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Comparative analysis of time and monetary opportunity costs of human-wildlife conflict in Amboseli and Mt. Kenya Ecosystems, Kenya

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ABSTRACT

Traditionally, the cost of Human-wildlife conflict (HWC) has largely focused on visible costs, ignoring the hidden costs (HC). The HC of HWC are losses that are uncompensated, temporarily delayed, or psychosocial in nature. HC, such as opportunity costs (OC) are scantly documented to inform policy changes for addressing HWC. This study demonstrates the importance of considering HC using Amboseli Ecosystem (AE) and Mt. Kenya Ecosystem (MKE) in Kenya. The objectives of this study were to: a). quantify the economic magnitude of the OC of HWC and its impacts on human wellbeing; b) compare the time and monetary OC; c) make recommendations for HWC related policy reform. Data was collected from 408 households using a multi-stage sampling technique. Opportunity costs were conceptualised as the mean time and money lost due to wildlife presence and attacks. Analysis indicates that the hours spent guarding livestock ($t = 3.820$, d.f $= 110$, $p = 0.000$) and crops ($t = 3.571$, d.f $= 130$, p $= 0.00$) in AE and MKE at night were significantly different. Conversely, daytime hours spent guarding livestock and crops in AE and MKE were similar ($P > 0.05$). On average, AE households spent KES 208, 540 (US$ 1913) compared to MKE who incurred KES 131,309.75 (US$1205) guarding livestock and crops. School children in AE lost more time in the morning (1.28 ± 0.053 h; $n = 98$) and in the evening (1.22 ± 0.044 h; $n = 93$) than in MKE. Overall, OC were more in AE than MKE, suggesting that HC varies with ecosystems. A review of the wildlife compensation policy and law to include HC can help deter resentments resulting from uncompensated HWC costs.

1. Introduction

Human-wildlife conflict (HWC) is a historical problem that begun when human beings started sharing space with wildlife as well as domesticating plants and animals for livelihood support. This dates back to the last Pleistocene era (about 15,000 years ago) and Neolithic period (Squires, 2011). The International Union for Conservation of Nature-World Conservation Congress (IUCN-WCC) resolution 101 of 2020 recognises that HWC has an impact on crop and livestock yields, profits and human safety (IUCN-WCC, 2020). IUCN-WCC further acknowledges that HWC compromises food security, economic growth and possibilities of attaining sustainable development goals (IUCN-WCC, 2020). As such, HWC remains a global challenge to both society and their means of livelihood. Traditionally, the cost of HWC has been documented in terms of direct costs, such as crop raiding, livestock loss and human death and injuries (see for example Madhusudan, 2003; Zakayo, 2014; Mashalla and Ringo, 2015 & Dai et al., 2019) while ignoring the hidden costs. Yet, Hoare (2001) asserts that HWC has a wide range of intangible negative social and psychological impacts including fear, loss of sleep and deviated focus.

1.1. Direct costs of HWC

The direct impacts of HWC includes crop damage, livestock predation, human deaths and injuries, property damage and diseases transmission. Crop raiding is a common problem to many farmers across the globe. For example, an estimate of crop loss to various wildlife species (e.g., white-tailed deer, wild pigs, bears and sandhill cranes) between 2015 and 2019 in the eastern and southern parts of the USA, revealed a soybeans loss worthy US$323.9 million and corn valued at US$194.0 million (McKee et al., 2021). In Brazil, the Military Highway Police of São Paulo documents an average of 2611 animal-vehicle crashes per year, with 8.5% of cases resulting to human injuries or fatalities (Abra et al., 2019). In addition, Abra et al., 2019 estimated the annual loss of

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US$ 25,144,794 to the society due to vehicle collision with wildlife species such as lowland tapir (*Tapirus terrestris*), and capybara (*Hydrochoerus hydrochoeris*). Similarly, in China, nine people were killed and five injured by brown bear in Qinghai Province between 2014 and 2017. In the same period, bear house break in losses in China were estimated to be U$ 4.03 million (Dai et al., 2019). Wildlife species can also transmit diseases to livestock. For example, it is estimated that badger-to-cattle transmission causes between 1% and 25% of new outbreaks of Tuberculosis (TB) in cattle in the United Kingdom (Donnelly and Nouvellet, 2013).

In Africa, where people and wildlife still share space, direct impacts of HWC are diverse. For instance, in the six coastal districts of Tanzania, spotted hyena killed 14 people and injured 24 others between 2016 and 2018 (Tanzania Wildlife Management Authority, 2019). Similarly, an analysis of HWC statistics for Laikipia and Kajiado Counties, showed that a total of 64.09 ha of crops were damaged by diverse wildlife between 2010 and 2018 (Manoa et al., 2020b). In the same period, Manoa et al. . (2020b) reported that Kajiado County lost livestock worth KES 1,785,000 (US$ 16,780.53) while Laikipia County lost KES 407,000 (US $ 3826.15).

1.2. Hidden costs of HWC

The hidden costs of HWC are losses that are uncompensated, temporarily delayed, or psychosocial in nature (Ogra, 2008; Barua et al., 2013). They include transaction costs, health costs and opportunity costs.

1.2.1. Transaction costs

Transaction costs are incurred due to bureaucratic inadequacies and delays associated with compensation of victims of HWC (Barua et al., 2013). The essence of the compensation schemes is to refund people the financial losses incurred through human injuries, death, crop and livestock loss, damage to property and so on. This is necessary in order to enhance the coexistence between people and wildlife (Treves et al., 2009). Yet, in reality those affected by HWC, particularly in developing regions experience difficult in accessing compensation as expected. Consequently, scholars such as Ogra and Badola (2008), DeMotts and Hoon (2012), and Barua et al. (2013), have pointed out corruption, lack of education and awareness, and inability of wildlife authorities to attend to claims in a timely way are hindrances to compensation schemes. The processing of compensation claims usually requires victims to provide a wide range of supporting documents such as death certificates and title deeds, proof of compensation claim travel related expenses, all which greatly magnify the time and money transaction costs (Madhusudan, 2003). Jadhav and Barua (2012), therefore claims that pursuing compensation can expose people to new spaces of institutional inequality.

Delays in the payment of HWC compensation claims by governments is not a new phenomenon in the world. Madhusudan (2003), for example, reported that villagers around the Bandra Tiger Reserve in India received only 14% and 5% of crop and livestock related compensation, respectively after extended delays. Another study conducted in the Boromo region in Burkina Faso, established that 98% of the people who incurred losses due to human-elephant conflicts opted not to report such incidents because the government had not paid the previous damages (Marchand, 2002). In Kenya, a performance audit for the Kenya Wildlife Service (KWS) revealed that HWC cases worthy KES 2,235,388,000 (US$ 21,029,049) had not been paid between 2013 and 2018 (GoK, 2018). From the economic perspective, the delayed payment of HWC compensation claims results to transaction costs over time.

1.2.2. Health costs

Human health can greatly be shaped by the stress and anxiety of living within wildlife ranges. People have been found to be sensitive to financial costs and impaired freedom of movement, which can be compromised by wildlife (Bowie, 2009). FAO (2009) argues that crop damage results to reduced cash income and has indirect repercussions on human health, nutrition, education and eventually on development. When crop damage occurs, people divert the finances reserved for healthcare towards the purchase of food items. In Indian Sundarban, for example, Chowdhury et al. (2008) observed that about half of the women who lost their husbands to tiger and crocodile attacks had psychological problems due to the inability of recovering the bodies of their loved ones for decent burials. Many had high rates of suicidal tendencies and depression. Another study by Jadhav and Barua (2012) established that injuries, fatality or physical threats from elephants worsened pre-existing medical conditions such as alcoholism and contributed to new ones such as post-traumatic stress disorder.

