of rangeland ecosystems and their ability to support livelihoods (Stein et al., 2017). The interaction between rangeland flowering plants and pollinators can potentially support crop production (Elisante et al., 2017; Vanbergen & Initiative, 2013) and beekeeping activities (Fakir & Babalik, 2009), consequently improve pastoralist livelihoods. As rangelands are the primary sources of forage for livestock, it is vital to assess if Maasai understand the importance and linkage between pollinators and rangeland wellbeing. However, rangelands have experienced increasing human population pressure and changes in land use due to increasing agriculture and reduced grazing land (Msoffe et al., 2011). The reduction in grazing land has led to overgrazing challenges and losses in native vegetation (Kibebe, 2005). While vegetation and soil type form the fundamental parameters in range management for most herder communities (Oba, 2012), the pollinator aspect as livelihood diversification and vegetation improvement is yet to be considered in rangelands management. Small-scale farmers are aware of pollinator species, particularly those with tangible benefits such as the genus *Apis* including *A. dorsata, A. florea, A. mellifera* and *Meliponula sp* (Ali et al., 2020; Kasina et al., 2009b) but their knowledge varies with location, culture, and access to information (Otieno et al., 2011). In contrast, little is known whether the Maasai pastoralist community of northern Tanzania has a similar understanding of pollinators.

Maasai social organization is based on clan, territory and age set organization (Baird & Hartter, 2017; Mccabe, 2003; Woodhouse & McCabe, 2018). Being a strongly patriarchal society (Sharp & Twati, 2017), men have control over their family and make most of the final decisions. Women are more engaged in household chores while men are responsible for herding, protecting cattle and making financial decisions (Sharp & Twati, 2017). With our study, we intended to assess how Maasai herders perceive insect pollinators by focusing on different taxonomic groups and their roles in pastoralist livelihoods. Specifically, we wanted to address the following research questions: What is the ability of Maasai pastoralists to recognize and distinguish different insect pollinators and how is it affected by socio economic factors? How knowledgeable are local Maasai on bee forage plants? What is the role of pollinators in pastoralist livelihoods and diversification? What is the ability of herders to link insect pollinators and wellbeing of rangelands? What are the threats to pollinators and future conservation basing on pastoralists knowledge? How does education and gender influence beekeeping activities? We hypothesized that men knew more about pollinators than women due to the patriarchal system of the Maasai, and that agro-pastoralists, i.e., being dependent on crop yields, knew more than pure pastoralists. We also expected that knowledge on pollinators increased with age and education level. We further hypothesized that Maasai can relate rangeland management practices to abundance of pollinators and that they can identify important forage plant species for bees.

The insights from this study will help in developing appropriate protection and management strategies for pollinators, especially focusing on educating pastoralists on benefits from pollinators.

Material and Methods

Study Area

Our study sites were located in Simanjiro district, Northern Tanzania (3° 33′ 42.55″ S and 36° 58′ 44.22″ E) in three villages; Loiborsiret, Narakauo and Kimotorok (Figure 1). The population of the district, according to the Tanzania National Census of 2012, was 178,693 and that of Loiborsiret ward is 13,569 (National

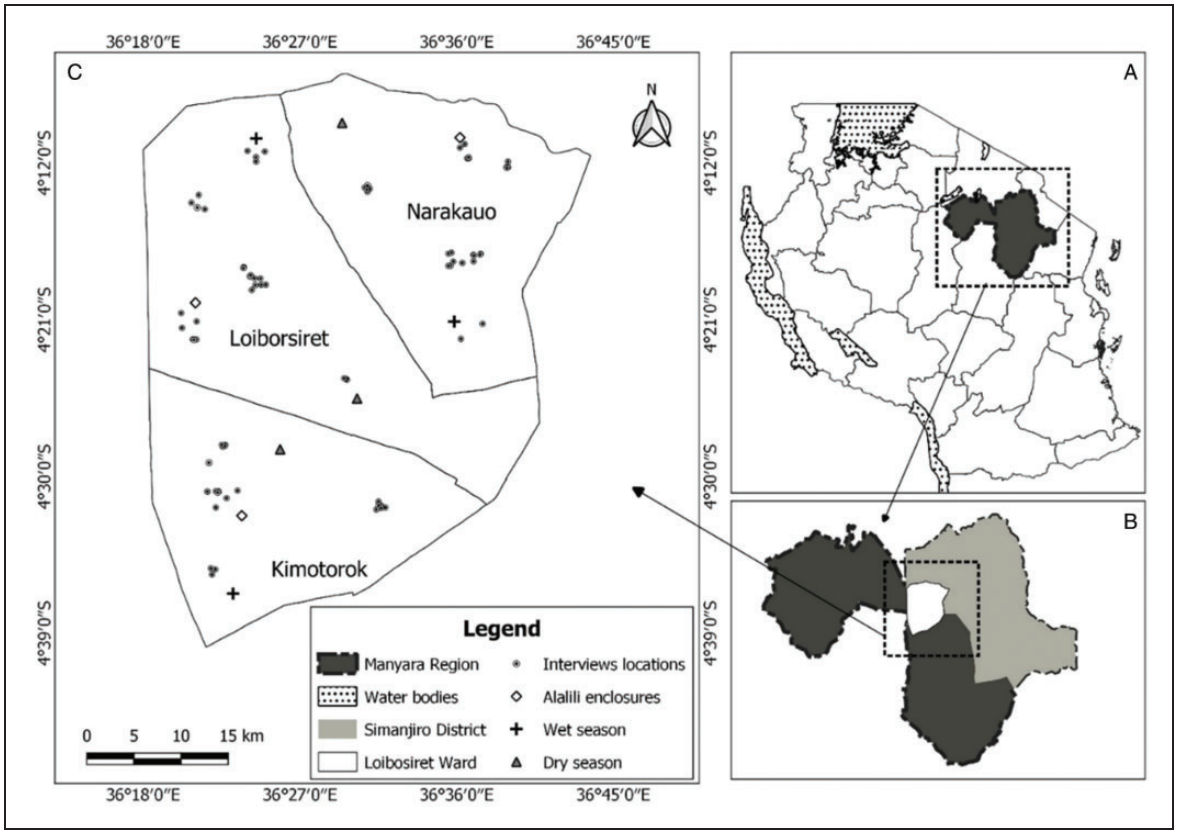

Figure 1. Map of the Three Study Sites in Loiborsiret Ward, Simanjiro District, Showing the Location of 181 Interviews, the Location of Our Sample Sites in Seasonal Enclosures, Called Alalili, and on Wet and Dry Season Open Rangelands During Assessments in Loiborsiret, Narakauo and Kimotorok Villages in 2019.

