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Income and Conservation Dynamics of the Biological Bee-Fence: A bio-Economic Simulation

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Abstract. Human-elephant conflicts in most African countries coincide in areas where poverty and natural resources are most profound. Although popularly believed to be an asset capable of generating consumptive and non-consumptive ecotourism revenue, African elephants are in some parts of Africa viewed as pests and predators worth eradicating as a result of high human-elephant conflicts (crop raiding, property damage, human and livestock predation). This has shifted the conservation debate to issues of how much biodiversity (elephants) can be saved in the face of suffering local communities. With that background, we tested the income and conservation premise of the biological bee-fence concept as a complementary problem animal control (PAC) measure from a rural setting where elephants interact with local poor communities using bio-economic simulations. We conclude that the biological bee-fence concept has a significant potential to deter elephants from invading surrounding communities` fields as well as generating the much needed household income. These findings reinforce the conservation and income premise of the biological bee-fence under a typical African rural setting worth up-scaling.

1. Introduction

Problem animal control (PAC) in rural areas remains a big challenge in Africa especially in areas where a significant population of Africa elephants interact directly with local communities [1], [2]. A study conducted in Zimbabwe by Jones [3] revealed that African elephants cause the following damages: (i) crop damage – 78%, (ii) threat to humans – 9%, (iii) property damage – 3%, and (iv) livestock predation – 10%. With respect to problem animal species, Jones [3] also noted that African elephants present the highest share with 87% followed by lions (8%) and, lastly, by other species with a 5% share. Elephants affect the following types of crops: maize – 30%, millet – 30%, cotton - 3%, vegetables – 7%, and sorghum – 30% [3]. Banes [4] based on a study in Okavango Delta area in Botswana estimated that small scale rain-fed crop production profits were reduced by 75% and in some incidences completely eliminated by elephants. Thus far, as African elephants are allowed to exist, they generate social costs as well as potential benefits in the form of ecotourism revenue [5]-[7]. With that background, the paper argues that rural households have a much greater potential to conserve African elephants [6] or assist in their extinction [8], depending on the perceived balance between social costs and potential benefits they derive from elephants. Thus far, available PAC measures normally characterised by “guards, guns and fences” have proved to be expensive and sometimes ineffective towards separating the two species (humans and elephants). Mixed reporting dominates the actual direct benefits to rural households, who share boundaries with elephants [9].

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With ineffective PAC measures and limited direct benefits from elephant, local communities find it difficult to support elephant conservation in most rural African countries. This creates a 'negative specie preservation value' for elephants in the eyes of local communities, a scenario that may negatively affect elephant conservation. To complement the existing PAC measures new deterrent cost effective and user friendly methods have been suggested [10]. The *Apis mellifera adansoni* may be a solution worth exploring, based on results from experimental pilot trials conducted in Zimbabwe [11], Kenya [12], [13] and South Africa [2]. The paper therefore appraised the potential of using honey bees to deter elephants and generate household income using bio-economic simulations.

2. Problem statement

High human – elephant conflicts are reported in most rural African communities [6], [9], [14]. This is largely true in cases where elephants cause property damage, invade crop lands, and cause human and livestock predation while offering minimum direct benefits to local communities. Given the sizes of most game parks, physical effective boundaries (game fences and guards) have always been a challenge. Elephants have always managed to take advantage of ineffective boundaries invading crop lands of local communities. This has created a long standing friction between rural households and elephants, the former viewing the latter as pests and life threatening predators [9], [14], [15]. We therefore ask the following question: Can honeybees be trusted by rural households to deter elephants and possibly generate their much needed household income through sale of honey?

2.1. Objectives

- To upraise the potential of honey bees to deter African elephants.
- To estimate the income potential of honey production under the biological bee-fence concept.

3. Related literature

This section presents background literature on the interaction between bees and elephants and the potential of honey bees to deter elephants.

3.1. The interaction between bees and elephants

In Africa, folk tales relating to conflicts (fights) between elephants and bees have been shared from generations to generations [12]. The scientific logic behind these folk tales lies on the fact that although elephants are thick-skinned, Vollrath and Douglas-Hamilton [16] noted that they also have their weak points that can be targeted by bees. Earlier on Sikes [17] reported that ecto-parasites like ticks easily penetrated the thin skinned belly of elephants. Also, behind ears and under the trunk of elephants blood vessels flow close to the surface [18], a crucial weakness factor that is targeted by predators like elephant-lice [19]. Jacobson *et al.,* [20] also noted that the inner trunk membranes and eyes are extremely sensitive capable of causing serious effects from a few bee stings. Since elephants have co-existed with forest honey bees it's logical to assume that some conflicts (fights) occasionally erupts in the wilderness as the two species cross each other`s line of boundary.