Similarly, a study conducted in Sagalla area of Taita-Taveta County (southern Kenya), 92% participants ($n = 26$) affirmed that elephant crop raiding caused them emotional and mental distress (Weinmann, 2018). This has been reported in other studies in Kenya. Farmers in Mirera area in Naivasha (Kenya), for example, were reported to have spent sleepless nights while trying to secure their farms aganist wildlife from the Longonot National Park which destroyed their crops. The farmers opted to guard their farms at night in fear of wildlife invasion (Kimani, 2016). And in Mwingi West (Kitui County), residents were reported to live in fear after a stray lion from Kora National Park killed two cows in their village, and efforts by KWS to capture and restrain the lion was taking long. The resident feared that school-going children could be attacked by the lion (Musangi, 2020). In another incident in Kajiado County, a group of 30 primary school children from Lenkisem village, were attacked by an elephant leading to the death of one child (Koech, 2021) while the rest were living in fear of attending school.

1.2.3. Opportunity costs

Opportunity cost is defined as the loss or sacrifice incurred by taking a particular action against HWC instead of other more preferred and beneficial alternatives (Fauna & Flora International (FFI, 2014). Opportunity costs are part of the social challenges experienced by communities living close to wildlife conservation areas (Manoa et al., 2020a). For example, Mariki (2016) observed that destruction of water pipes by elephants in West Kilimanjaro (Tanzania) resulted to people walking longer distances to fetch water at the expense of other social and economic chores. Elsewhere, Manoa and Mwaura (2016) documented that pastoralists in the Amboseli region of Kenya who had not adopted predator-proof kraals spent most nights in the wet season guarding their livestock against predators.

A review of the hidden costs of HWC in Kenya by Manoa et al. (2020a) revealed gaps in the characterisation, quantification and comparision of opportunity and other hidden costs in Kenyan rangelands (e.g. Kajiado) and forest ecosystems (e.g. Mt. Kenya), which are associated with high wildife densities. As such, it has for a long time been difficult to acertain the effect of hidden costs on people's livelihoods for wildlife policy reform. This study fills up the gap by comparing time and monetary opportunity cost of HWC for Amboseli Ecosystem (AE) and Mt. Kenya Ecosystem (MKE). The two study ecosystems are important wildlife conservation areas, which host several state, community and private wildlife areas which include national parks, wildlife conservancies, biosphere reserves and world heritage sites (Manoa et al., 2020a). The specific objectives of this study were to: a). quantify the economic magnitude of the opportunity costs of HWC and its impacts on human wellbeing; b) compare the time and monetary opportunity costs, and c) make recommendations for HWC related policy reform.

2. Materials and methods

2.1. Study areas

Amboseli Ecosystem (AE) is located in Southern part of Kajiado County and lies along the boundary of Kenya and Tanzania boarder

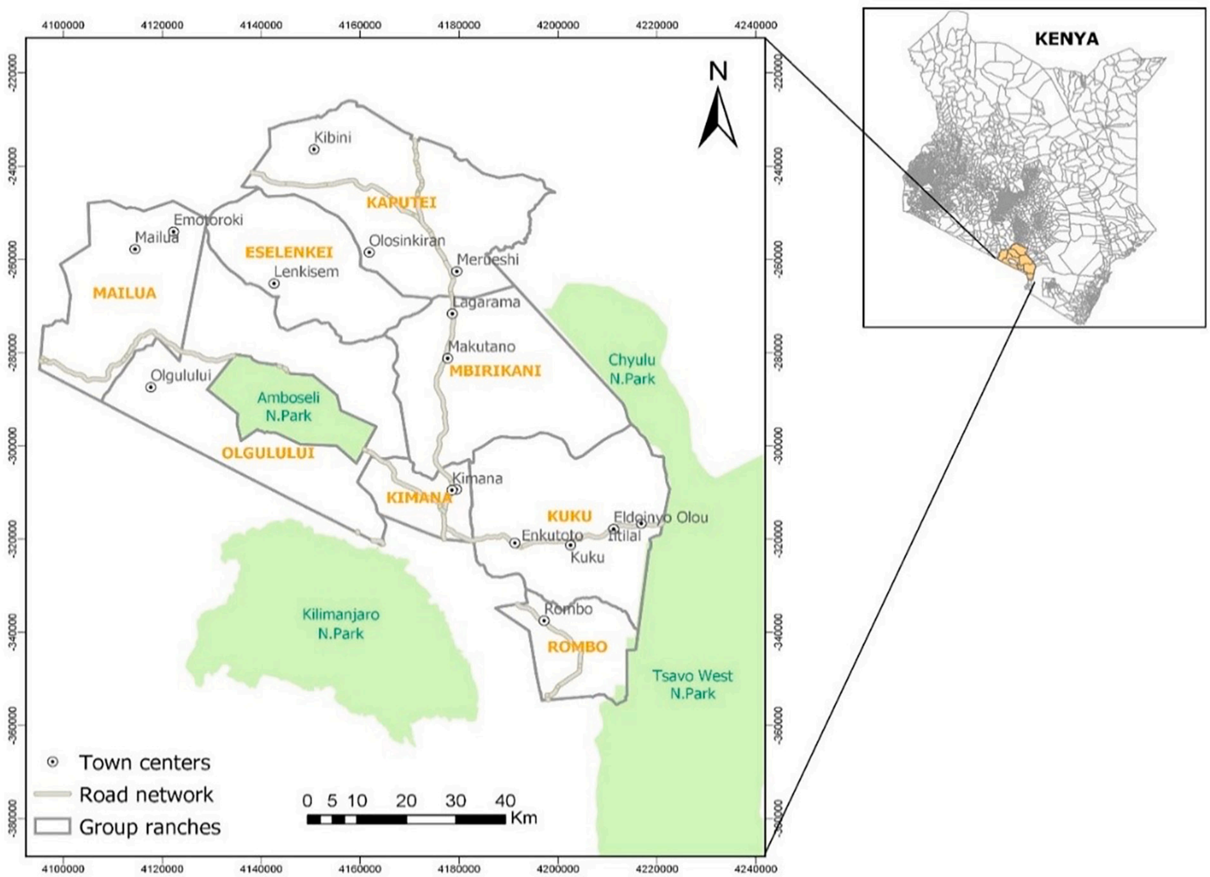

Fig. 1. Amboseli ecosystem (Manoa, 2021).

(Fig. 1). Kajiado County (36°5′, 37°55′ E; 1° 10′, 3°10′ S) (County Government of Kajiado, 2018). The ecosystem is hosting the world renowned Amboseli National Park and UNESCO Man and Biosphere (MAB) World Biosphere Reserve, which is linked to six community group ranches: Ol gulului/Olorashi, Imbirikani, Kuku, Rombo, Eselenkei, Kimana/Tikondo and a number of wildlife conservancies that form a buffer zone, totalling to 5700 km^2 (KWS, 2020). It is bordered to the south by the Mount Kilimanjaro National Park, which is a World Heritage Site. On the other hand, the MKE (0°25′ S, 0°10′ N; 37°00′ E, 37°45′ E0 as shown in Fig. 2 (County Government of Meru, 2018), is located in Meru County and Laikipia County within the Central part of Kenya and consists of the Mt. Kenya National Park, Mt. Kenya National Forest Reserve both of which have also been designated as a World Biosphere Reserve and World Heritage Site. The ecosystem is linked to the north by Ngare Ndare Forest and the Lewa Wildlife Conservancy, all estimated to be 958 km^2. This part of the ecosystem was the focus of the study.