Bureau of Statistics, 2017). The area has a bimodal rainfall averaging 650 mm per annum, with a short rainy season between November and January and long rainy season between March and May (Woodhouse & McCabe, 2018, Miller et al., 2014). The primary residents of the district are Maasai pastoralists, and livestock keeping is the most dominant livelihood form, followed by crop cultivation as the majority of Maasai have become sedentary (Msoffe et al., 2011). Crops cultivated include maize (*Zea mays*), mainly for subsistence, hyacinth beans (*Dolichos lablab*) and the cash crop sesame (*Sesame indicum*). Vegetation is dominated by arid scrubland and *Acacia* - *Commiphora* woodland in combination with scattered open grasslands and seasonal swamps (Nnko et al., 2017). Simanjiro plains support the coexistence between humans, livestock and wild animals, and its fertile pastures offer a critical grazing and calving area for wildebeest *Connochaetes taurinus* and zebra *Equus quagga* during the wet season (Woodhouse & McCabe, 2018). Grazing management in the plains rotates between wet and dry season grazing areas albeit most Maasai are now settled in permanent villages, reducing movement within village lands and across village boundaries (Woodhouse & McCabe, 2018). Grazing resources in Simanjiro are still a common property; however, in most villages, individuals are recently being allocated private holdings (McCabe et al., 2010). Maasai use traditional enclosures (*Alalili*), which are managed grazing areas that allow access only to young or sick goats, sheep, and cattle. The maximum livestock number allowed in these enclosures should not exceed thirty animals per boma (Personal communication). The use of Alalili helps recovery of rangeland vegetation and preventing range degradation, a practice that might promote insect pollinators conservation.

Data Collection

Social Study. We used purposive sampling (non-probability sampling) and Participatory Rural Appraisal (PRA) to target only the Maasai tribe and exclude residents from other ethnicities because the Maasai are primary residents and dominant pastoralists in the area (Baird & Hartter, 2017). Before the commencement of data collection, we obtained permits from the ward and village leaders. The research team comprised of a researcher and two research assistants trained beforehand, a local Maasai and a graduate student. Our study used a mixed approach including both quantitative and qualitative data sources (Chisanga et al., 2019; Ontiri et al., 2019). Our key informant

interviews ($n = 10$) included the ward officer, adult Maasai pastoralists and non-governmental organization employees, including the Tanzania People and Wildlife (TPW) beekeeping officer, to obtain their views on insect pollinators and livelihoods in the area. In addition, we conducted focus group discussions with five participants in each study village. Group discussion members included a total of 9 men and 6 women ($n = 15$). We held separate conversations with men and women, considering the culture of the Maasai people, in which women do not speak while in meeting with men who are the primary decision-makers (Ontiri et al., 2019; Woodhouse & McCabe, 2018). We selected the group members considering age, gender balances, and time lived in the respective location for at least 20 years. Finally, we administered a household survey using a pre-tested semi-structured questionnaire to collect quantitative data, including A4 color printed pictures of our six target insect pollinators as well as mounted specimens. The survey was conducted between October to November 2019 and involved a total of 181 respondents from the three study villages (Loiborsiret 61, Narakauo 60 and Kimotorok 60). We selected our respondents in such a way that the sampling fraction was at least 5% of the population of individuals that fit in our criteria were included in the sample (Mbinile et al., 2020). The households (bomas) were located at least 0.5 km apart from each other. We selected the research villages based on the level of external interventions like participation in conservation projects, land use plans for instance presence of wet and dry season grazing sites, presence of alalili enclosures for dry season grazing and proximity of villages to each other.

During household interviews, we only included Maasai who had lived in the area for at least ten years and resided in different sub-villages in order to capture a wide range of information. We tested the pastoralists' ability to recognize insect groups by showing each respondent a picture of adult individuals and mounted specimens of six insect pollinators, including *Apis mellifera* (honeybee, *Apidae*), *Lasioglossum spp* of subgenus *Ipomalictus* (solitary bee, *Halictidae*), wasps (*Eumenidae*), hoverfly (*Syriphidae*), *Eurema hecabe* (butterfly, *Pieridae*) and *Cheilomenes sp* (beetle, *Coccinellidae*). Respondents were required to respond with Yes or No to whether they recognized the insect shown in the picture. They were further requested to provide the insect name in Swahili or their local Maasai language and state benefits of each insect. The insect species were selected based on their abundance in the rangelands from our detailed survey to study the influence of rangeland management on abundance and diversity of insect pollinators in Simanjiro rangelands. We conducted the interviews in Swahili and used a Swahili-Maasai translator in some cases. The first section of the questionnaire consisted of socio-demographic information including age, gender, occupation, education level, household size and sources of household income. The second section included questions on general knowledge about different groups of pollinators and their link to rangeland resources and management (Online Appendix 1). The last part comprised questions on honey bees, *Apis mellifera,* as the most important pollinator, to see the pastoral understanding of honeybees, beekeeping possibilities for livelihood diversification and threats facing bee pollinators in the area (Online Appendix 1).

Vegetation Survey and Sampling. During the dry and wet season in the year 2019, we identified present herbaceous and woody plant species, recorded their phenology, especially flowering time, and whether they were visited by bees within sampled transects. In each of the nine sampled sites in the study villages, which comprised three seasonal enclosure types, called alalili used for grazing of sheep, goats and few cows (10–30); three wet and three dry season grazing sites that are open to all livestock with no limit during wet and dry season, we established three 100 m long line transects, along which we established three quadrats of 5×5 m ($25\,m^2$), placed 30 m apart from one another making a total of 81 quadrats for all sites. In each quadrat, we recorded bee visitation to plants for fifteen minutes per each observation. We conducted our observations two times a day, in the morning from 08.00–11.00 am and the afternoon at 02.00–05.00 pm. All site observations were carried out under suitable weather conditions for bee activities such as clear sunny days, temperatures above 15 °C, and low wind speed (Westphal et al. (2008). Plants were identified in the field by either local or scientific name and later confirmed at the National Herbarium of Tanzania at Arusha. Bee visitors were recorded and identified to genus level in situ using the ABC Taxa guide (Eardley et al., 2010) and with the help of an expert.

