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Pastoralist Knowledge of Pollinator Ecosystem Services in a Maasai Community

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Abstract

This research examines the social-ecological relationship of pollinators and pastoralists in Simanjiro, Tanzania. In this study, research objectives centered on defining the significance of pollinators, specifically bees, within Maasai pastoralist societies and the role of pollinator biodiversity in the surrounding dryland community. While long-term data on cultivation, pastoralism and wildlife diversification have been collected in East Africa, previous research did not investigate pollinator ecosystem services' significance relative to pastoralist livelihoods in Tanzania. Six semi-structured interviews, with a Maasai/English interpreter assisting, were conducted with five men and two women who were beehive owners. Questions focused on pollinator knowledge, roles of pollinators and habitat quality, including ranking of various elements related to habitat. Qualitative data analysis revealed varying levels of pollinator knowledge among the owners. Honey production provided additional family income, supported celebratory traditions and fulfilled certain medicinal needs of the community. Further analysis of the interview feedback and ranking of responses identified that, in order of importance, open pastures, woodlands, shambas (cultivation areas), korongo (drainages) and engusero (wetlands) were home to the majority of the plants Maasai believed to be important for pollinators. To improve bee habitat conditions, Maasai beekeepers suggested increasing water availability, restricting tree cutting, cleaning hives and constructing additional hives. Beekeepers were concerned about habitat fragmentation, water scarcity, the availability of nesting sites and the decline of floristic species leading to pollinator population decline. The findings from this study support previous research on semi-arid ecosystems conducted, expanding global understanding of pollinator roles in dryland communities. By understanding the significance of pollinators and the ecosystem services that they provide to drylands and dryland communities, land managers - including those in pastoralist societies - can be in a better position to implement future management strategies that support pollinators and ecosystem services associated with them.

Keywords: Maasai, Pollinators, Agropastoralism, Pastoralism, Ecosystem Services, Livelihoods

1. Introduction

In academia, the term 'ecosystem services' has been coined to refer to the values and benefits that humans attribute to the natural world. Ecosystem services encompass provisional, cultural, aesthetic and regulating services that share complex, interdependent relationships with human dynamics through social-ecological systems[8]. Understanding dependencies of various stakeholders from a regional and local perspective may permit improvements of land management and the distribution of resources people depend upon[5]. Stakeholder values vary by community, showing that ecosystem service perceptions should shape resource management and the formation of alternative livelihoods differently from place to place[7, 14]. The use of traditional knowledge to analyze ecosystem services also reveals unperceived benefits of factors that contribute to ecosystem quality, such as the role of problematic plant species in relation to pollinator success[3, 30].

Pollinator species and the ecosystem services that they provide are essential to the survival of angiosperms (flowering plants) throughout the world[1]. There is growing evidence that pollinator services improve both the nesting and foraging potential for other organisms. This consequently promotes biodiversity through improvements in ecological factors such as soil and water quality[34]. Pollinator activity is additionally essential for human diets, with honeybees alone being responsible for 35% of the world's food production[11]. Recent concerns for bee colonies are mostly due to noticeable population declines in North America and Europe, with the past five years having greater losses than any time during the last 50 years[1]. As shown by previous research, habitat fragmentation, loss of floristic species and the availability of nesting sites are the leading causes for pollinator population declines[11, 12]. This pattern may also apply to pollinators in regions of Africa, however, lack of long-term data collection inhibits assessment[23]. Understanding of the effects of development and overgrazing patterns suggest that these areas could be experiencing pollinator declines[6, 23]. While long-term data on cultivation, pastoralism and livelihood diversification have been collected in East Africa[19], no research has investigated the relationship and potential dependence of pastoralist livelihoods on pollinator species in this geographic region.

Research forecasts that there will be massive food shortages in the next quarter century in sub-Saharan Africa. Based on current rates of human population expansion and land necessities, there may also be an increase in large-scale annual floods and droughts that place an additional stress on food production and biodiversity[9, 10, 29]. Projected effects of climate change also suggest increased pressures on ecosystem dynamics, placing stress on pollinator populations and reliant organisms. The subsequent loss of pollinator species decreases essential ecosystem services relating to soil quality and angiosperm reproduction, increasing food insecurity as well[34, 24]. It is not possible to talk about the future of pollinator species without evaluating the effects of climate change on biota and the interconnected relationships of plants, humans and wildlife. Temperature data analysis, for example, demonstrates loss of pollinator visitation due to floral temperature shifts brought about by climate change[31]. With recent and predicted drops in the density of pollinators on a global scale, this issue needs to be assessed at community levels[15]. The criticality of this burgeoning problem is becoming clear to organizations throughout the world, but much work needs to be done in countries such as Tanzania, where knowledge concerning pollinator services is lacking[23].