The two ecosystems have diverse wildlife species ranging from large herbivores such as elephants, rhinos, buffaloes, giraffes, wildebeest, hippos, zebras, impalas and Thompson gazelles to carnivores such as lions, leopards, cheetahs and hyenas. AE has about 1800 elephants (KWS, 2020), while MKE is estimated to have 2000–3000 elephants (KWS, 2010). The elephants, hyenas and lion migrate widely within and outside the ecosystems, and are known to destroy crops, attack livestock and people (KWS, 2010; KWS, 2020; Manoa and Mwaura, 2016).

The two ecosystems experiences two-rain seasons in March-May (long rains) and October–December (short rains), Rainfall in AE ranges from 500 mm to 600 mm, whereas MKE receives between 300 mm (on Laikipia side) and 2500 mm (on Meru side). While AE has a temperature range of 10^0C to 34^o C, MKE registers slightly lower temperatures of as low as 8^0C and as high as 32^o C ((County Government of Kajiado, 2018, County Government of Meru, 2018).

Most parts of the AE are sparsely populated, with population densities of 51 person per km^2 with about 75% of the residents depending on pastoralism for their income ((Table 1, KNBS, 2019a). However, there is growing influx of agrarian communities into the ecosystem from the more humid high population density areas. On the other hand, MKE population varies, with Meru County having population density of 318 people per km^2, while Laikipia County, which is a semi-arid area has 52 people per km^2 (County Government of Meru, 2018; KNBS, 2019b). The main economic activity in MKE is crop faming in Meru County, while many parts of Laikipia County are associated with pastoralism, large-scale ranches and small-scale agriculture.

2.2. Data collection and analysis

Data collection took place between March and October 2019. Extensive literature review and key informant consultations with 20 key informants from conservation organizations and local administration was conducted to help locate the sites with the highest incidences of HWC in the two ecosystems. A multi-stage sampling was used to cluster the population in each ecosystem according to the existing administrative units (sub-locations) from which samples was drawn. Within the sub-location, sample sizes corresponded to the population sizes of the local villages. The researchers adopted the simplified Yamane (1967) formula to calculate the sample size as follows:

$$n = \frac{N}{1 + \mathrm{N(e)2}}$$

Where n = Sample size; N=Population size; e = Margin of error.

Based on the 2017 population census data of households in Meru County (400,407), Laikipia County (119,768) and Kajiado County

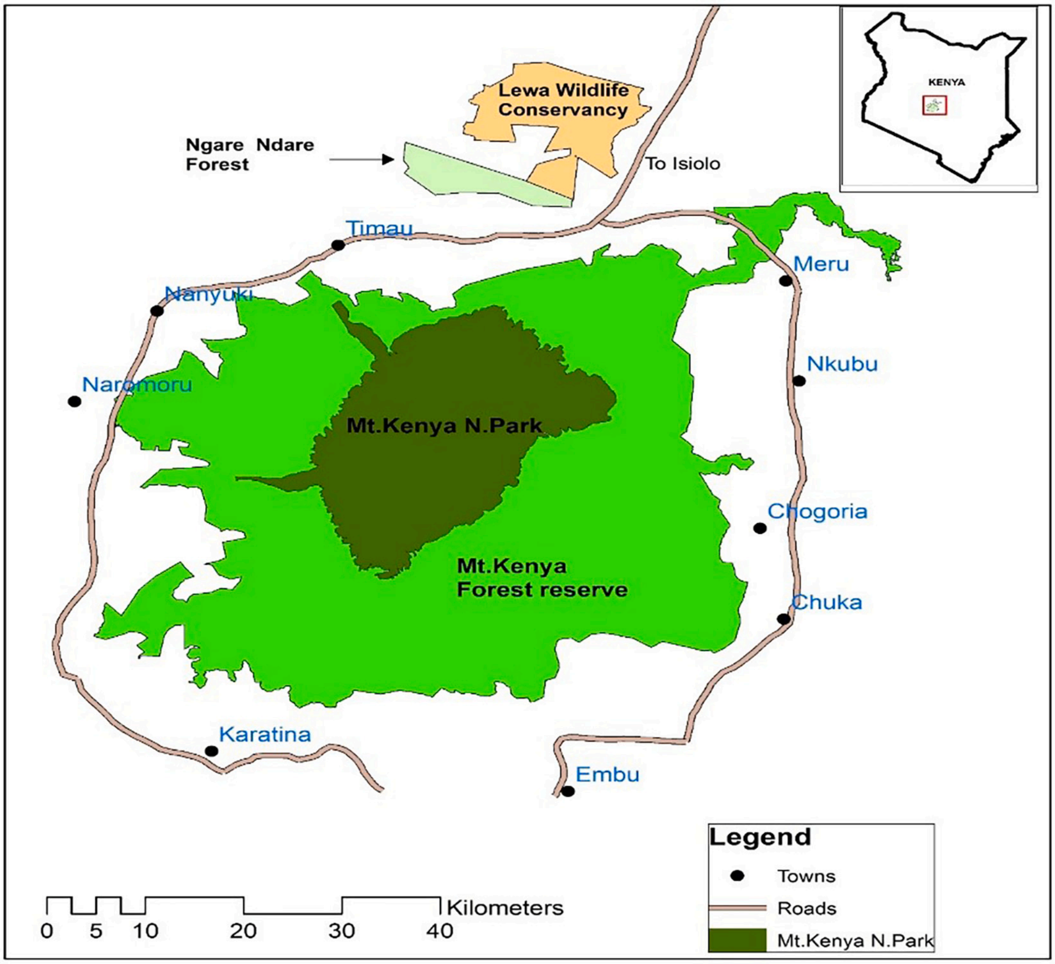

Fig. 2. Mt. Kenya ecosystem (Manoa, 2021).

(199,964), the sample size of 204 households per ecosystem was derived.

MKE sample size $= \frac{520{,}175}{1+520{,}175(0.07)2} = 204$

AE sample size $= \frac{199{,}964}{1+199{,}964(0.07)2} = 204$

To determine the sampling interval per village, the researchers divided the estimated number of households per village with the 2017 population projection of 4 persons per household in MKE and 5 persons in AE. Target households were identified using the systematic sampling technique based on the common landmarks at sub-location level, such as schools, health centres, churches, local markets, water points, dips. In each household, the researcher sought permission to interview an adult with a focus mostly on the household heads (males). Where these were absent, their spouses or any other adult (above 18 years) who had lived in the household for at least one year was interviewed. For participants to qualify as respondents in the research, they had to have resided within the study area and had recently (no more than 12 months ago) experienced one kind of HWC or another. To elicit the opportunity costs, household respondents were asked to state the time and money spent on guarding livestock and crops against wildlife attacks.

Opportunity costs was calculated as the mean time and money spent on guarding livestock and crops in order to prevent livestock predation and crop raids. In addition, school time lost and delayed reporting to livelihood activities by adults as well as repair of damaged properties were considered as opportunity cost. Where households employed people to guard their property against wildlife, the wages paid per day or month was considered as opportunity cost. However, where individual household members were engaged in guarding, the number of hours expended was used to calculate the monetary loss. This was done based on average daily wages of KES 400 (US$ 3.71)[1] in AE and KES 600 (US$ 5.57) in MKE. It was based on the assumption that people worked for an average 8 h daily, translating to KES 50 (US$ 0.46) and KES 75 (US$ 0.70) per hour, respectively. An independent student-test statistical analysis was used to test significant differences between opportunity cost in AE and MKE.

