

Research Article

Game Damage to Forest Plantations in Hombe Forest, Mt. Kenya Forest Ecosystem

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Abstract

Forests remain the major habitats for wildlife in many parts of the world. However, game damage to forest plantations remains a threat to the development and management of forests. The wildlife debarks, bark strip, uproot, break branches, trample, browse plantation forest tree species and graze on grassland. There is little and conclusive information on the impact of game damage on forest in Kenya. The aim of the current study was to assess the game damage to forest plantations by wildlife at Hombe Forest Station. Primary data was collected using an observation schedule complemented with secondary data from the Kenya Forest Service and Kenya Wildlife Service. Eighteen Permanent sample plots (PSP) of one (1) Ha each were established in three sites. The study established that many of the dead and drying trees can be attributed to game damage. The two major game species were the elephants (*Loxodonta africana*) and buffaloes (*Syncerus caffer*). It was established that all tree species showed signs of damage from wildlife, *Cupressus lusitanica* damage was highest in site C compared to site B and A (One-Way ANOVA; $F_{(2)} = 16.234$, $P < 0.001$), the differences in game among the site may be attributed to higher density of animals observed in site A compared to the other sites. The major impacts to forest are trunk breaking and uprooting of Eucalyptus, bark stripping, debarking, and knocking down of Cypress. Forest destruction was due to game damage. It was found out that *C. lusitanica* experienced the highest impact on game damage especially debarking/bark stripping which accounted for 74.7% while broken branches were 17.8% and browsing 7.5 %. In terms of species preference to game damage *C. lusitanica* was leading with 93%, with Mexican green ash (*Fraxinus pennsylvanica*) at 5% and *Vitex keniensis* 2.0%. Forest plantations of *C. lusitanica* were the most destroyed species, while *Eucalyptus saligna* were the least destroyed. The Kenya Forest Service needs to fence industrial forest plantations to avoid losing all the investments in establishing, management and protection of plantations. The planting of non-palatable industrial forest plantation tree species like *F. pennsylvanica* Mexican green Ash and *V. keniensis* Meru Oak are recommended in the game prone areas.

Keywords

Game Damage, Plantation Forest, Wildlife Conservation and Forests, Forest Plantations, Hombe Forest, Mount Kenya Western Ecosystem, Fencing, Kenya

1. Introduction

Wildlife holds immense significance in maintaining healthy ecosystems, supporting biodiversity, and providing numerous

benefits to humans, including medicine, and tourism [1, 2]. Wildlife species are integral parts of ecosystems, each playing

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a specific role in regulating natural cycles like pollination, seed dispersal, nutrient cycling, and predator-prey relationships [3]. Moreover, wildlife and natural landscapes are major attractions for ecotourism, generating economic benefits for local communities [4]. Due to these benefits derived from wildlife, there is consensus that wildlife management is important for maintaining ecological balance, preserving biodiversity, and supporting human livelihoods [5]. The trend has always been to develop protective areas such as national parks, wildlife sanctuaries to protect the animals in their natural habitat. However, sometimes some of these animal escapes from the game parks and reserves, get into the surrounding environments and cause game damage [6].

In the context of wildlife conservation and forests, "game damage" refers to the detrimental impact that wildlife, particularly large herbivores, on forest ecosystems, including tree plantations and natural forests, leading to economic and ecological consequences [7, 8]. This damage can manifest in various ways, including browsing (eating leaves and young shoots), uprooting, bark stripping, fraying, trampling, and root damage [9]. Small ungulates such as red deer (*Cervus elaphus* L.), moose (*Alces alces* L.) and grey squirrel (*Sciurus carolinensis*) among others are known to destroy forest plantations [10-12]. Browsers also contribute to damage forest plantations as they are known to eat terminal buds and side shoots as well as of young plants [13]. Meanwhile Bark stripping by monkeys have been reported in pine and cypress plantations [14]. Game damage can cause changes in forest structure and composition by changing the types of trees that dominate a forest, potentially reducing biodiversity [15]. The economic impact of game damage can be significant, especially in forest plantations where the damage can lead to reduced timber yields and increased management costs [16, 17]. The ecological impact can include changes in forest structure and composition, reduced biodiversity, and altered ecosystem functions. Moreover, game damage can result in significant economic losses for landowners and forest managers.