The Maasai of Simanjiro, Tanzania are semi-nomadic pastoralists moving with their livestock in a seasonal rotation. Political and economic pressures, in the form of changes in governance and resource management systems, have led to the growth of agro-pastoralism within this district[2, 10, 14]. Agro-pastoralism, a lifestyle of growing crops in addition to raising livestock pastorally, is a growing practice in Tanzania where pastoralists in some areas subsidize their diets through cultivation[22]. These land use changes place additive pressure on dryland ecosystems in which traditional pastoralist practices are more sustainable[9, 24, 27]. As with other semi-arid regions, land use changes in Tanzania destabilize ecosystem dynamics, leading to the decline of ecosystem services essential to sustain pastoralist practices[20, 29]. In some locations, opportunities for alternate livelihoods have been accepted as means of increasing economic diversification, poverty resistance and dietary supplement[4, 13, 32]. Other forms of alternative income methods in East Africa have also been on the rise in recent years, primarily market trade of local goods like honey[7, 18]. The rise of cultivation in Tanzania has particularly brought about an increased dependence on pollinator services, which are critical for the propagation of crops common to the area; especially maize. Ecologically important plants are also reliant on pollinators in Tanzania, including intenga (*Kotschya recurvifolia*) and inzigula (*Dodonaea viscosa*)[17].

The most common pollinators in Tanzania are, in order, honeybees, wasps and megachille bees. Other identified pollinators in Tanzania include beetles and butterflies, which do not have as large an impact on the pollination of angiosperms due to alternative food sources[26]. In addition to ecosystem services that bees provide, beekeeping is a source of income for over two million people in Tanzania[28]. Recently, beekeeping has become incentivized by outside organizations for varying reasons including female economic empowerment and reducing elephant crop destruction in East Africa[16, 33]. Previous research in dryland ecosystems suggests that bee colonies significantly impact the reproduction of pollinated plants, which in turn contribute to the physicochemical characteristics of honey produced[21, 22].

In Simanjiro, assessing the role of pollinators will give Maasai and land managers insight into the significance of pollinators within local plant communities and pastoralist practices. This is a pilot study that sought to commence pollinator studies in Simanjiro, Tanzania. While previous studies have investigated the importance of pollinator services to social-ecological dynamics, little research has been conducted that focuses on these relationships. In dryland communities such as Simanjiro, where pastoralism is a threatened livelihood, further studies may help outline the interdependence of pollinators and indigenous people.

There were three primary objectives of this pilot study: (1) to evaluate Maasai perceptions of pollinators and pollination, (2) to compare plant diversity and habitat distribution relative to pollinators and (3) to understand the relationship between pastoral practices and pollinator services. While this research gives an overview of various forces of biotic pollination, questions concentrated specifically on honeybee pollination. This focus was decided upon based

on the direct connection that interviewees had through beekeeping, as their knowledge on the subject reflected both experience and traditional indigenous knowledge. Furthermore, as mentioned previously, honeybees have been cited in previous studies as a more densely populated and productive pollinator in Tanzania[26, 28].

With respect to the three primary objectives, hypotheses were as follows: (1) Maasai would be able to identify multiple species of bees, an assortment of other insects and sunbirds as local pollinators, as well as thoroughly describe the pollination process; (2) Maasai would correlate bee presence to pollinated plant density across habitat types, and identify water as the primary limiting factor for bee inhabitation; and that (3) Maasai utilize harvested honey from wild and household hives to support their livelihoods as a dietary supplement or for income stability.

2. Methods

Prior to conducting field work, IRB approval was granted for conducting interviews. Six semi-structured interviews were conducted in the villages of Sukuro and Kitiengare during the summer of 2017 with two women (interviewed together) and five men (one-on-one interviews) who had varying levels of apiary experience. Translators were necessary as the interviewer spoke English and interviewees spoke Maa. Questions focused on pollinator knowledge, roles of pollinators and habitat quality with respect to pollinated plants. Within these interviews, participants were asked to rank bee-pollinated plants across five different habitat types common in Simanjiro: shambas (cultivation plots), engusero (wetlands), korongo (drainages), woodlands and open pastures. Ranking involved comparison between important bee-pollinated plants which were identified by Maasai beekeepers. These five habitat types were also used to assess bee presence.