2.3. Willingness to pay (WTP) and willingness to accept (WTA) compensation

Contingent valuation method (CVM) and Time Value for Money (TVM) concept was used in the estimation of opportunity costs by determining the and Willingness to Pay (WTP) in order to prevent loss and the Willingness to Accept (WTA) compensation for inevitable losses by the respondents. Where respondents gave their WTP in terms of crops and livestock, the quantities were converted to money using the market price obtained from Kajiado, Meru and Laikipia Counties. The mean WTP/WTA figures were obtained from the open-ended questions.

[1] 1US$ = KES 107.72

Table 1
Summary statistics of the study areas.

Variables	AE	MKE	Sources
Average human population density/ Km^2	52	170	CGK (2018); CGM (2018)
Population growth rate/annum	5.5%	2.1%	KNBS (2019b)
Sex ratio (Male: Famale)	50.2%	49.8%	KNBS (2019b)
Road network	2419.2 Km	5968 km	CGK (2018); CGM (2018)
Education			CGK (2018); CGM (2018)
a) Retention rate	67%	90%	
b) Completion rate	83%	78%	
c) Transition rate	89%	80%	
Main occupation (%)	75% pastoralism	Crop farming	KNBS (2019b)
Monthly income less than KES 10,000 (US $ 92.83)	64.2%	66.7%	Manoa (2021)
Types of houses	67.1% corrugated iron sheet roofs	97.5% corrugated iron sheet roofs.	CGK (2018); CGM (2018)
Main crops	Maize & beans	Maize, beans, wheat & potatoes	Manoa (2021)
No. of health facilities	253	498	CGK (2018);
Poverty rate (%)	36.9	15.5%	CGM (2018)
Common problematic species population:			KWS (2020); KWS (2010); Kimiti et al. (2019)
a) African elephants	1800–2000	2000–3000	
b) African lion	141	55	
c) Spotted hyena	346	138	

3. Results

3.1. Time opportunity costs

3.1.1. Time spent guarding against wildlife

Guarding livestock and crops was a common practice in both AE and MKE. Households in AE spent more time guarding livestock during the day (4.16 ± 0.185 h) and during the night (3.63 ± 0.126 h) compared to their counterparts in MKE who spent 3.46 ± 0.466 h in the daytime and 2.48 ± 0.338 h during the night. In addition, individuals in AE guarded their crops more during the day (4.57 ± 0.249 h) and night (3.88 ± 0.180 h) than those in MKE who used 4.39 ± 0.178 h e daytime and 2.86 ± 0.1957 h during the night (Table 2). The combined household time spent on both livestock and crops in AE and MKE during the day (16.58 h) was more than the total time spent during the night (12.85 h).

An independent student t-test indicated that night-time hours spent guarding livestock ($t = 3.820$, d.f = 110, $p = 0.000$) and crops ($t = 3.571$, d.f = 130, $p = 0.00$) were significantly different in the AE and MKE. The AE respondents spent 1.151 h more for night livestock guarding with 1.026 additional hours for crop guarding than the MKE respondents. However, the daytime hours spent guarding livestock and crops in AE and MKE were similar ($P > 0.05$).

Table 2
Time lost during guarding.

	Ecosystem	N	Mean-hrs	S.E
Livestock day guarding hours	AE	88	4.16	0.185
	MKE	24	3.46	0.466
Livestock night guarding hours	AE	89	3.63	0.126
	MKE	23	2.48	0.338
Crop day guarding hours	AE	51	4.57	0.249
	MKE	98	4.39	0.178
Crop night guarding hours	AE	50	3.88	0.180
	MKE	82	2.86	0.1957

3.1.2. School time lost and delay in income generating activities

The presence of wildlife in village areas resulted to late reporting to school in the morning and leaving school earlier in the evening, which led to loss of school time for the affected students. The mean school time lost in the morning (1.28 ± 0.053 h; $n = 98$) and in the evening (1.22 ± 0.044 h; $n = 93$) in AE was more than the time lost in MKE in the morning (0.79 ± 0.026 h, $n = 115$) and evening (0.93 ± 0.037 h, $n = 125$) as shown in Table 3. Majority of respondents in AE (51.5%, $n = 105$) and MKE (43.6%, $n = 89$) had their children reporting to school at 10:00 am instead of the scheduled reporting time of 6:00 am. In addition, 19.1% ($n = 39$) of the respondents in AE and 35.8% ($n = 73$) in MKE had their children reporting to school at 8:00 am instead of official time of 7:00 am.

In the evening, most of respondents in both AE (53.9%, $n = 110$) and MKE (38.7%, $n = 79$) had their children leaving school at 3:00 pm instead of 3:30 pm. Another 19.6% ($n = 40$) in AE had their children leaving school at 4:00 pm instead of 5:00 pm, while in MKE 23.5% ($n = 48$) of the respondents had their children leaving school at 3.30 pm instead of 4.30 pm. The variation in schools closing time was based on the lower primary, upper primary and secondary schools operational timings.

In areas where parents feared that their children could be attacked by wildlife, they were forced to escort them to and from school. The time used to escort children in morning in AE (0.55 ± 0.02 h; $n = 107$) was higher than in MKE (0.38 ± 0.04 h; $n = 179$). This meant that the adults usually reported late to their respective livelihood activities such as ploughing, milking, and casual work stations because of wildlife presence in their localities (Fig. 3).

In the MKE, 32.4% ($n = 66$) respondents and 5.9% ($n = 12$) indicated delayed reporting to their income related activities in the morning. In AE, seven out of the 12 people reported to work at 9:00 am instead of the planned 8:00 am. The remaining five people reported to work at 8:00 am instead of the scheduled 6:00 am to 7:00 am. In MKE, most respondents said they were required to report to livelihood activities at 7:00 am (9.3%, $n = 19$) and 6:00 am (6.9%, $n = 14$). However, most people delayed, and reported at 8:00 am (17.6%, $n = 36$) and 7:30 am (4.9%, $n = 10$).

The school time lost by children in the morning ($t = 8.669$, d.f = 211, $p = 0.000$) and in evening ($t = 5.101$, d.f = 216, $p = 0.000$) was significantly different in AE and MKE, with the former losing 0.495 h and 0.298 h more, correspondingly. Similarly, the time adults used to escort children to school ($t = 8.166$, d.f = 284, $p = 0.000$) and the time delayed fetching water and fire wood ($t = 3.424$, d.f = 52, $p = 0.001$) were significantly different for the two ecosystems.

3.1.3. Time spent on property repairs and crop replanting

Eleven (11) water tanks in AE and 21 in MKE were damaged by elephants within a period of one year. In addition, eight property fences in AE and 25 in MKE were damaged within the same period. On average, the time used to repair the damaged properties per year in AE (24.08 ± 5.33-h, $n = 12$) was higher than in MKE (4.35 ± 1.868 h, $n = 43$). After crop raiding by wildlife, households in AE spent an average of 124 ± 47.88 h replanting the crops, while those in MKE used 60.03 ± 8.13 h to crop replanting.

Table 3
School time lost.

Session	Ecosystem	N	Mean	S.E
Time lost in the morning	AE	98	1.28	0.053
	MKE	115	0.79	0.026
Time lost in the evening	AE	93	1.22	0.044
	MKE	125	0.93	0.037
Escort children to school	AE	107	0.55	0.015
	MKE	179	0.38	0.013
Time lost for delayed water and firewood fetching	AE	46	1.50	0.060
	MKE	8	2.25	0.412

Fig. 3. An elephant blocking the way for community travelling to Kimana market in the AE in 2019.