Data Processing and Analysis

We analyzed qualitative data using the triangulation method and grouped open ended responses according to themes (Chisanga et al., 2019). Household size was categorized as small (1–5), medium (6–10), moderately large (11–15), large (16–20) and extremely large (above 20). Source of pollinator knowledge was categorized as coming from extension officers, friends and relatives, and media (radio and television). Pollinator benefits were categorized into income, food production, and environmental. Pollinator conservation strategy was categorized as avoiding forest fires, practicing environmental protection, beehive sitting. Quantitative information obtained from structured questionnaire were coded and analyzed using statistical package IBM SPSS Statistic

version 20.0 (Sarper et al., 2009). Normality and equality of variance were tested using the Shapiro-Wilk test at $\alpha = 0.05$. Most of our analysis were based on non-parametric tests due to non-normal distribution of variables. Chi-square ($\chi 2$) frequency test was used to explore differences between those who could correctly identify each pollinator to those who could not for the six main pollinator species. Chi-square ($\chi 2$) test was also used to determine the relationship between occupation (pastoralists and agro-pastoralists) versus dependent variables including insect species identification and pollinator benefits on livelihoods. We derived an index on pollinator identification scores and grouped responses as Low (less than 50), medium (50–69) and high (70 and above) (Tarakini et al., 2020). We used Logistic regression to determine factors influencing pollinator identification scores where age, gender, education level, and occupation formed our independent variables. Bivariate correlation analysis was performed to determine if participation in beekeeping was influenced by socio-economic factors like gender, education level, age and occupation. We compared bee visitation observations in the field across alalili, wet and dry season grazing areas using one-way ANOVA with the number of insect visitors as a response variable.

Ethics Consideration

The Tanzania Commission for Science and Technology (COSTECH) granted the permit to conduct this study through the Tanzania Wildlife Research Institute (TAWIRI). We later presented the permit to respective district, ward and village leaders. Before interviews, we obtained the verbal consent of all respondents to ensure their willing participation. All respondents' names are anonymous to maintain confidentiality.

Results

We surveyed 55% (100) men and 45% (81) women using a semi-structured questionnaire. The average (±SD) age of women respondents was 35 ± 10 years ($n = 81$), which was significantly lower than that of men (43 ± 13 years, $n = 100$; $t = 4.45$, $df = 179$, $p < .001$). The mean household size (±SD) of the interviewed respondents was 7 ± 9 (1 minimum, 90 maximum). Of all respondents, 50% (91) had never been to school, 43% (78) had primary education, and 7% (12) possessed secondary education (Supplementary Table S1). Men had a higher education level than women ($R = -.210$, $p = .004$). A large proportion of respondents 75% (136) were agro-pastoralists, cultivating maize, sesame and beans. However, all respondents declared that livestock keeping (cattle *Bos taurus*, sheep *Ovis aries*, goats *Capra hircus*, poultry *Gallus gallus domesticus*, and donkeys *Equus asinus*) as their primary income source.

Overall, all 181 respondents were able to identify at least one or more insect pollinators from the six insect species shown to them. *Apis mellifera* was the only pollinator correctly identified by all respondents (Figure 2). The average pollinator identification score was 57.2%, characterized as medium. Against our expectations, we found no significant difference in identification skills with respect to occupation, whereby agropastoralists were not more knowledgeable in identifying compared to pastoralists for *Lasioglossum sp* ($\chi^2 = 2.494$, $p = .114$), *Eurema hecabe* ($\chi^2 = 0.019$, $p = .890$), *Syriphidae* ($\chi^2 = 0.024$, $p = .589$); *Cheilomenes sp* ($\chi^2 = 2.943$, $p = .086$) and *Eumenidae* ($\chi^2 = 0.015$, $p = .903$).

As expected, we found that significantly more men could correctly identify solitary bees, *Lasioglossum sp,* compared to women ($F = 7.397$, $df = 1$, $p = .007$) but there was no difference for other pollinator species. We also found that age significantly influenced identification skills, with middle aged respondents (30–39 years old) being more knowledgeable compared to other age groups in identification of *Eumenidae* ($\chi^2 = 9.818$, $df = 3$, $p = .020$), *Eurema hecabe* ($\chi^2 = 12.432$, $df = 3$, $p = .006$), with no difference for other pollinators. Education level only significantly influenced correct identification of *Eumenidae* ($\chi^2 = 6.951$, $df = 2$, $p = .031$), and the majority (71.8%) of respondents that correctly identified this species had primary education compared to other levels. Honeybee, *A. mellifera*, was perceived as the most important pollinator compared to other insect groups, as mentioned by about 93% of males and 78% of females, with significant variation between gender ($\chi^2 = 14.820$, $df = 3$, $p = .02$). *Eurema hecabe* and *Lasioglossum sp* were not reported as harmful, but also no benefit was associated with them by 89% respondents. Our fitted multinomial logistic regression to test factors affecting pollinator identification scores revealed gender was the only significant factor that affected pollinator identification scores ($\chi^2 = 6.319$, $df = 2$, $p = .042$), with males having higher

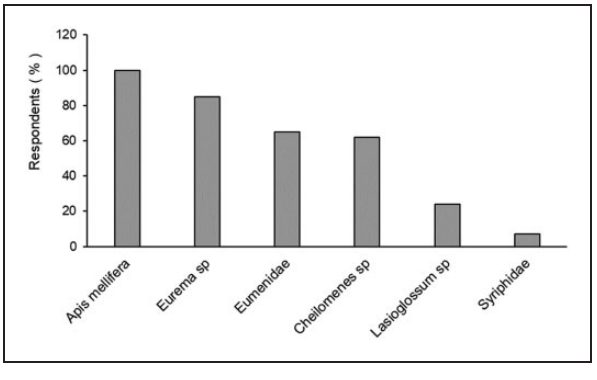

Figure 2. The Proportion of Respondents That Correctly Identified Various Insect Species According to the Questionnaire Survey in Three Villages of Loiborsiret, Narakawo and Kimotorok During Our Field Survey in 2019 ($n = 181$).

likelihood of higher identification scores than women. The fitted model was significant different from the constant only model ($\chi^2 = 23.607$, $df = 12$, $p = .023$). Out of all respondents, 101 (46.3%) claimed that they had gained knowledge on pollinators through friends and relatives, 74 (33.9%) through personal initiatives such as time spent herding in the bush, and 40 (18.3%) through extension officers and media such as local radio and television 3 (1.4%).

Maasai Knowledge on Bee Favourite Plants

As Maasai are a traditionally nomadic tribe, respondents revealed satisfactory local knowledge on bee fodder plant species. *Commiphora africana* was cited by 94 respondents as the leading favourite plant for bees, followed by *Acacia mellifera* (90) and *Albizia anthelmintica* (85) (Figure 3). We found that most (66%) of the mentioned pollinator plant species were trees, while the contribution of shrubs (34%) and herbs (0%) in supporting pollinators was less recognized among the interviewed Maasai. However, in our field observations we recorded several shrubs, herbs, and grasses that served as an equally important bee fodder plant (Supplementary Tables S2 and S3; Figure 4). *Aspilia mossambiensis*, *Justica debile* and *Acacia tortilis* (tree) were the leading plant species from our field observations, with a total of 268, 201 and 150 visitations, respectively (Supplementary Table S3).