At the time of this paper's publication, the research team is in the process of identifying and confirming botanical families from Maa common names that were given during interviews.

Results were summarized using Excel.

2.1. Interview Questions

2.1.1. pollinators in general

1) Can you explain how bees produce honey?
2) Are there other animals and insects that visit plants and may pollinate as bees do?
3) Which animals?
4) What plants are being visited and pollinated by these animals?

2.1.2. pollinator-facilitating plants

5) Which plants are favored by bees?
6) Which three of these plants are the most important in supporting honey production?
7) Rank these three species from most important/favored (1) to least important/favored (3) for bees.
8) Rank these three species from most common (1) to least common (3) in the areas that you use from day-to-day.
9) For each plant (starting with most important):
    a. Is this plant common or uncommon in open pastures?
    b. Is this plant common or uncommon in shambas?
    c. Is this plant common or uncommon in woodlands?
    d. Is this plant common or uncommon in korongo?
    e. Is this plant common or uncommon in engusero?

2.1.3. bees

10) Do you notice many types of bees? How many can you count?
11) Are there particular bees that you prefer and that you like to see around?
12) Are any of the bees around here very aggressive?

a. If yes, are these species newer to the area, or have they been here a long time?
b. If yes, are these species as productive as the docile species?

13) During what time(s) of the day are bees most active?
14) During which months are bees the most active?
15) During which months do bees make the most honey?
16) During which month(s) are bees likely to swarm?
17) Have bee populations been changing?
    a. If yes, have you noticed more or fewer bees compared to five years ago?
    b. If yes, have you noticed more or fewer bees compared to ten years ago?
    c. If yes, what do you think is causing this change in bee populations?
18) If bee populations were to decrease, what effect does that have on people, livestock and the environment?
19) How can we help bees thrive?
20) What are the things that bees need nearby to thrive?
21) Can you describe the best habitat for bees?
22) Is there a favorite tree where wild bees like to establish their hives?
23) Are bees common or uncommon in:
    a. open pastures?
    b. shambas?
    c. woodlands?
    d. korongo?
    e. engusero?

2.1.4. neighborhood and wild beehives

24) Do you purchase any bee products?
    a. How do you pay for them?
    b. What do you use these products for?
25) Do any of your neighbors have household hives?
26) Has anyone come to Sukuro or Kitiengare to establish beehives?
    a. If yes, who are they?
    b. Do they keep a few or many hives? How many?
    c. Where do they keep their hives?
27) Do you ever harvest from other people's hives?
28) Would men or women traditionally be the ones to collect honey from wild hives in the past?
29) Are men or women typically collect honey from wild hives now?
30) Does anyone in your household ever harvest products from wild hives?
31) How does the quality of bee products harvested from wild hives compare to that from household hives?
32) Where are there wild hives?

2.1.5. beekeeping

33) How do bees contribute to your livelihood?
34) Do you keep beehives?
35) *Those Who Do Keep Hives only:*
    a. How many hives do you have?
    b. When did you first start keeping beehives?
    c. Where do you get them from (build, buy, or were given)?
    d. What materials do you use to build your hives?
    e. Where did you get the materials you used to build your hives? (traditional or modern)
    f. How do modern and traditional hives compare in the quality of honey you can get from them?
    g. For what reasons did you decide to keep bees?
    h. How did you learn how to keep bees?

i. How did you choose your hive's location?
j. Is there a favorite type of tree where you like to set up your hives?
k. Is it more important that your hive be in the right place, or that it is close to your boma?
l. Where are your hives?

2.1.6. harvesters

36) How long does it take you to walk to your hives from your boma?
37) What bee products do you use from your hives?
38) What do you do with the honeycombs?
39) How has the success of hives changed since you began harvesting from them?
40) What challenges have you faced with beekeeping? (Freelist)
    a. Rank these challenges from worst (1) to least problematic.
    b. (For top three challenges) How do you address this challenge?
41) Do you harvest from your hives yourself, or does someone else harvest?
    a. Who?
    b. Do you pay for their service? How do you pay them?
42) What are the rules and penalties for those who take honey without permission?
    a. Have you had problems with people taking honey without permission?
43) Can you describe how you harvest honey?
44) Do you sell bee products?
    a. What bee products do you sell and who do you sell to?
    b. How much of (specified product) do you sell?
    c. How much money do you typically make from selling the bee products over the course of one year?
    d. Who keeps the money gained from selling these products?
        i) What do they do with the money gained from selling these products?