3.2. Monetary opportunity cost

3.2.1. Amount spent guarding against wildlife

Individual households in AE spent a KES 137,570.22 (US$1262) on livestock guarding compared to MKE who spent KES 84,011.36 (US$ 770.75) per year (Table 4). In addition, the amount AE households spent on crop guarding, KES 70,970 (US$ 651) was higher than in MKE, KES 47, 298.39 (US$ 434). Some households hired guards to keep off wildlife from their crops and livestock. The average amount spent per year on hired livestock guards by households in AE (KES 46,835.82 ± 2115.35 (US$ 430), $n = 67$) was higher than in MKE (KES 34,166.75 ± 5976.98 (US$ 313.50), $n = 12$). Similarly, the amount used to hire guards to scare off wildlife from farms in AE (KES 31,888.89 ± 6221.48 (US$ 293), $n = 9$) was higher than in MKE (KES 18,497.75 ± 1545.25 (US$ 170), $n = 89$).

The t-test for the amount spent by respondents in AE and MKE on crop and livestock guarding both for household members and hired labour was significantly different (Table 5), with the expenditure in AE being higher than in MKE.

3.2.2. Money spent on property repairs and crop replanting

The average amount spent on material and labour for repairing damaged water tanks and property fences in AE, KES 12,686.67 ± 4351.51(US$117.77 ± 40.40), $n = 15$) was almost equal to that spent in MKE, KES 12,118.61 ± 1186.39 (US$ 112.50 ± 11.01), with a slight difference of KES 568.06 (US$ 5.27) per year per household. Other than property repairs, respondents in both AE and MKE, indicated that they spent an average of KES 30,185 ± 9989 (US$280.21 ± 92.73) and KES 21,005.59 ± 3166.86 (US$ 194.99 ± 29.40) respectively replanting their crops after wildlife raids.

Table 4
Amount spent in KES and US$ on crop and livestock guarding.

Expenditure	Ecosystem	N	Mean (KES)	S.E
Amount household spent on crop guarding	AE	50	70,970.00 (US$ 650)	6209.20
	MKE	93	47,298.39 (US $434)	3040.75
Amount spent on hired labourer to guard crops	AE	9	31,888.89 (US$ 293)	6221.48
	MKE	89	18,497.75 (US$ 170)	1545.25
Amount household spent on guarding livestock	AE	89	137,570.22 (US$ 1262)	11,794.88
	MKE	22	84,011.36 (US$ 770)	9610.17
Amount spent on hired labourer to guard livestock	AE	67	46,835.82 (US$ 430)	2115.35
	MKE	12	34,166.75 (US$ 314)	5976.98

Table 5
T-test on money in KES spent on livestock and crop guarding.

Expenditure	t-test values	d.f	Sig. (2-tailed)	Mean Difference	Remarks
Amount spent on crop guarding	3.847	141	P = 0.000	23,671.613	Significant
Amount spent on hired labourer to guard crops	2.559	96	P = 0.012	13,391.136	Significant
Amount household spent on guarding livestock	2.207	109	P = 0.029	53,558.861	Significant
Amount spent on hired labourer to guard livestock	2.266	77	P = 0.026	12,669.071	Significant

3.2.3. Money spent on other HWC mitigation measures

The other common mitigation measures used to protect crops from wildlife are shown in Table 6. They include scarecrows (Fig. 4), fencing, dogs, light and noise emitting devices such as old magnetic tapes. Farm fencing using barbed wire and rolls of twisted chain-links was the most expensive method used in AE (KES 34,423.08 (US$316), $n = 13$) and MKE (KES 23,833.33 (US$ 218.70), $n = 6$). Unlike in MKE, dogs and noise mitigation measures were not used to protect crops in the AE.

Just like in crop mitigation measures, the use of livestock enclosure sheds (*boma*) using chain-link fence (Fig. 5) was the most expensive method used in AE, KES, 45,718.92 (US$ 419.44) and MKE, KES 23,250 (US$ 213.3) as shown in Table 7. The most common method used for livestock protection was a hedge fence, with 158 households or 65.8% of the sampled households using it. On average, the cost of the hedge fence was higher in AE (KES 11,289.29 (US$104), $n = 140$) compared to MKE

Table 6
Costs for crop protection methods used in AE and MKE.

Crop mitigation measures	Ecosystem	N	Mean (KES)	S.E
Scarecrows	AE	7	685.71 (US$6.29)	120.37
	MKE	55	1068.18 (US$ 9.80)	74.92
Fencing	AE	13	34,423.08 (US$ 316)	11,720.41
	MKE	6	23,833.33 (US$ 218.70)	11,402.97
Dogs guarding	AE	–	-.	-.
	MKE	55	2005.45 (US$ 18.40)	116.10
Lighting devices	AE	3	4033.33 (US$ 37)	260.34
	MKE	19	4063.16 (US$ 37.30)	407.69
Noise devices	AE	–	-.	-.
	MKE	26	1234.62 (US$ 11.33)	206.21

Fig. 4. A scarecrow in a beans field at Imuruto village in AE.

Fig. 5. Cattle entering predator-proof shed (*boma*) at Inkorienito village in Amboseli Ecosystem.

Table 7
Cost in KES and US$ for livestock protection measures used in AE and MKE.

Livestock mitigation measures	Ecosystem	N	Mean KES (US$)	S.E
Hedge	AE	140	11,289.29(US$104)	822.80
	MKE	18	7150.00 (US$ 65.60)	819.38
Chain-link fence	AE	37	45,718.92 (US$ 419.44)	3798.49
	MKE	44	23,250.00 (US$ (213.3)	1735.75
Scarecrow	AE	12	808.33 (US$ 7.42)	83.90
	MKE	4	975.00 (US$ 8.95)	184.28
Dogs	AE	41	1951.22 (US$ 17.90)	584.12
	MKE	23	2206.52(US$ 20.24)	261.20
Lighting devices	AE	39	17,017.44 (US$ 156.12)	2134.50
	MKE	4	8375.00 (US$ 7.68)	1434.33

(KES 7150.00 (US$ 65.60), $n = 18$). Similarly, the average cost of night lighting devices used in AE, KES 17,017.44 (US$ 156) was twice the cost in MKE, KES 8375.00 (US$ 76.83).

3.2.4. WTP and WTA for Hidden costs

Respondents in MKE were willing to pay and accept higher rates for various hidden costs than their counterparts in AE (Table 8). The highest mean WTA by respondents per day for time loss in income generating activities was KES 255.64 ± 15.93 (approx.US$ 2.37) in AE and KES412.76 ± 12.54 (approx. US$3.83) in MKE. Similarly, time loss for income-generating activities elicited the highest WTP in AE, KES102.44 ± 7.99 (approx. US$ 0.94) and in MKE, KES 118.45 ± 9.34 (approx.US$ 1.10). The lowest WTP and WTA was recorded in AE for restricted night travel of KES 43.13 ± 3.19 (approx.US$ 0.40) and KES 84.22 ± 5.78 (approx.US$ 0.78) respectively. Generally, the WTA for the various hidden costs was double the respective WTP values.

Table 8
WTP and WTA per day in KES and US$ for different hidden HWC.