Major game damage to forest plantations occur due to resource switching in times of seasonal scarcity of preferred diet that force wild game to rely on fallback resources [18, 19]. Although it has been rational to allow wild game to access critical forest resource to overcome seasonal feedstock scarcities, however, there is need to minimize resultant economic damages [20].

In Kenya, there have been reports of wildlife like elephants and buffaloes destroying plantations of pines, cypress and eucalypts through debarking, uprooting and trampling [21, 22]. The game damages have been recorded in most of the forests found within the Mt. Kenya Region [22], which threatens economic development and management of plantation forests [21]. In Hombe forest, industrial plantations comprising of *Eucalyptus* spp, *Pinus patula*, *Grevillea robusta*, *Cassuarina equisetifolia*, *Acacia mearnsii*, *Acacia melanoxylon*, *Cupressus lusitanica*, *Brachylaena hutchinsii*. However, there is limited research on the pattern of game damage in

terms of tree species affected. Therefore, the aim of the current study was to determine the pattern of game damage in relation to tree species in Hombe Forest, Mount Kenya Western Ecosystem.

2. Methodology

2.1. The Study Area

The study was conducted within Hombe Forest Station situated 35 Km from Nyeri town and 30 km from Karatina town and it is in Ruguru Location, Mathira Sub County, Nyeri County, Central Region of Kenya [23]. It borders Ragati Forest to the East, Kabaru Forest to the West, Mt. Kenya to the North and to the South, it borders Sagana, Iruri, Kiamaringa and Ruturu sub-locations settlements. Hombe forest Station falls both within the West of Mt. Kenya forest reserve and world heritage site on the Southwestern side of Mt. Kenya forest. The area stretches from approximately from 0°15'S to 0°23'S Latitude and 37°03'E to 37°08'E Longitude.

The short rainy season occur in October to December and the long raining season occurs from March to May, with the hottest months being January/February, August/September and coldest month of June/July. The average mean temperature is 18°C and the mean annual rainfall is 1000 mm, it is on the leeward side of Mt. Kenya [24]. The altitude is 2020 m asl. Hombe forest covers a total of 3,618.0 ha. of which 126 ha. are bushland/grassland, 1,223.0 ha being plantations and 2,269.0 ha is under indigenous forest.

The forest was established for industrial forest plantation tree species since 1940s [25]. The species are mainly exotics and include *Cupressus lusitanica*, *Pinus patula*, *Eucalyptus* species, *Acacia mearnsii*, *Acacia melanoxylon*, *Flaxinus pennsylvanica*, *Grevillea robusta*, *Casuarinas equisetifolia* *Araucaria*. Indigenous tree species established under industrial plantation forest are *Vitex keniensis*, *Brachylaena hutchinsii* and *Podocarpus falcatus*.

Soil on the highly raised regions, are moderate to high fertility [24]. The soils; on the upper slopes above 2,400 m asl have dark surface horizons and low bulk density. These soils include Regosols, Histosols and Andosols. In the forested mountain areas where there is plentiful rainfall; the soils are volcanic in origin, intensively red with considerable amount of clay as well as fairly rich in organic matter. The hydrology is dominated by five rivers (Ragati, Muthira, Ruiruiru, Hombe and Sagana) and four streams (Satumia, Nguniu, Kakurua and Kahiti) which drain into Tana River.