The ability of bees to fly and availability of weak points on elephants as revealed above logically makes the African honey bees winners of this possible fight. McComb *et al.,* [21] acknowledges that smell is a crucial sense in the social and foraging decisions for elephants. Building on this idea, Vollrath and Douglas-Hamilton [16] assumed that the bee wax smell may deter elephants from harming a hive and from feeding in its immediate surroundings, otherwise this would start a fight to which an elephant would be the looser. Payne [22] also noted that elephants have a strong sense of hearing, a crucial factor Vollrath and Douglas-Hamilton [16] also assumed to be useful towards explaining why elephants could avoid colonised hives that emit a hissing sound. Since elephants are known to be intelligent with a very good memory, it's logical to assume and believe that elephants will avoid areas with bees, a conclusion that makes the commonly shared African folk tale of bees stinging elephants a true anecdote. This has triggered research towards testing the effectiveness of the concept using practical and scientific approaches.

3.2. Potential of honeybees to deter elephants

Vollrath and Douglas-Hamilton [16] tested this concept in Kenya and discovered that African bees deter elephants from damaging vegetation and trees mounted with hives. Vollrath and Douglas-Hamilton [16] further argued that bees could be employed profitably to protect not only selected trees, but also selected areas, from elephant damage. Contrary to these findings, Karidozo and Osborn [11] tested the same concept by mounting bee hives strategically around crop fields in the Zambezi Valley of Zimbabwe. Their findings revealed that the deterrent effect was not statistically significant. With that background, Karidozo and Osborn [11] argued that bees alone may not stop elephants from crop raiding. Similar conclusions were also forwarded by Ndlovu *et al*., [2], arguing that most elephant crop raids occur at night and prominently in winter when temperatures are low. The authors therefore conclude that during these times African honey bees will be dormant and unlikely to deter elephants unless there are some trigger mechanisms.

Still pursuing the same idea, King *et al.,* [12] conducted a pilot study to evaluate the concept of using bees to mitigate elephant crop depredation in Laikipia, Kenya. The authors noted that the experimental farm protected by bee hives had fewer raids and consequently had higher productivity. King *et al.,* [12] further noted that socio-economic indicators suggested that not only was the concept popular and desired by the community but also that it could pay for its construction costs through the sale of honey and bee products. Based on their conclusion, King *et al.,* [12] called for a wider experimental test of the concept across different agricultural systems to jointly evaluate its effectiveness.

With such a conflicting background society may therefore query the practical relevance of the concept. In this section the paper looks at the earlier loopholes in the design of the concept against improvement suggested in recent studies. Karidozo and Osborn [11] used three test plots as follows; (a) an artificially planted field strategically located in the bush, (b) paths along elephant refuge areas, and (c) paths around natural water points regularly visited and used by elephants. In their first test plot we applaud their brevity in strategically creating artificial fields in the bush where we expect elephants to be attracted by the green plants. Their hives were also mounted on poles 3m long at a height of 2m and 20m equidistant from each other [11]. Using this design paired with control plots for 2 seasons (2004 & 2005) the study concluded that the claimed deterrent effect was not statistically significant [11]. In test plots two and three, elephants retreated and opened new entrance route a clear indication that they avoided live hives [11]. Similar observations were also noted by Ndlovu *et al*., [2] for their level 4 responses where 15 out of 21 elephants exposed to the bee noise with honey scent treatment ran away from the source of treatment.

For the success of this concept several factors are crucial to include; (a) bee stinging, (b) bee hissing sound, (c) a triggering mechanism to agitate bees and (d) the bee wax smell. For purposes of introducing the bees to elephants, some repeated stinging should happen to send a threat cue. Once the threat cue has been internalised, then the bee hissing sound and wax smell factors would give a realistic threat cue as elephants approach beehive mounted areas. Comparable conclusions were also noted by Ndlovu *et al*., [4: pg. 1] highlighting that, "buzzing bees or honey scent as isolated treatments (as may be the case with dormant beehives) were not effective elephant deterrents, but rather an active beehive emitting a combination of auditory and olfactory cues was a viable deterrent".

Recent designs have tried to reduce the space between hives and also to link the hives with a connecting taut wire [12], [13]. Large spacing without a connecting wire may promote free passage of elephants without agitating bees. Also mounting beehives under a bee-hut as suggested in Figure 1, may force approaching elephants to target the space between hives [12], [13]. Once this route is selected, the taut wire will swing attached hives and agitate bees from several nearby hives [12], [13]. In the process bees are most likely to attack the elephants thereby sending a warning threat message.