WTP/WTA	Ecosystem	N	Mean KES (US$)	S.E
WTP to mitigate diseases	AE	156	61.06 (US$ 0.57)	4.46
	MKE	80	67.50 (US$ 0.63)	6.59
WTA compensation for diseases	AE	156	126.67(US$ 1.18)	9.82
	MKE	80	155.81(US$ 1.45)	19.51
WTP for fear of attack	AE	164	65.88 (US$ 0.61)	12.75
	MKE	128	68.56 (US$ 0.64)	3.43
WTA compensation for fear of attack	AE	163	112.91(US$ 1.05)	8.14
	MKE	129	143.02 (US$ 1.32)	8.62
WTP for restricted night time travel	AE	83	43.13 (US$ 0.40)	3.19
	MKE	122	69.06 (US$ 0.641)	3.28
WTA compensation for restricted night time travel	AE	83	84.22 (US$ 0.78)	5.78
	MKE	121	129.96 (US$ 1.21)	6.79
WTP for missing social gathering	AE	106	52.50 (US$ 0.48)	4.80
	MKE	95	63.90 (US$ 0.59)	3.47
WTA compensation for missing social gathering	AE	106	118.11(US$ 1.10)	14.61
	MKE	97	124.02 (US$ 1.151)	6.77
WTP for school absenteeism	AE	84	66.25 (US$ 0.62)	5.55
	MKE	121	97.85 (US$ 0.91)	4.71
WTA compensation for school absenteeism	AE	84	128.57 (US$ 1.19)	10.96
	MKE	119	215.50 (US$ 2.00)	19.52
WTP for loss of sleep	AE	139	60.29 (US$ 0.56)	3.50
	MKE	105	81.38 (US $0.76)	3.97
WTA compensation for loss of sleep	AE	139	114.33 (US$ 1.06)	6.98
	MKE	105	177.33 (US$ 1.65)	10.37
WTP for missing income generating activity	AE	101	102.44 (US$ 0.95)	7.99
	MKE	116	118.45 (US$ 1.10)	9.34
WTA compensation for missing income generating activity	AE	101	255.64 (US$ 2.37	15.93
	MKE	116	412.76 (US$ 3.83)	12.54

4. Discussion

4.1. Time opportunity costs

4.1.1. Time spent guarding against wildlife

The AE households spent more time guarding their livestock and crops both during the day and night than those in MKE. The time used to guard property against wildlife at night in AE and MKE were significantly different ($P < 0.05$), but the equivalent time spent on the same during the day was similar in the two study areas. The difference in guarding time can be attributed to wildlife movements and implementation of deterrent measures. In AE, the Amboseli National Park is not fenced, thereby granting free movement of wildlife between the park and the community group ranches, where human settlements and private property are located. The park represent about 8% of the entire ecosystem, which is a small area for a huge wildlife population including some problematic species such as elephants, lions, and hyena, whose home ranges are estimated at 5200–7790 km^2 ((Ngene et al., 2017), 28–37 km^2 (Tuqa et al., 2014) and 24–1000 km^2 (Hofer, 2002), respectively.

In MKE, there is regular wildlife movement between Mt. Kenya National Park and Forest Reserve and the adjacent conservancies and forests. However, the MKE is characterized by several electric fences around neighbouring conservation areas, which minimises wildlife entry into human settlements. For example, the movement of elephants from Mt. Kenya Forest Reserve into Lewa Wildlife conservancy is controlled by an electric fence along the designated corridor that links the two conservation areas, with an underpass along the Nanyuki-Meru/Isiolo highway. Since 2016, the Big Life Foundation has been erecting several short electric fences around AE (Big Life Foundation, 2020). However, this was done for selected high crop farming areas on the southern part of the Amboseli, Kimana and Namelok irrigation farms, leaving out other areas such as Kuku, Rombo, Imbirikani, Eselenkei and Olgulului. Consequently, households in other AE had to spend more time guarding their livestock and crops because of the widespread presence of wildlife in human settlement areas.

Guarding against wildlife property damages is a common practice in areas where people live in close proximity to wildlife habitats around the world. The findings of this study are similar to the observation by Howard (1995) in Nyabyeya forest reserves in Uganda, where the highest cost of crop guarding against destruction was $96–$519 per household. In another study conducted in Tanzania around Mpanga/Kipengere Game Reserve, 53.4% ($n = 90$) respondents indicated that they guarded their crops against wild animals both during the day and night time (Mashalla and Ringo, 2015).

The findings in this study are similar to the study by Musyoki (2014) who established that farmers in Mahiga “B” village in Nyeri County, spent substantial time guarding their crops against wildlife raids. The difference in time scheduling for guarding in Mahiga “B” and the timings recorded in this study can first be attributed differences on the time when the two studies were conducted including the sample size, interview duration and study locations. Musyoki's study only covered 5 months (August–December) and was based on 9 farmers, while this study was based on a 12-month period with a sample size of 408 respondents. In addition, in Musyoki's study area, a 1000 km of electric fence has been erected around the Aberdare Mountains and Mt. Kenya to reduce contact between people and wildlife (Pearce, 2015).

Spending time guarding livestock and crops has several social-economic implications to people. Firstly, night guarding denies people opportunities to engage in other income generating activities during the day due to lack of sleep. Secondly, as outlined by Barua et al., (2013) guarding against dangerous and feared wildlife species such elephants is associated with fatigue and alcohol abuse for anxiety relieve and fear mitigation among adults. Based on the average casual wages paid in AE (KES 50) and MKE (KES 75) per hour as observed from the two study areas, then the average combined time lost guarding livestock per household per day in AE was KES 389.0, compared to KES 445.50 in MKE. Equally, for crop guarding, a household in AE lost up to KES 422.50 per day while those in MKE lost KES 543.75 per day. This is a considerable amount of money to lose per day for people who are majorly rural, with 40% living in poverty (Kenya Institute for Public Policy Research and Analysis-KIPPRA, 2020).

4.1.2. School time lost and delays in reporting to income generating activities

The schooling hours for children in both ecosystems was affected because of wildlife presence but those in AE were affected more than the ones in MKE. Household activities by parents was also affected due to the need to escort children to school for safety reasons. It was observed that livestock in the two areas are released from the kraals to start grazing between 8:30 am and 9:30 am. More time was lost by children and adults in AE due to the location of schools within wildlife dispersal and migratory routes compared to MKE. According to Croze and Moss (2011) wildlife species such as elephants, zebra and buffaloes spent about 80% of their time outside the Amboseli National Park. The Park is not fenced and there is free movement of wildlife compared to MKE, where wildlife movement is restricted by the wide spread electric fences around conservation areas. As such, children have to wait for wildlife to either retreat back into the park or in the bush within their home locations. In the evening, children have to leave school early before the wildlife start moving into the human settlement areas. During the fieldwork, it was observed that villages such as Ol moti, Olgulului, Risa, Injakta, Lenkisem were all close to community boreholes which were an attraction to wildlife as sources of water.

The findings in AE were similar to a study conducted on communities bordering protected areas in Tanzania, which showed that 41.3% of the children usually encountered wildlife on their way to school, mostly in the morning and evening. The study showed that all the 46 students interviewed, had encountered an elephant, mostly when the animals were drinking water at the boreholes (Sayuni and Sengelela, 2019). In addition, Sayuni and Sengelela further notes:

> *“When pupils encounter elephants, some go back home, some wait for the elephants to pass by or use another road or look for someone to assist. Sometimes they fail to attend classes or arrive very late, sometimes at 10 am instead of 7:30 am, so they miss some subjects/lessons. The villages are very distant, and the houses are distant too”*

Therefore, wildlife presence in communities can seriously interfere with children education. Those who report late in morning and leave early in the evening usually miss some lessons, which can negatively affect their performance in national exams and long-term performance in life. This problem has been reported in other parts of Kenya. For example, a study by Sitati et al. (2012) on schools in Transmara District in Kenya, established that pupils living within the elephant ranges who had missed school for 20–60 days had lower mean scores (216–282 marks) in the final national exam compared to those outside elephants ranges (246–323 marks). This is likely to affect the long-term professional lives for people in wildlife areas who can lag behind other societies in a country.