2.2. Data Collection

Data was collected from three sites within the forest. The Hombe forest area was sub-divided into three sites namely site A, which has minimal interference from human settlement, site B within Hombe Forest Station is situated and finally Site C near the settlement boundary. The initial tree density es-

establishment for various tree species was obtained from the inventory record. The study involved establishment of 1 ha. circular plots within the selected sites. Eighteen Permanent Sample Plots (PSP) of one (1) ha each were established and

initial density determined. Six plots were established in each site. The plots were then monitored weekly and the number of trees damaged by the game and type of damage were recorded. The plots were monitored for six (6) months.

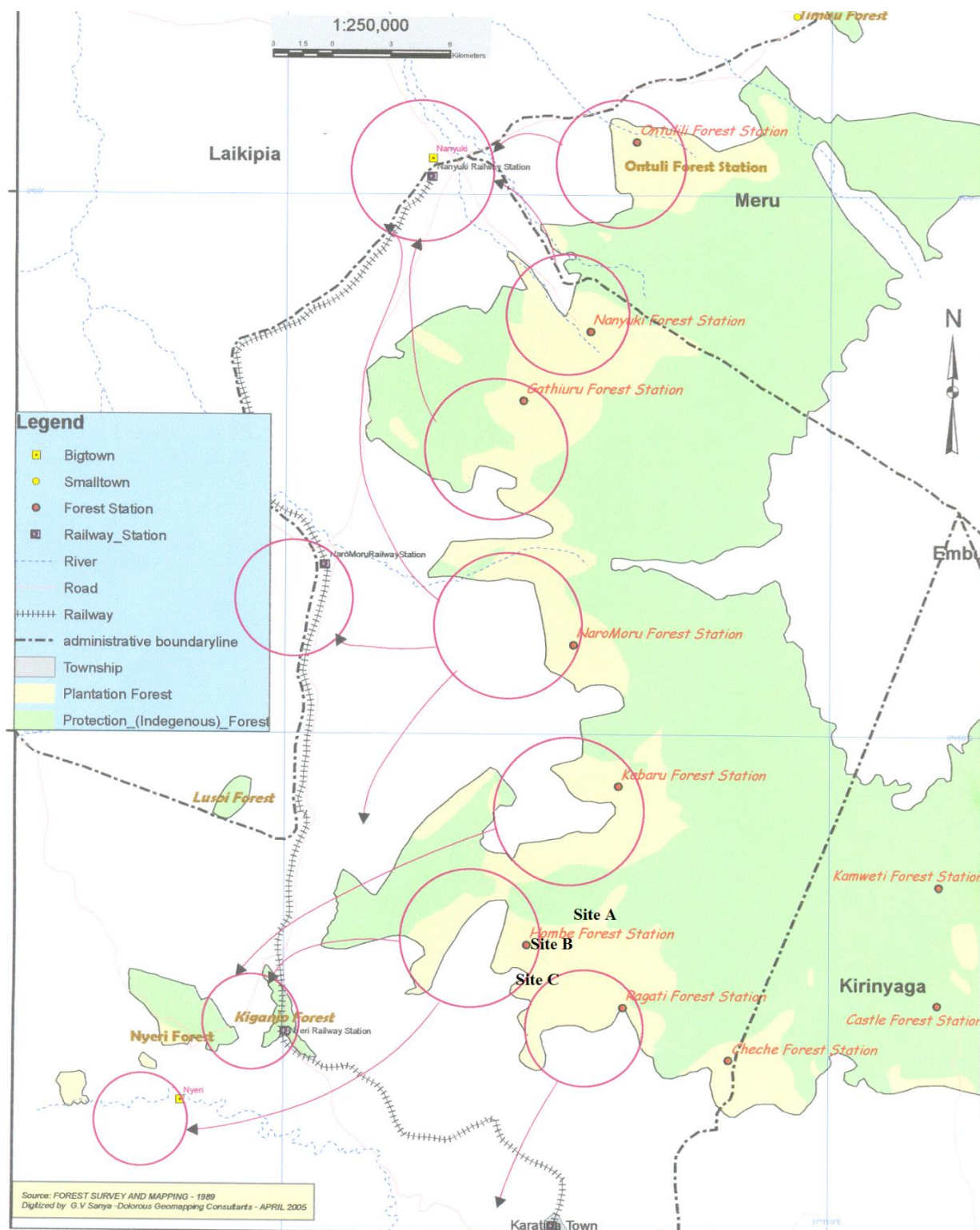


Figure 1. Map of plantation and indigenous forest west of Mt. Kenya, showing the location of Hombe Forest and sampling sites.