We did not find any significant correlation between plants mentioned by respondents and field observations

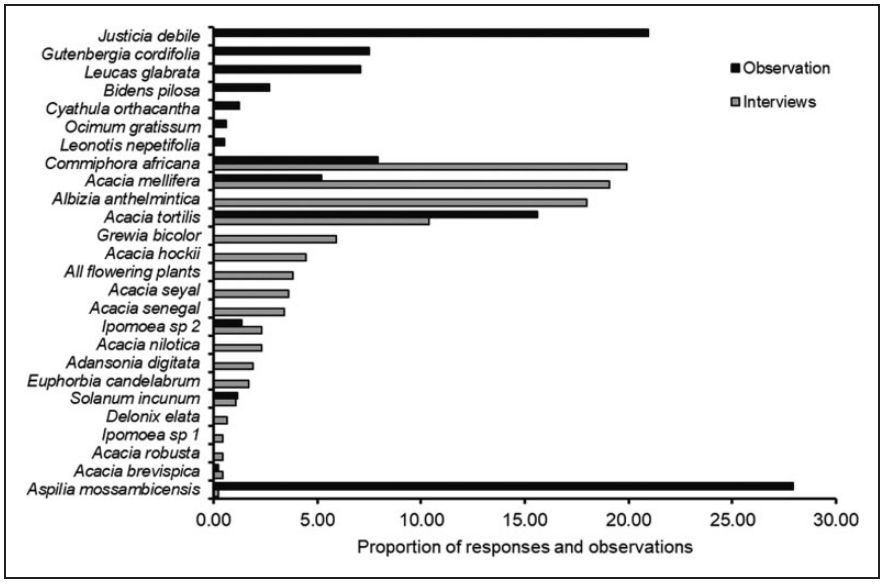

Figure 3. Plants Most Favored by Bees According to Questionnaire Surveys With 181 Respondents and Field Observations Across the Three Main Study Sites, i.e., Alalili Enclosures, Wet and Dry Season Grazing Sites, in Simanjiro During 2019.

Figure 4. Honeybee Visitation on Herbaceous Plants, *Aspilia* sp. and *Solanum* sp. in Simanjiro Rangelands During Wet Season Data Collection (Photo by Faith Mpondo, Field Survey, 2019).

(*Pearson's* $R = -.093$, $p = .643$). We also found that alalili enclosures contained more pollinator visitors compared to both rainy season and dry season rangelands, however the difference was not significant ($F = 0.617$, $df = 2$, $p = .551$).

Linkage Between Pollinators and Grazing Lands

Surprisingly, only eight respondents (4%) agreed on the importance of pollinators to rangeland wellbeing. Further, 34 (19%) did not see any relevance of pollinators to rangelands while the majority (77%) did not know. In contrast, 69% of respondents perceived that rangelands and alalili are important to pollinators as they offer essential habitat, while 16% could not see any importance of grazing areas for insect pollinators. Generally, Maasai perceived that pollinators need alalili and other grazing lands more than the rangelands need pollinators. Significantly more agro-pastoralists compared to pastoralists perceived rangelands to be important for pollinators as they offer essential habitat ($\chi^2 = 9.889$, $df = 3$, $p = .020$).

Socio-Economic Importance of Pollinators to Maasai Community

For most respondents (93%), income was the most essential pollinator benefit, which did not differ between agro-pastoralists and pastoralists ($\chi^2 = 2.032$, $df = 2$, $p = .362$). The majority (90%) of respondents had seen pollinators visiting crops and other plants in the area, an observation that did not differ significantly between pastoralists and agro-pastoralists ($\chi^2 = 2.794$, $df = 2$, $p = .247$). Most respondents (61%) participated in beekeeping for income addition, while the remaining 39% were non-beekeepers. More Maasai women (89%) were beekeepers compared to men (39%; $\chi^2 = 46.962$, $df = 1$, $p \leq .0001$). Maasai participation in beekeeping was positively influenced by education level and occupation, negatively by gender (Table 1). Beekeepers earned an income from honey, which ranged from 36 to 431 USD annually.

Most non-beekeepers (62%) claimed that keeping bees is an activity for the poor only, while others (24%) claimed that it is a woman's job. The remaining 14% reported that they also wished to start beekeeping if they could be supported with modern equipment.

Pollinator Conservation and Trend in the Area

Most respondents, i.e., 130 (72%), claimed that insect pollinator numbers have recently declined in the area while 21% reported an increasing trend and 4% a constant pattern. Climate change, i.e., reduced rainfall, prolonged drought, and increasing agricultural activities, was reported as leading cause for the decline of insect pollinators in the area (Figure 5). Bee migration, i.e., absconding a hive due to disturbances, and swarming (a natural phenomenon) was mentioned by a few respondents as a reason for decline. Most, i.e., 165 (91%) of respondents reported that they were not aware of any strategies to ensure pollinator conservation in rangelands. In comparison, very few respondents reported potential scenarios that might promote the conservation of pollinators in rangelands. The strategy mentioned by only few (9%) respondents included avoiding forest fires, practicing environmental protection and beehive sitting i.e. establishment of an apiary.

Table 1. Correlation Statistics to Describe Whether Participation in Beekeeping Is Determined by Socio-Economic Characteristics Such as Gender, Age, Education or Occupation ($n = 111$).

Factors	Correlation coefficient	*p*-value
Gender		
Male	−0.509	<.0001
Female		
Age		
20–29	0.066	.381
30–39		
40–49		
50 and above		
Education level		
No formal education	0.421	<.0001
Primary education		
Secondary education		
Occupation		
Pastoralist	0.194	.009
Agro-pastoralists		

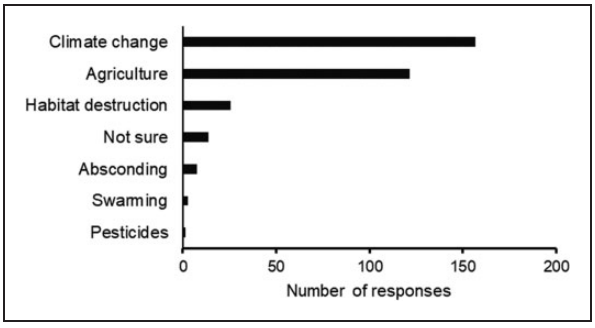

Figure 5. Factors for a Potential Decline in Pollinators in Simanjiro From the Survey in Loiborsiret, Narakauo and Kimotorok Villages in 2019 as Reported by 181 Respondents. The bars represent the frequency a cause was mentioned whereby multiple responses were possible.