Wildlife did not only interfere with the children school time, but also their parents. The presence of wildlife prevented people from attending to their different social and economic activities on time. More people (32.4%) in MKE were affected than in AE (5.9%). This is because most households in MKE are crop farmers who need to wake up early in the morning to attend to their crops as well as assessing the damage caused by wildlife overnight. The people in AE are, typically pastoralists for whom livestock grazing usually starts when the morning dew has cleared, and predators retreated into the thicket and parks. Wildlife restriction on people's movement is not a new phenomenon. In 2003, residents of Taita-Taveta County were blocked from attending to their socio-economic activities because of uncontrolled movement of wildlife in villages and farms around Tsavo National Park (Kimega, 2003). Kimega noted that during the dry seasons, women in the Taita –Taveta County were restricted from fetching water as result of roaming elephants around the water supply points.

4.1.2.1. Time spent on property repairs and crop replanting. The repair of damaged water tanks, fences, and other HWC related trouble-shooting facilities were found to consume considerable time at household level in the two ecosystems. Although MKE households had more water tanks and fences damaged by wildlife, the time used for repairs was higher in AE than in MKE. The difference can be associated with the extent of the damage, technical knowhow, and the availability of repair tools. Most MKE households, who largely depend on agriculture have tools such as hoes, machetes, and hammers that are required for repairs. In addition, this study found out that more people in MKE had formal education compared to those in AE and were hence relatively more exposed to the required technical skills.

4.2. Monetary opportunity costs

4.2.1. Monetary cost of guarding against wildlife

The study established that a lot of money was spent on guarding crops and livestock against wildlife in the two ecosystems. However, the amount spent in AE was significantly higher than in MKE. Households in AE had to forego a total of KES 255,376.04 (US$ 2343) per annum in safeguarding livestock and crops compared to KES 165,476.50 (US$ 1518). Overall, these figures are higher than the total income earned from all sources by a household in AE (KES 120,000.70 (US$ 1100.92) and MKE, KES 107,968.02 (US$ 990.53), implying that the return on investment was negative/loss. An analysis of crop loss in South Luangwa in Zambia and Tarangire in Tanzania also revealed that the mean loss due to single crop raiding by wildlife exceeded the monthly rural per capita income of a farmer (Gross et al., 2019).

Spending money on livestock and crop guarding against wildlife is widespread practice. For example, in South Africa the need to protect livestock from carnivores has forced some farms to invest up to 300 livestock guarding dogs (Stannard and Cilliers, 2018). However, according to Rust et al. (2013) who investigated 94 farms that had invested in 97 dogs to guard against wildlife, the maintenance cost of a single dog per year was approximately US$ 2780 which was quite expensive for small-scale farmers to afford. In Uganda, a study conducted in Hoima District by Kate (2012) established that a farmer spent between $10–35 per month to hire extra labour to guard their farms against baboons. Similarly, in Narok County (Kenya), Korir (2015) reported that soya beans farmers were forced to employ at least three workers to guard their farms against zebras and gazelles raids. This forced each farmer to spend an average of KES 18,000 (US$165.14) per month on wages. Spending money on property guarding against wildlife denies the farmer the expected full profit from their livestock and crops. It also reduces the famer's investment in agricultural produce and livestock because some money has to be allocated for the guarding against wildlife.

4.2.2. Money spent on property repairs and crop replanting

This study did not find any significant difference in the money spent on repairing damaged properties and replanting crops in AE and MKE. Overall, the amount spent on repairs was less compared to money spent on guarding crops and livestock. This finding is quite similar to the national analysis of human-wildlife conflict data between 2005 and 2016 in Kenya, which indicated that property damage constituted only 4% of the 29,647 reported HWC cases (Long et al., 2020). The existing records show that destruction of water tanks and farm fences by wildlife usually occurs mostly in dry seasons when wildlife move into human settlement areas in search of water and pasture, and that could be reason why the cases and related expenditure were lower for property damages. In addition, some of the affected water tanks are communally owned, which means that the damages are shared by many households thereby lowering individual household expenditure per property damage.

Replanting crops in AE was found to be more expensive than in MKE. This finding can be attributed to the difference in the farm sizes in the two areas, with households in AE having twice the size of farms compared to MKE. Other factors, such as physical and geographical parameters, which were not investigated in this study, could also have contributed to the difference. For instance, in a study conducted in farms within Trans Mara County (Kenya), it was established that large farms bordered by hedges were more likely to be raided (Sitati et al., 2005) because hedges provided shelter and hiding to various wildlife species. In addition, the study by Sitati et al. (2005) revealed that greater farm guarding efforts and the use of early warning systems also determined the level of crop raiding, and hence the amount used for replanting.

4.2.3. Money spent on mitigation measures

The hidden costs incurred through the money spent on the various protection measures for crops and livestock in both AE and MKE were similar, except for the installation of chain-link fences, scarecrows, dogs and noise producing devices. This is because these methods are relatively cheap to implement, compared to fencing and night-time light producing devices including solar units. Most scarecrows were made of sticks and old clothes while noise-producing devises were made using materials such as old magnetic tapes and tin cans. These two methods were implemented with the intention of frightening wildlife, especially birds and small mammals. The findings on the use scarecrows and magnetic tapes in this study resembled those of a study conducted in Machakos County, where 60% of the farmers preferred the use scarecrows and magnetic tape to scare away birds based on their cost effectiveness (Mutune, 2017). Similarly, a study undertaken in Moi's Bridge, where farmers encountered a 20% and 80% crop loss to birds and other animals respectively, showed that they spent between KES 70–150 (US$ 0.64–1.38) to install scarecrow (FarmbizAfrica, 2016). Another study conducted in the same area by Nemtzov and Galili (2006), revealed that each scarecrow cost about US$ 10. In this study, scarecrows were minimally used to frighten carnivores in both ecosystems. The low use of scarecrows for livestock protection could be attributed to its ineffectiveness as demonstrated by Woodroffe et al. (2006) in African rangelands.

Dogs were used to protect crops and livestock in both AE and MKE mainly for alerting households of wildlife invasion, as well as scaring away small mammals and birds. Unlike the trained dogs such as Anatolian Shepherd used in Southern African countries, the people in AE and MKE depended on ordinary untrained dogs whose cost ranged from KES 1900–2200 (US$ 17.43–20.18) per dog compared to the trained Anatolian Shepherd that cost between US$ 1000 in Tanzania (Ruaha Carnivore Project, 2020) and US$ 2780 in South Africa and Namibia (Rust et al., 2013). Although dogs have been documented to be effective in guarding sheep against cheetah and other small carnivores, studies indicate that they are associated with some hidden ecological costs. For example, an analysis of the 183 scats from six livestock guarding dogs in South Africa revealed that the dogs preyed on 10 different wild mammals (Drouilly et al., 2020). In Kisii (Kenya), an attempt by farmers to protect their crops from monkeys using dogs was unsuccessful because their barking whenever the monkey invaded the farms did not stop the monkeys from crop raiding (Okoyo, 2016).