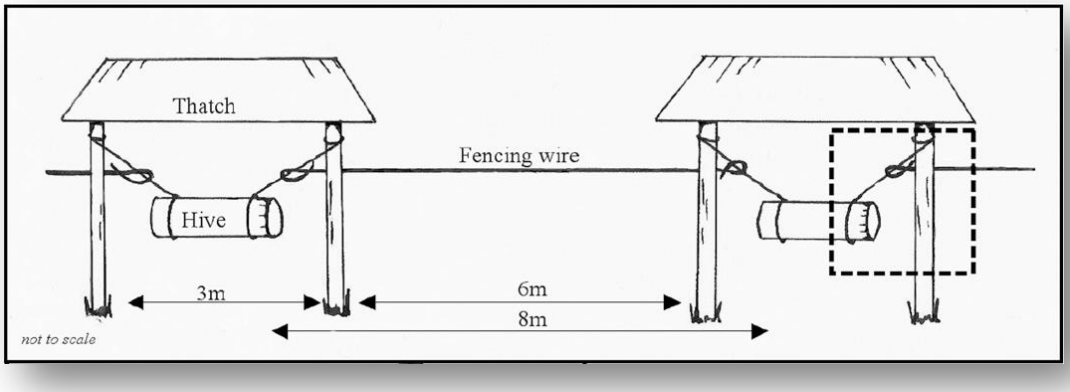


Figure 1. Biological bee fence design [13]

We therefore argue that the biological bee fence may have a positive deterrent impact under the following conditions:

- Colonized (active) bee hives emitting bee hissing sounds and wax smell. This is more critical for elephants that may have previously been exposed to bees since they are better equipped with realistic threat cues [2].
- A bee fence designed with reduced spacing between hives and a connecting taut wire [12], [13] which was largely missing in earlier designs by Karidozo and Osborn, [11].

Literature further questioned the practicality of the above conditions, given that elephants' crop raids are more pronounced during the night and winter seasons when bees are inactive [2]. Future research should therefore focus on understanding the concept's long-term effect, given the possibility that elephants may get habituated to the threat [2]. Also critical to understand across different agro-systems is the potential of the connecting taut wire to trigger bee agitation during the night and winter periods when temperatures are very low. The cost benefit analysis of using night "bee-hissing" drones with sharp spikes needs to be explored to complement natural bees during the night, winter and rain periods when they are inactive. To enhance uptake by potential users (rural households sharing boundaries with game parks) several studies suggest linking the system with direct economic benefits of honey and wax as well as other indirect biodiversity benefits. In the next section the paper upraises the economic potential of the system using bio-economic simulations.

4. Income potential of honey production under the biological bee-fence concept

Several studies point to the merit of linking honey production with the biological bee-fence [11], [12], [13]. Suggested reasons range from; income generation, employment creation, financing the construction of the biological bee fence and strategic livelihoods for rural households [11], [12], [13]. In this section we provide a bio-economic simulation of honey production under the biological bee fence concept. Using standard average yields, running costs and selling prices the paper generated two gross margin budgets (Table 1 & Table 2) for purposes of estimating the economic premise behind honey production under a biological bee fence (1ha). Average yield from a standard Kenyan Top Bar (KTB) hive range between 10kg and 15kg with 2 clearly defined production cycles per year [13]. To fully protect 1ha using a biological bee fence 40 beehives are necessary [13]. Lastly raw honey can be sold at an average price of US$1.5/kg in most rural African countries. Using the above operational assumptions two gross margin budgets were used to estimate the income potential of hectare piece of land protected by a biological bee fence with 40 KTB hives as detailed in Table 1 and Table 2.

The gross margin analysis in Table 1 reveals a gross income value of US$600.00 during year one 1st cycle against an operational cost of US$1,715.00. In Table 2 we generated year one 2nd cycle gross margin estimates for purposes of getting a true picture after removing inputs that can be reused in

subsequent years (hives, harvesting kit and protective clothing). Results reveal that operational costs are likely to be reduced from US$1,715.00 to a mere US$50.00 per cycle against a gross income value of US$600.00.