Discussion

Maasai Knowledge and Recognition of Common Pollinators

Our finding that all interviewed respondents were able to identify honey bees (*Apis mellifera)* correctly, compared

to other insect groups, is similar to Kasina et al. (2009) from a survey in Kakamega district, Kenya. In the Amhara region, Ethiopia, also more than half of the respondents were not aware of other insect pollinators than honeybees, *Apis mellifera* (Misganaw, 2017), as was the case in West Bengal, India (Bhattacharyya et al., 2017) and Zvimba district, Zimbabwe (Tarakini et al., 2020). In general, small bees are less likely to be identified, even by experienced people (Smith et al., 2017), which we also saw in our study, as few Maasai identified solitary bees, *Lasioglossum* of subgenus *Ipomalictus*. Our finding implies that the conservation of other pollinator groups apart from honey bees in the areas is at jeopardy, for instance even *Syriphidae* was least identified by our respondents even though dipterans are the second dominant pollinator group after hymenoptera and available at large numbers in the area. However, the knowledge articulated by our respondents on pollinator species was better than that of other farming communities (e.g., Elisante et al., 2019), where some respondents were not able to identify even a honey bee. The knowledge in our study villages is likely linked to sensitization by Tanzania People and Wildlife (TPW), an NGO working in the area promoting beekeeping. Knowledge of pollinators can vary depending on location and efforts of authorities and other stakeholders to enhance community awareness on pollinators (Smith et al., 2017). Especially fathers and grandparents formed an essential source of knowledge among the interviewed respondents in our study, which is in line with (Angassa & Oba, 2008).

Maasai Knowledge on Plants Favored by Pollinators

Our respondents mentioned plant species mostly favored by bees as *Commiphora africana, Acacia mellifera* and *Albizia anthelmintica,* species that were available both within alalili enclosures and open grazing areas. Our results are similar to those reported from Amhara region, Ethiopia, and Mubi region, Nigeria, where the majority of respondents were able to list plants visited by honeybees during the flowering season (Abdullahi et al., 2011; Misganaw, 2017). Maasai are quite knowledgeable on plant species as they use them for medicinal purposes for themselves and livestock (Nankaya et al., 2020). (Woodhouse & McCabe, 2018), reported Simanjiro plains as the richest rangelands in terms of biodiversity of both flora and fauna which is in line with our findings where most bee plants recorded in grazing and forest reserve by (Abdullahi et al., 2011); are also found in Simanjiro. Hence, the high diversity of bee fodder plants in Simanjiro rangelands highlights the potential of beekeeping in addition to livestock keeping as income generation. As reported by (Greenleaf et al., 2007), forage resources for honey bees are an essential consideration for beekeepers and overuse or destruction of resources should be avoided (Havstad et al., 2007).

Perceived Pollinator Role for Rangelands

Most respondents in our study were not aware that pollinators have any importance in their rangelands and enclosures (alalili) wellbeing. This finding suggests that pollinator species residing within Simanjiro rangelands might face minimum conservation attention from local Maasai pastoralists. According to (Kearns et al., 1998), pollinators are keystone species in most terrestrial ecosystems, including rangelands. Solitary bees (*Halictidae*) have been reported to collect pollen from temperate grass species, which promote a better seed set compared to only wind pollinated grasses (Harmon et al., 2011). Our results that Maasai do not relate rangeland health to pollinator presence are in line with findings by (Misganaw, 2017), whereby more than half of the respondents stated that they did not know the role of bees and other insects when they visit crops indicating limited knowledge of pollination. Additionally, crops grown by our respondents in Simanjiro, including sesame (Stein et al., 2018), and beans have been reported to benefit from pollinators (Elisante et al., 2020). A study by (Stein et al., 2017) in Burkina Faso, West Africa revealed an increased production in sesame yield by 62% compared to plants that had been excluded from pollinators. Our findings imply the need of disseminating pollination knowledge among pastoral communities so that they can acquire multiple benefits from pollination for livestock forage and increased crop production.

Pollinator Role in Livelihood Diversification and Gender Participation

Livelihood diversification involves participation in more than a single source of income to reduce risks (Baird & Hartter, 2017), particularly in times of climate change (McCabe et al., 2010). Many Maasai have diversified their income through off-farm payment, agriculture and other small-scale economic activities into their traditional pastoralist livelihoods (McCabe et al., 2010; Woodhouse & McCabe, 2018), which agrees with our findings. Beekeeping plays a vital role in improving biodiversity conservation, socio-economic development, food security and poverty reduction in many parts of the world and is an environmentally friendly economic activity for income addition (Abdullahi et al., 2011; Austin et al., 2020). Our observed involvement of more women as compared to men in beekeeping is mainly due to the support by TPW, albeit men were involved in some activities such as hive sitting, monitoring,

honey harvesting, processing and finally marketing. The majority of Maasai men saw beekeeping as income generation for poor households only, with very few or no cattle possession, a fact that has also been reported by (Lyver et al., 2014). This perception regarding beekeeping is mostly limited to Maasai pastoralists, as in most rural areas both men and women participate in beekeeping for their livelihood improvement (Nyunza, 2018), regardless beekeeping being stereotyped as a male activity in some culture (Austin et al., 2020). Our findings highlight the need for more education on beekeeping benefits among Maasai men inorder to promote their participation as beekeeping can be practiced alongside livestock keeping.

The Decline in Pollinators and Conservation Strategies in Maasai Plains

The global decline of both managed and wild pollinators is a primary concern in conservation (Black et al., 2011; Potts et al., 2010). Most of our respondents were also aware of a declining trend in pollinators and the underlying causes, which were also highlighted by other researchers in various agricultural and natural ecosystems (Marques et al., 2017; Misganaw, 2017; Potts et al., 2010; Tarakini et al., 2020). In Simanjiro plains, land clearance is at an unprecedented scale, and large portions of rangelands are cleared for small and large-scale cultivation (Msoffe et al., 2011). Most of our respondents were not aware that this impacts pollinators, nor of pollinator conservation strategies that could stop the decline. This is similar to findings with (Winfree, 2010) who found bee abundance and species richness to be negatively affected by habitat fragmentation. As most Maasai are currently agro-pastoralists, harnessing pollinator benefits like pest control from *Coccinellidae* beetles (Mkenda et al., 2020) and pollination to boost crop yields will contribute towards conservation as has been shown in (Elisante et al., 2020; Klein et al., 2007). With the exclusion of natural disasters such as climate change and drought, there is need to create awareness about the human disturbances that promote pollinator declines, especially in pastoralist communities. As we showed, the linkage between pollinators and rangeland wellbeing was not directly established by the Maasai. A study by (Elwell, 2012) reported that livestock grazing does not affect abundance, richness or diversity of the overall pollinator assemblages or functional groups if on moderate levels. In general, if livestock grazing is done moderately it can promote dominating of herbaceous plants, which might support diverse insect pollinators in a sustainable way (Black et al., 2011).