Light emitting devices such as solar units and flashlights were used for the night-time guarding of livestock and crops in AE and MKE. Overall, the lighting devices for crop protection cost about KES 4, 000 (US$36.70) for crop protection and KES 17,017.44 (US$156.12) and KES 8375 (US$ 76.84) to implement in AE and MKE for livestock protection, respectively. The flashlight usually gives an illusion to the invading wildlife that humans are in the farm or around the livestock kraal. The difference in the hidden cost for the two areas can be linked to the type of lighting device used. Some farmers simply used a rechargeable solar panel with 3 bulbs, while others had a fully set solar flicking lights connected to a car battery and solar panels. In AE, the relatively high price for implementing night-time livestock protection light devices can be attributed to the introduction and high demand for the modified expensive unit by Coexistech Ltd. Elsewhere, a study undertaken in the southern section of Nairobi National Park established that a solar flashlight system introduced by Friends of Nairobi National Park consisting of 4–6 bulbs at a cost of KES 25,000 (US$ 229.36) per unit reduced livestock attacks by 96% (Lesilau, et al., 2018). Another study carried out in Amboseli showed that flashlights were 90% effective in keeping off predators from kraals (Okemwa, 2015).

The use of chain-link fences, also known as predator-proof boma, to keep off predators from livestock enclosures was common the two ecosystems. This involves fencing of livestock enclosures with rolls of chains-links that are supported with strong posts and a metal door as opposed to the popular hedge fence that consist of the acacia twigs. The cost of chain-link fences was higher in AE than in MKE because, the predator-proof boma design used in AE comprised of 1.8 m high-recycled plastics poles with chain-links and flattened iron drums. The project was implemented by wildlife charity-Born Free Foundation. The beneficiaries paid 25% of the total cost (estimated to be KES 240,000 equivalent to US$2202) which correlates to the size and number of livestock (Manoa and Mwaura, 2016). The lower cost of chain-link in MKE is attributed to the fewer number of livestock per household (38) compared to AE (98). In addition, the fence designs were different, with people in AE having been improved their fences through better communication, education and awareness training (Manoa and Kasaine, 2019). Elsewhere, a cost-benefit analysis of predator-proof bomas in Tanzania revealed that investing in boma fortification is cost effective compared to the traditional fence as it yielded positive net present values after two to three years (Kissui et al., 2019). The traditional hedge fences are less effective because of their low height and the ability of the predators to jump in and attack livestock (Manoa and Mwaura, 2016).

In addition to the above strategies, communities in AE and MKE also used barbed wire fencing, but this method was only used by 4.66% of the total respondents, which can be explained with the relatively high cost required to install the fence, which ranges between KES 23,000 (US$ 211) and 34, 500 (US$ 316.51). In addition to the rolls of barbed wires, the fence also requires the purchase of installation poles, at the cost of KES 200-1200(US$ 1.83–11) each, nails KES 150–250 (US$1.38–2.29) per kg and labour. It is projected that fencing an acre of farm would comprise 102 posts, 2 rolls of barbered wires, 3.5kgs of nails and labour are required, all totalling to about KES 40,000 (US$ 366.97) (EcoPost, 2020).

4.2.4. *WTP and WTA for hidden costs*

Respondents expressed their willingness to accept compensation and willingness to pay for the various hidden costs associated with HWC. The daily WTA and WTP values for households was higher in MKE than in AE. The WTA values for different opportunity costs were higher than the WTP by about 50%. The differences in the two values have been documented in other previous environmental economics studies as reviewed by Gregory & Brown (1999), KNBS. (2019a). *Enhanced Food Balance Sheet for Kenya, 2014-2018 Results.* Government of Kenya with a WTA: WTP ratio ranging of 1.4–61.0. The disparity in the WTA and WTP has been attributed to the fact that losses matter more to people compared to commensurate gains and reductions in losses are worth more than foregone gains. Most CVM studies in the world have reported exaggerated WTAs compared to the WTP. For example, duck hunters were willing to pay US$ 247 above the real cost to waterfowl for one year but demanded a minimum of US$ 1044 to forego the opportunity to hunt the same birds (Hammack & Brown, 1974).

5. Conclusion and recommendations

This study has demonstrated that time and monetary opportunity costs can be characterized, quantified and compared across ecosystems. Although, the two study areas experienced hidden costs, time and monetary opportunity costs incurred by households in AE were higher than MKE. AE households spent an average of 7.79 h during the day guarding livestock and crops compared to MKE households who spent 5.94 h. This suggest that the magnitude of hidden costs is largely dependent on the types of wildlife species, their ease of movement and land use practices. MKE has several electric fences that reduced wildlife from accessing human settlements, and hence less time and money opportunity costs. In addition, physical barriers such as electric fences also influenced the time and monetary opportunity cost of HWC. Although, physical barriers are not a hundred percent effective in barring wildlife, it is likely that investment in such structures by the government and conservation stakeholders can help people living in wildlife areas to reduce hidden costs of HWC. This study reveals that HWC results to sleepless nights, reduced school time and lower crop yields. The reduced school attendance can result to poor performance in national exams, poor progression in student careers, while sleepless nights results to health problems and drugs abuse.

It is therefore imperative for the government to incorporate the opportunity costs of HWC and measures of addressing them. Hidden costs such as opportunity cost are likely to promote community resentment towards wildlife conservation because of the substantial amount of time and money spent on HWC compensation with marginal success. Instead of the government policy focusing on compensation for visible cost, effort should go to minimising hidden costs through investment in preventive measures and improving the already existing measures that the community living in wildlife areas have adopted. This will go a long way in reducing interruption of education goals and people's career, proper health and psychological well-being. Since wildlife conservation does not mean the same thing to different stakeholders, the HWC policy should be revised together with other policies such as land, agriculture, mining, water and forestry, for conformity and addressing contradicting areas. As demonstrated by the AE and MKE study sites, the HWC policy must recognize the need for tailor -made solutions that are site specific, rather than generalizing. In addition, for the HWC policy to be effective and practical, the government together with wildlife stakeholders must have an implementation plan that is strongly supported by the necessary human and financial resources needed to deal with the HWC. As such, the government can embrace geo-spatial technology maps to establish household base in wildlife conflict zones capturing resources like land titles to speed-up process of HWC claims and agony of proofing. MKE has high fencing, than AE, thus working with private sectors to strategically useelectric fences can help to deter wildlife movements thus reducing people's livelihood disruption. It is also imperative for the government to adopt and promote modern technology like mobile phones to minimise cost of proof of damage on livelihood and in the process accumulate database of hotspots where priority mitigation like surveillance and electric fencing would be implemented. Providing subsidies for HWC deterrent devices such as predator-proof bomas, the same way the government subsidises fertilizer and seeds to farming communities can also help to reduce the burden of HC. There is also a need to consider insurance cover like in livestock sector, where technology has been employed to improve data report accuracy.

The ever-growing backlog of unpaid compensation claims for losses incurred through both visible and hidden costs of HWC in Kenya might require a comprehensive review of the compensation policy and legal framework. This should focus on the identification of alternative compensation options and strategies including tax rebates and other goodies for the HWC loss victims in order to sustain coexistence between society and wildlife. These options can include tax reliefs and concessions including waivers on county land rates or at least special discounted land rates. Other alternative offers could include income tax rebates on employment, investment and business income including business licenses for the victims and their families. In addition, they could also benefit from educational grants and bursaries as well as free social security and government national health insurance.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementray data

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