3. Results

3.1. Perceptions Of Pollinators

In total, Maasai interviewees recognized six pollinator species other than bees in Simanjiro, five of which were insects (oltmitimi, inmayoru, olkimbia, oltung'ung' and butterflies) with the last being 'sunbirds.' Since reference to animal classification is subjective in Maa (e.g. 'illkunyinyik' translates to 'small bees'), interviewee descriptions were compiled to suggest that three bee species inhabit Simanjiro (Table 1). These descriptions, in addition to interviewees' preferences between bees identified, propose a relationship between honey productivity, aggression level and bee size.

Table 1. Classification of bee descriptions depicted three different bee species in Simanjiro. Interviewees ranked described bees according to the amount of honey produced and aggression level (see question 12 in section 2.1.3.) (1 = highest, 3 = lowest)

Maasai Bee Name(s)	Description	Productivity Rating	Aggression Rating
Ilkunyinyik/ Ndapukuite /Lotoroki	Small bees, pollinate trees, nest in ground	**1**	**1**
Inyorye /Olemaat	Medium-sized bees, pollinate trees, nest in tree hives	**2**	**2**
Olemorwak	Large bees, nest in ground or tree hives, smaller colonies	**3**	**3**

Since pollination is not a translatable term in Maa, interviewees were prompted to explain how bees produce honey. Most defined the pollination segment as the process in which an animal eats or visits flowers. When asked how bees impact people, the environment and livestock, all interviewees responded that bees only improve the lives of beekeepers.

In terms of bee presence within the five habitats investigated (shambas, korongo, engusero, pastures and woodlands), there was an even distribution with the exception of open pastures. Open pastures were thought to be slightly less common of a habitat for bees to inhabit. It is important to note the role of habitat conditions in relation to bee presence. An experienced beekeeper explained that bees were especially common in engusero and korongo during the wet season, while shambas served as good habitat mostly along the edges of cultivation plots.

3.2. Plant Diversity And Distribution

In total, 28 species of pollinated plants were identified by interview participants. Of these plants, 21 were believed to have a dependent relationship with bees in the area, as they were generally favored by bees for pollination purposes. Each interviewee selected their top three bee-favored plants and ranked them with respect to bee visitation frequency, resultant honey quality and commonality of the plant (Table 2). Thus, bee-favored plants were narrowed down to 13 by interviewees. Some plants were listed within the top three by multiple interviewees (osiyamalil, olekitenyi and oltelemet), suggesting their higher value for bees according to Maasai.

Table 2. The value score of each plant indicated by interviewees was calculated from rankings of bee importance, honey production importance and commonality of the plant in Simanjiro (see questions 6-8 in section 2.1.2.). Three points were given to the highest rank, two points were given to the second highest ranking and one point was given to the lowest rank given by each interviewee. Category scores of greater than three were ranked by multiple interviewees and therefore resulted in a higher value score. ND signifies no data

Bee Favored Plants	Bee Importance	Honey Production Importance	Commonality	Value Score
Osiyamalil	6	6	6	**18**
Olekitenyi	4	4	4	**12**
Oltelemet	3	3	6	**12**
Oltepesi	3	3	2	**8**
Endemusoro	3	3	2	**8**
Endapuki	2	2	3	**7**
Oloponi	3	1	2	**6**
Olchorai	2	2	1	**5**
Arng'arooji	1	3	1	**5**
Oiti	2	1	1	**4**
Enderkesi	1	1	1	**3**
Ormukutan	3	ND	ND	**ND**
Oltesikong	2	ND	ND	**ND**

Key (per interviewee):
1st best = 3 points
2nd best = 2 points
3rd best = 1 point

Interviewees also indicated whether each of their top three bee-favored plants were common or uncommon in the five habitats studied. Thus, the distribution of these 13 plants was recorded and organized based upon their value score from Figure 3 (Fig 1).