Implication for Conservation

The results from this study show that majority of Maasai pastoralists have limited knowledge concerning insect pollinators apart from honey bees. While good work has been done on promoting beekeeping in the area, there is a need to create actions that will facilitate information and knowledge exchange between experts and Maasai on insect benefits, especially pollination. Communities should be well informed in broader insect benefits for all groups instead of honeybees only. Media such as radio and television may form an important tool to disseminate pollinator information, especially in rural areas of developing countries, where extension services are limited (Tarakini et al., 2020). More emphasis should be directed on balancing grazing management in alalili enclosures inorder to maintain large variety of pollinators and bee fodder plants that might contribute to beekeeping. The involvement of Maasai pastoralist in conservation and monitoring of pollinators in rangelands is of vital importance to understand current status and trends as well as understanding how grazing management and climate change in the area affect pollinators. This is of vital importance, especially in times when most Maasai have incorporated agriculture in their cultural pastoralism livelihood. Training on beneficial insects that assist in crop pollination and pest management (Mkenda et al., 2020), will help in bridging the knowledge gap and promote pollinator conservation in rangelands.

Acknowledgments

We extend sincere appreciation to Simanjiro district authority. We acknowledge and appreciate the great support from Ward and Village Executive Officers as well as village chairmen. We thank A. Pauly and E. Mboya for assistance in insect and plants identification. We are also grateful for our research assistants O. Laizer and J. Lembaji.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: We acknowledge financial support from the Centre for Research, Agricultural advancement, Teaching Excellence and Sustainability (CREATES) as the main funder. We acknowledge additional support from Eva Crane Trust based in the U.K. [Grant number ECTA_20190903_Mpondo].

ORCID iD

Faith Thomas Mpondo https://orcid.org/0000-0002-6552-9074

Supplemental material

Supplemental material for this article is available online.

References

Abdullahi, G., Sule, H., & Chimoya, I. A. (2011). Diversity and relative distribution of honeybees foraging plants in some selected reserves in Mubi region, Sudan savannah ecological zone of Nigeria. *Advances in Applied Science Research*, *2*(5), 388–395.

Ali, M., Sajjad, A., Farooqi, M. A., Bashir, M. A., Aslam, M. N., Nafees, M., Aslam, M. N., Adnan, M., & Khan, K. A. (2020). Assessing indigenous and local knowledge of farmers about pollination services in cucurbit agroecosystem of Punjab, Pakistan. *Saudi Journal of Biological Sciences*, *27*(1), 189–194. https://doi.org/10.1016/j.sjbs.2019.07.001

Allen-Wardell, A. G., Bernhardt, P., Bitner, R., Burquez, A., Cane, J., Cox, P. A., Dalton, V., Feinsinger, P., Ingram, M., Jones, C. E., Kennedy, K., Kevan, P., Koopowitz, H., Medellin, R., Medellin-Morales, S., Nabhan, G. P., Pavlik, B., Tepedino, V., & Torchio, P. (2016). The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology*, *12*, 8–17. http://www.jstor.org/stable/238

Angassa, A., & Oba, G. (2008). Herder perceptions on impacts of range enclosures, crop farming, fire ban and bush encroachment on the rangelands of Borana, Southern Ethiopia. *Human Ecology*, *36*(2), 201–215. https://doi.org/10.1007/s10745-007-9156-z

Austin, A., Schouten, C. N., Hinton, J., & Lloyd, D. J. (2020). Barriers to women's participation in beekeeping in Papua New Guinea. *Bee World*, *98*(1), 27–31. https://doi.org/10.1080/0005772x.2020.1818465

Baird, T. D., & Hartter, J. (2017). Livelihood diversification, mobile phones and information diversity in Northern Tanzania. *Land Use Policy*, *67*(5), 460–471. https://doi.org/10.1016/j.landusepol.2017.05.031

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*(5), 1251–1262. https://doi.org/10.1890/1051-0761(2000)010

Bhattacharyya, M., Acharya, S. K., & Chakraborty, S. K. (2017). Pollinators unknown: People's perception of native bees in an agrarian district of West Bengal, India, and its implication in conservation. *Tropical Conservation Science*, *10*, 194008291772544. https://doi.org/10.1177/1940082917725440

Black, S. H., Shepherd, M., & Vaughan, M. (2011). Rangeland management for pollinators. *Rangelands*, *33*(3), 9–13. https://doi.org/10.2111/1551-501X-33.3.9

Chisanga, K., Mbega, E., & Ndakidemi, P. A. (2019). Socio-economic factors for anthill soil utilization by smallholder farmers in Zambia. *Sustainability*, *11*(18), 4849–4817. https://doi.org/10.3390/su11184849

Dar, S. A., Hassan, G. I., Padder, B. A., Wani, A. R., & Parey, S. H. (2017). Pollination and evolution of plant and insect interaction. *Journal of Pharmacognosy and Phytochemistry*, *6*, 304–311.

Eardley, C. D., Gikungu, M., Schwarz, M. P. (2009). Bee conservation in sub-Saharan Africa and Madagascar: Diversity, status and threats. *Apidologie*, *40*(3), 355–366.

Eardley, C., Kuhlmann, M., & Pauly, A. (2010). *The bee genera and subgenera of sub-Saharan Africa* (Vol. 10). Belgian Cooperation Development Brussels.

Elisante, F., Mbega, E. R., & Ndakidemi, P. A. (2017). Significance of pollination services in crop and plant diversity in tropical Africa. *Journal of Biodiversity and Ecosystem Services*, *11*(6), 206–223.