Table 1. Gross margin budget 1st cycle year 1

Item	**Production Period (Months)**	**Price (US$) Yield (kg)**	**Gross Income (US$)**
Selling price		US$1.5/kg	
Production cycles/year (pc)[a]	2		
80% colonization = 32 hives (c)[b]			
Average yield per hive		12.5kg	
Total yield in 6 months	32 x 12.5	400kg	
Total yield per year	32 x 12.5 x 2	800kg	
Gross Income / hive in 6 months	(12.5kg x $1.5 x 1hive)		18.75
Gross Income / 32 hives in 6 months	(12.5kg x $1.5 x 32hives)		600
Operational Costs	Quantity	/40 hives (US$)	/40 hives (US$)
Hives *	40	1600	
Protective clothing *	1	35	
Harvesting kit (Smoker) *	1	20	
Labour		20	
Transport (to collection point)		30	
Containers (200l) *		10	
Total Variable Costs (Year 1, 1st circle)		1715	**1715**

*: - these costs are incurred once and the equipment can be used for the next 5 years before replacement
(pc)[a] : - harvesting is done 3 times a year during good years and sometimes twice a year during bad years (drought)
(c)[b]:- on average per production cycle only 80% of the hives will be colonized while 20% is normally empty

Table 2. Gross margin budget 2nd cycle year1

Item	**Production Period (Months)**	**Price (US$) Yield (kg)**	**Gross Income (US$)**
Selling price		US$1.5/kg	
Production cycles/year (pc)[a]	2		
80% colonization = 32 hives (c)[b]			
Average yield per hive		12.5kg	
Total yield in 6 months	32 x 12.5	400kg	
Total yield per year	32 x 12.5 x 2	800kg	
Gross Income / hive in 6 months	(12.5kg x $1.5 x 1hive)		18,75
Gross Income / 32 hives in 6 months	(12.5kg x $1.5 x 32hives)		600
Operational Costs	**/ hive (US$)**	**/40 hives (US$)**	**/40 hives (US$)**
Hives *	-	-	
Protective clothing *		-	
Harvesting kit (Smoker) *		-	
Labour		20	

Transport (to collection point)		30	
Containers (200l) *		-	
Total Variable Costs (Year 1, 2nd circle)		50	50

*: - these costs are incurred once and the items can be used for the next 5 years before replacement
(pc)[a] : - harvesting is done 3 times a year during good years and sometimes twice a year during bad years (drought)
(c)[b]:- on average per production cycle only 80% of the hives will be colonized while 20% is normally empty

Table 3 presents the projected linear gross margins from year 1 to year 5. Simulation results reveal an estimate average annual gross margin of US$1,200 against an operational cost of US$433. This translates to an annual average gross margin of US$767, monthly average gross margin of US$64 and a daily average gross margin of US$2. Thus far, per every $ invested towards the biological bee-fence a return (GM/$TVC) of 1.8 is expected as summarised in Table 3.

Table 3. Projected gross margins

Period (Years)	GI / CYCLE (US$)	Total VC / CYCLE (US$)
Year 1	Cycle 1: 600	Cycle 1: 1715
	Cycle 2: 600	Cycle 2: 50
Year 2	Cycle 1: 600	Cycle 1: 50
	Cycle 2: 600	Cycle 2: 50
Year 3	Cycle 1: 600	Cycle 1: 50
	Cycle 2: 600	Cycle 2: 50
Year 4	Cycle 1: 600	Cycle 1: 50
	Cycle 2: 600	Cycle 2: 50
Year 5	Cycle 1: 600	Cycle 1: 50
	Cycle 2: 600	Cycle 2: 50
Average annual Gross Income / Total VC	1200	433
Average annual Gross Margin	US$767	
Average monthly Gross Margin	US$63.92	
Average daily Gross Margin	US$2.13	
GM/$VC	1.8	

Using simple linear gross margin analysis, bio-economic simulations results suggest that on average a biological bee fence for one household surrounding a field of 1ha, has an income generating potential of US$2 per day per household and a return on investment of 1.8. The analysis excludes other high value honey by-products like bee wax and processed liquid honey that require formal markets. Thus far the suggested returns are only based on raw honey easily marketable in most rural areas of Africa.

5. Conclusions

The paper concludes that the biological bee fence (with colonised hives) has a significant potential to deter elephants from invading local communities' crop lands. To trigger agitation of bees more importantly during the night and winter periods when temperatures are low a connecting taut wire is necessary. The paper further concludes that 40 Kenyan Top Bar beehives normally ideal for 1ha (2 production cycles per year) can generate a non-farm household income of US$2 per day per household

with a return on investment of 1.8. These findings reinforce the income and conservation premise of the biological bee-fence under a typical African rural setting worth up-scaling.

6. Recommendations

The paper makes the following recommendations: The biological bee fence has a potential to complement available problem animal control measures in areas where human-elephant conflicts exists with economic and conservation benefits. Rural development agencies (NGOs, government and private sector) may target beekeeping promotion to enhance household income and deter elephants from invading crop lands.

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