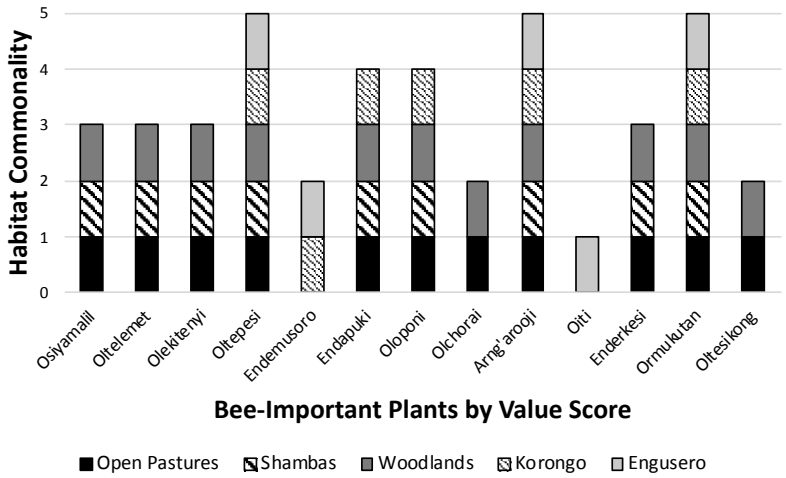

Figure 1. The commonality of 13 bee-favored plants across five habitat types was compared to determine distribution of plants.

The commonality ranking of pollinated plants in each habitat type shows that open pastures (26%), woodlands (26%) and shambas (22%) are home to the majority of the plants interviewees believed to be important for bees. Bee-important plants are less common in korongo (14%) and engusero (12%). Data also suggests that on average, higher valued plants for bees are less distributed between the five habitat types than lower valued plants.

3.3. Beekeeper Practices And Honey Use

The most common response for the reason why interviewees began beekeeping was for income. Money that was generated by honey sales was used by interviewees to purchase livestock, household necessities, medicine and to pay education fees. Honey selling prices differed greatly across beekeepers, resulting in a disparity of potential incomes. One beekeeper interviewed was an experienced business owner who knew that he could sell his honey for $3.94 USD/Liter. At that rate, he earned $1,193.50 USD more per year than the lowest-priced seller who owned the same number of hives. Selling honey to the regional non-profit organization, Mama Asali, also proved a more consistent source of income than by Maasai market demands.

In addition to income reasons, honey is used by Maasai for food, medicine, ceremonies and to barter for livestock. For ceremonies, honey is a key ingredient in an alcoholic beverage which is generally served to the elders present. Women will also use a mixture of milk and honey to bless livestock corrals.

All Maasai harvest honey the same way, involving the smoking of a low-growing mushroom that causes bees to become drowsy and less aggressive. Only one of the beekeepers wore protective clothing when harvesting honey, however, he still reported being stung regularly.

The two women interviewed did not harvest from the beehives that they owned but had men from their families harvest for them. All interviewees confirmed that Maasai men are the ones to harvest honey from beehives, both traditionally and in recent years. While interviewees knew of organizations that encourage female entrepreneurship through beekeeping in Maasai villages (such as African People & Wildlife), women in their neighborhood did not participate. The five male interviewees harvested from beehives themselves with occasional assistance from family members or neighbors.

All interviewees preferred owning household hives over wild beehives because of larger honey yields, better honey flavor and the fact that sediment is more easily blown into ground nests of wild hives. Most beekeepers primarily purchased or built traditional household hives, which are constructed of hollowed-out logs. While modern household beehives were desired by some beekeepers, they were more expensive than traditional hives and less available to Maasai markets. Two interviewees used modern beehives to some extent.

Household hives are suspended from mature trees using ropes or wires. Oltepesi, oiti and osilalei were considered among the best types of trees for hanging hives. Interviewees stated that tree selection was important in determining hive location, however, isolation from livestock and people was a more significant factor. There have been cases in which livestock and people have been stung to death, and in response, restrictions for hive locations exist in high-

density areas. Beekeepers had to walk anywhere from 5 to 90 minutes from their household to their hives because of these restrictions, with an average walk time of 50 minutes.

Beekeepers all reported having more success keeping bees since they began harvesting, with general belief that in recent years bee populations have been increasing. Concerns for bee populations in the future included the availability of nesting sites, the decline of floristic species and water scarcity. Suggestions to address these challenges included increasing water availability, restricting tree cutting, protecting hives from rodent roosting and constructing more hives for bees to inhabit. Beekeepers also generally felt restricted in their ability to sell honey and desired methods to draw more customers.

4. Discussion

Support for hypothesis (1) showed that interviewees recognized several types of bees, various other insects and sunbirds as local pollinators in Simanjiro. However, understanding of the pollination process was somewhat lacking and did not incorporate abiotic components. Interviewees also did not recognize the value of pollinators outside of beekeeping purposes. This suggests that there may be a disconnect between Maasai and the significance of pollinator services for their livelihoods and ecological processes. It is possible that this result is evidence of the negative impacts of a small sample size in combination with sampling bias and does not portray the viewpoints of the broader Maasai community.