Elisante, F., Ndakidemi, P. A., Arnold, S. E. J., Belmain, S. R., Gurr, G. M., Darbyshire, I., Xie, G., Tumbo, J., & Stevenson, P. C. (2019). Enhancing knowledge among smallholders on pollinators and supporting field margins for sustainable food security. *Journal of Rural Studies*, *70*(November 2018), 75–86. https://doi.org/10.1016/j.jrurstud.2019.07.004

Elisante, F., Ndakidemi, P., Arnold, S. E. J., Belmain, S. R., Gurr, G. M., Darbyshire, I., Xie, G., & Stevenson, P. C. (2020). Insect pollination is important in a smallholder bean farming system. *PeerJ*, *8*, e10102. https://doi.org/10.7717/peerj.10102

Elwell, S. L. (2012). *The effects of livestock grazing and habitat type on plant-pollinator communities of British Columbia' s endangered shrubsteppe*. Available online at http://summit.sfu.ca/item/12129

Fakir, H., & Babalik, A. (2009). Important medicinal—Aromatic plant species for beekeeping in Isparta region rangelands. *Journal of Animal and Veterinary Advances*, *8*, 1406–1411.

Greenleaf, S. S., Williams, N. M., Winfree, R., & Kremen, C. (2007). Bee foraging ranges and their relationship to body size. *Oecologia*, *153*(3), 589–596. https://doi.org/10.1007/s00442-007-0752-9

Harmon, J. P., Ganguli, A. C., & Solga, M. J. (2011). An overview of pollination in rangelands: Who, why, and how. *Rangelands*, *33*(3), 4–8. https://doi.org/10.2111/1551-501X-33.3.4

Havstad, K. M., Peters, D. P. C., Skaggs, R., Brown, J., Bestelmeyer, B., Fredrickson, E., Herrick, J., & Wright, J. (2007). Ecological services to and from rangelands of the United States. *Ecological Economics*, *64*(2), 261–268.

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2016). The assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production. In S. G. Potts, V. L. Imperatriz-Fonseca, & H. T. Ngo (Eds.), *Secretariat of the intergovernmental science-policy platform on biodiversity and ecosystem services* (p. 552).

Kasina, M., Kraemer, M., Martius, C., & Wittmann, D. (2009). Farmers' knowledge of bees and their natural history in Kakamega district, Kenya. *Journal of Apicultural Research*, *48*(2), 126–133. https://doi.org/10.3896/IBRA.1.48.2.07

Kearns, C. A., Inouye, D. W., & Waser, N. M. (1998). Endangered mutualisms: The conservation of plant-pollinator interactions. *Annual Review of Ecology and Systematics*, *29*(1), 83–112.

Kibebe, J. D. N. (2005). *Socio-economic and ecological impacts of safari hunting and commercial farming on key stakeholders: Simanjiro District, Tanzania* [MSc thesis]. Norargic University, Norway.

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings Biological Sciences*, *274*(1608), 303–313. https://doi.org/10.1098/rspb.2006.3721

Kosior, A., Celary, W., Olejniczak, P., Fijał, J., Król, W., Solarz, W., & Płonka, P. (2007). The decline of the bumble bees and cuckoo bees (hymenoptera: Apidae: Bombini) of Western and Central Europe. *Oryx*, *41*(1), 79–88.

Lyver, P., Perez, E., Carneiro da Cunha, M., & Roué, M. (2014). *Indigenous and local knowledge about pollination and pollinators associated with food production: Outcomes from the global dialogue workshop*. UNESCO.

Marques, M. F., Hautequestt, A. P., Oliveira, U. B., de Freitas Manhães-Tavares, V., Perkles, O. R., Zappes, C. A., & Gaglianone, M. C. (2017). Local knowledge on native bees and their role as pollinators in agricultural communities. *Journal of Insect Conservation*, *21*(2), 345–356. https://doi.org/10.1007/s10841-017-9981-3

Mbinile, S. D., Munishi, L. K., Ngondya, I. B., & Ndakidemi, P. A. (2020). Conservation and management challenges facing a medicinal plant Zanthoxylum chalybeum in Simanjiro area, Northern Tanzania. *Sustainability*, *12*(10), 4140. https://doi.org/10.3390/su12104140

Mccabe, J. T. (2003). Maasai of Northern Tanzania. *Human Organization*, *62*(2), 100–111. https://doi.org/10.17730/humo.62.2.4rwrt1n3xptg29b8

McCabe, J. T., Leslie, P. W., & DeLuca, L. (2010). Adopting cultivation to remain pastoralists: The diversification of Maasai livelihoods in Northern Tanzania. *Human Ecology: An Interdisciplinary Journal*, *38*(3), 321–334. https://doi.org/10.1007/s10745-010-9312-8

Miller, B. W., Leslie, P. W., & McCabe, J. T. (2014). Coping with natural hazards in a conservation context: Resource-use decisions of Maasai households during recent and historical droughts. *Human Ecology: An Interdisciplinary Journal*, *42*(5), 753–768.

Misganaw, M. (2017). Perception of farmers on importance of insect pollinators in Gozamin district of Amhara region, Ethiopia. *Biodiversity International Journal*, *1*(5), 54–60. https://doi.org/10.15406/bij.2017.01.00029

Mkenda, P. A., Ndakidemi, P. A., Stevenson, P. C., Sarah, E. J., Darbyshire, I., Belmain, S. R., Priebe, J., Johnson, A. C., Gurr, G. M., Mkenda, P. A., Ndakidemi, P. A., Stevenson, P. C., Sarah, E. J., Darbyshire, I., Belmain, S. R., Priebe, J., Johnson, A. C., & Tumbo, J. (2020). Knowledge gaps among smallholder farmers hinder adoption of conservation biological control. *Biocontrol Science and Technology*, *30*(3), 256–222. https://doi.org/10.1080/09583157.2019.1707169

Msoffe, F. U., Kifugo, S. C., Said, M. Y., Neselle, M. O., van Gardingen, P., Reid, R. S., Ogutu, J. O., Herero, M., & de Leeuw, J. (2011). Drivers and impacts of land-use change in the Maasai steppe of Northern Tanzania: An ecological, social and political analysis. *Journal of Land Use Science*, *6*(4), 261–281. https://doi.org/10.1080/1747423X.2010.511682

Munyuli, M. B. T. (2011). Pollinator biodiversity in Uganda and in Sub-Sahara Africa: Landscape and habitat management strategies for its conservation. *International Journal of Biodiversity and Conservation*, *3*(11), 551–609.