This study focuses on honeybee populations due to their direct connection with Maasai of Simanjiro through beekeeping. Results show that three species of bees inhabit Simanjiro, with the size of the bee sharing a relationship with the level of aggression and productivity as perceived by interviewees. According to results, the smaller the bee, the more honey is produced by its hive and the more aggressive it is. A hypothesis of this relationship, put forth by an interviewee, is that the smaller bees generally have larger colonies and therefore produce more honey and can be more protective of their hives.

A total of 28 species of plants were listed as pollinator-dependent by interviewees in the drylands of Simanjiro. Of these, 13 plants were chosen to be especially important to bees. Evidence did not support hypothesis (2), as bee presence was fairly uniform throughout the five habitat types studied. Therefore, data collected suggests that there does not appear to be a clear relationship between bee presence and pollinated plant density. A more detailed scaling of commonality (rather than common vs. uncommon) and a larger sampling size would allow this finding to be more thoroughly investigated.

The 13 listed plants were most common in open pastures, woodlands and shambas. The three highest valued of these 13 plants are less distributed among habitats than the remaining 10 on average, but are found in open pastures, woodlands and shambas as well. Managers may seek to increase efforts in these three habitat types, but also acknowledge factors (such as seasonality and cultivation extremity) that fluctuate dominant pollinator foraging locations. Future studies may discern these factors, as well as determine other social-ecological roles of these plants. For example, oltelemet is the third highest valued bee-pollinator plant according to this study, but it also is considered a problematic plant in Simanjiro.

This research supports hypothesis (3) in that honey harvest provides income stability of beekeepers and is used as a dietary supplement within Maasai villages. However, honey also serves a role for medicinal, ceremonial and bartering purposes. Maasai beekeepers generally sought methods to improve their honey selling business. Practicing interviewees expressed lack of a sufficient customer base as one of their primary beekeeping concerns. In part, Maasai culture dictates honey demand. As discussed by interviewees, honey is not a traditional food source and was historically not harvested by Maasai to the extent that it is today. Additionally, some Masaai celebrations occur only on some specific years, causing fluctuations in honey sales. Having access to outside customers might help to mitigate this issue. Initiatives, such as Mama Asali's honey company, encourage beekeeping practices by permitting Maasai to sell honey at higher prices in addition to expanding their customer base. African People & Wildlife, the organization backing Mama Asali, also empowers female participation in economic endeavors[33]. Interviewees expressed interest in economic workshops, which could potentially decrease income disparities based on the gap between selling prices and market value. Access to other beekeeping gear such as protective clothes and modern beehives may also encourage Maasai involvement.

A notable commonality between interviewee responses were the harvesting methods used. Burning of the low-growing mushroom presents a possible concern as it may negatively impact beekeeper, bee and other wildlife's health through smoke inhalation. Another suggestion made by interviewees was to protect bee habitat from tree harvest and over-cultivation. Setting aside pieces of land for beekeeping in convenient locations (as interviewees walked an

average of 50 minutes to reach their household hives) would make the practice more accessible to Maasai without increasing the risk of livestock and other people being stung.

The observation that bee populations have increased in recent years may either be due to ideal climatic conditions or from the growth of beekeeper knowledge and experience, since this finding is not supported by previous population research. Despite beekeeper success in increased honey yields, interviewees were still concerned for the future of beekeeping. Irregularity in the cyclic pattern of wet and dry seasons is readily acknowledged by Maasai. As dry seasons lengthen in Simanjiro, both the environment and people's livelihoods must adapt. Interviewees believed water access to be the primary limiting factor for bee populations in Simanjiro (supporting hypothesis (3)), which is greatly influenced by rainy season duration, climate change and land use practices[9, 16]. Habitat loss plays an added stress on bee populations, as acknowledged by interviewees as well. Addressing issues of habitat fragmentation and water scarcity is important not only for pollinator populations but also for pastoral practices in dryland communities.

The purpose of this research is to bring awareness to the significance of pollinator and pastoralist interactions to both the environment and human livelihoods by addressing each of the stated hypotheses. Many of these findings will be shared with Maasai in Tanzania. By returning data from this study to interviewees and various stakeholders, comprehension of successful beekeeping strategies and pollinator ecosystem services may also increase productivity, participation and resilience. Managers of pollinator populations in Simanjiro should seek to understand Maasai relationships through beekeeping and continue to take into consideration the concerns of stakeholders. Ultimately, further understanding of this social-ecological system, beyond the scope of this pilot study, is required before management decisions are made.

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