Munyuli, T. (2011). Farmers' perceptions of pollinators' importance in coffee production in Uganda. *Agricultural Sciences*, *2*(3), 318–333. https://doi.org/10.4236/as.2011.23043

Nankaya, J., Gichuki, N., Lukhoba, C., & Balslev, H. (2020). Medicinal plants of the Maasai of Kenya: A review. *Plants*, *9*(1), 1–17. https://doi.org/10.3390/plants9010044

National Bureau of Statistics. (2017). *The population of regions and districts of Tanzania*. https://www.citypopulation.de/en/tanzania/admin/

Nnko, H. J., Ngonyoka, A., Salekwa, L., Estes, A. B., Hudson, P. J., Gwakisa, P. S., & Cattadori, I. M. (2017). Seasonal variation of tsetse fly species abundance and prevalence of trypanosomes in the Maasai steppe, Tanzania. *Journal of Vector Ecology: Journal of the Society for Vector Ecology*, *42*(1), 24–33. https://doi.org/10.1111/jvec.12236

Nyunza, G. (2018). Anthropogenic and climatic factors affecting honey production: The case of selected villages in Manyoni District, Tanzania. *Journal of Agricultural Biotechnology and Sustainable Development*, *10*(3), 45–57. https://doi.org/10.5897/JABSD2017.0292

Oba, G. (2012). Harnessing pastoralists' indigenous knowledge for rangeland management: Three African case studies. *Pastoralism: Research, Policy and Practice*, *2*(1), 1.

Ontiri, E. M., Odino, M., Kasanga, A., Kahumbu, P., Robinson, L. W., Currie, T., & Hodgson, D. J. (2019). Maasai pastoralists kill lions in retaliation for depredation of livestock by lions. *People and Nature, 1*(1), 59–69. https://doi.org/10.1002/pan3.10

Otieno, M., Woodcock, B. A., Wilby, A., Vogiatzakis, I. N., Mauchline, A. L., Gikungu, M. W., & Potts, S. G. (2011). Local management and landscape drivers of pollination and biological control services in a Kenyan agro-ecosystem. *Biological Conservation*, *144*(10), 2424–2431. https://doi.org/10.1016/j.biocon.2011.06.013

Patrí, G. B. (2014). *Aspects of Landscape and Pollinators — What is Important to Bee Conservation?* 158–175. https://doi.org/10.3390/d6010158

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W. E. (2010). Global pollinator declines: Trends, impacts and drivers. *Trends in Ecology & Evolution*, *25*(6), 345–353. https://doi.org/10.1016/j.tree.2010.01.007

Potts, S. G., Woodcock, B. A., Roberts, S. P. M., Tscheulin, T., Pilgrim, E. S., Brown, V. K., & Tallowin, J. R. (2009). Enhancing pollinator biodiversity in intensive grasslands. *Journal of Applied Ecology*, *46*(2), 369–379. https://doi.org/10.1111/j.1365-2664.2009.01609.x

Sarper, F., Akaydin, G., Şimşek, I., & Yeşilada, E. (2009). An ethnobotanical field survey in the Haymana district of Ankara province in Turkey. *Turkish Journal of Biology*, *33*(1), 79–88. https://doi.org/10.3906/biy-0808-28.

Senapathi, D., Biesmeijer, J. C., Breeze, T. D., Kleijn, D., Potts, S. G., & Carvalheiro, L. G. (2015). Pollinator conservation - The difference between managing for pollination services and preserving pollinator diversity. *Current Opinion in Insect Science*, *12*, 93–101. https://doi.org/10.1016/j.cois.2015.11.002

Sharp, J., & Twati, L. (2017, December). *Documentation of Maasai culture*.

Smith, B. M., Chakrabarti, P., Chatterjee, A., Chatterjee, S., Dey, U. K., Dicks, L. V., Giri, B., Laha, S., Majhi, R. K., & Basu, P. (2017). Collating and validating indigenous and local knowledge to apply multiple knowledge systems to an environmental challenge: A case-study of pollinators in India. *Biological Conservation*, *211*(September 2016), 20–28. https://doi.org/10.1016/j.biocon.2017.04.032

Stein, K., Coulibaly, D., Stenchly, K., Goetze, D., Porembski, S., Lindner, A., Konaté, S., & Linsenmair, E. K. (2017). Bee pollination increases yield quantity and quality of cash crops in Burkina Faso, west Africa. *Scientific Reports*, *7*(1), 1–10. https://doi.org/10.1038/s41598-017-17970-2

Stein, K., Stenchly, K., Coulibaly, D., Pauly, A., Dimobe, K., Steffan-Dewenter, I., Konaté, S., Goetze, D., Porembski, S., & Linsenmair, K. E. (2018). Impact of human disturbance on bee pollinator communities in savanna and agricultural sites in Burkina Faso, west Africa. *Ecology and Evolution*, *8*(13), 6827–6838. https://doi.org/10.1002/ece3.4197

Stewart, A. B., Sritongchuay, T., Teartisup, P., Kaewsomboon, S., & Bumrungsri, S. (2018). Habitat and landscape factors influence pollinators in a tropical megacity, Bangkok, Thailand. *PeerJ*, *6*, e5335. https://doi.org/10.7717/peerj.5335

Tarakini, G., Chemura, A., & Musundire, R. (2020). Farmers' knowledge and attitudes toward pollination and bees in a Maize-Producing region of Zimbabwe: Implications for pollinator conservation. *Tropical Conservation Science*, *13*, 1940082920918534. https://doi.org/10.1177/1940082920918534

Vanbergen, A. J., & Initiative, P. (2013). *Threats to an ecosystem service: Pressures on pollinators*. https://doi.org/10.1890/120126

Westphal, C., Bommarco, R., Carré, G., Lamborn, E., Morison, N., Petanidou, T., Potts, S. G., Roberts, S. P. M., Szentgyörgyi, H., Tscheulin, T., Vaissière, B. E., Woyciechowski, M., Biesmeijer, J. C., Kunin, W. E., Settele, J., & Steffan-Dewenter, I. (2008). Measuring bee diversity in different European habitats and biogeographical regions. *Ecological Monographs*, *78*(4), 653–671. https://doi.org/10.1890/07-1292.1

Winfree, R. (2010). The conservation and restoration of wild bees. *Annals of the New York Academy of Sciences*, *1195*, 169–197. https://doi.org/10.1111/j.1749-6632.2010.05449.x

Woodhouse, E., & McCabe, J. T. (2018). Wellbeing and conservation: Diversity and change in visions of a good life among the Maasai of Northern Tanzania. *Ecology and Society*, *23*(1): 43. https://doi.org/10.5751/ES-09986-230143

Zurbuchen, A., Landert, L., Klaiber, J., Müller, A., Hein, S., & Dorn, S. (2010). Maximum foraging ranges in solitary bees: Only few individuals have the capability to cover long foraging distances. *Biological Conservation*, *143*(3), 669–676. https://doi.org/10.1016/j.biocon.2009.12.003