2.3. Data Analysis

Tree damage (%) was determined as (final density – initial density)/Initial density*100 and means computed. Differences in game damage among sites and between difference species was analyzed using two ways ANOVA. Differences in means for each species per site were compared by One-Way ANOVA followed by Tukey's post hoc test.

3. Results and Discussion

All tree species showed signs of damage from wildlife (Table 1). The two major species of game in Hombe forest are the elephants (*Loxodonta africana*) and buffaloes (*Syncerus caffer*). These two species of big game are known to inflict primary damage on *Eucalyptus* spp and *Prunus africana* through uprooting, browsing, debarking, bark stripping and trampling [26, 27]. Elephants may uproot and eat the entire tree [28] while buffalo breaks the top of young trees by scratching their underside on them [29, 30]. Other primates such as monkeys and wild pigs present in the forest may also contribute to plantation forest damage [25]. During the interview with the game wardens, there were reports of prior damage of *Eucalyptus* species, *A. mearnsii*, *A. melanoxylon*, *G. robusta* and *Brachyleana hutchinsii* had been destroyed completely by these species before the start of the research project.

There were difference in species damage among sites and between difference species (Two-Way ANOVA; $F_{(2,14)} = 14.234$, $P < 0.001$). The *C. lusitanica* damage was highest in site C compared to site B and A (One-Way ANOVA; $F_{(2)} =$

16.234, $P < 0.001$), the differences in game among the site may be attributed to higher density of animals observed in site A compared to the other sites. The wild animals tend to be more frequent and spend more time in the plantation. Site B had moderate game damage despite the wildlife frequenting the area during the night. This could be because most of the time the animals are chased away by both Game and Forest Rangers since the Hombe Forest Station office and staff quarters is situated within this site. Site C experience the least game damage and this could be attributed to its closeness to the human settlement and hence the wildlife least frequent the area.

There was no significant differences in the game damage in *F. pennsylvanica* (One-Way ANOVA; $F_{(2)} = 0.854$, $P = 0.534$). *V. keniensis* was damaged at site A, and *Warburgia ugandensis* in sites B. Meanwhile game damage to *Croton megalocarpus*, *Podocarpus falctus*, *Olea africana* and *Brachyleana hutchinsii* occurred at site C. The current results also indicate preference for *C. lusitanica* among the elephants in the study area. This is a rather surprising observation since the animals show great variation in feeding pattern depending largely on the quality and quantity of available feeds and also due to physiological or behavioral status prevailing at the particular moment [31, 32]. However, elephants may occasionally browse *C. lusitanica* in areas where it is planted, there's little evidence to suggest it is a preferred food source or that they actively seek it out [33]. Lower foraging at site C, this could be attributed to its closeness to the human settlement and hence the wildlife least frequent the area.

Table 1. Percentage (mean \pm SE) damage of tree species at the three sampling sites.

Species	Site A	Site B	Site C
<i>Cuppressus lusitanica</i>	1.20 \pm 0.08 ^c	0.90 \pm 0.03 ^b	0.82 \pm 0.06 ^a
<i>Fraxinus pennsylvanica</i>	0.05 \pm 0.13	0.03 \pm 0.11	0.05 \pm 0.13
<i>Vitex keniensis</i>	0.02 \pm 0.11	0	0
<i>Warburgia ugandensis</i>	0	0.05 \pm 0.14	0
<i>Croton megalocarpus</i>	0	0	0.07 \pm 0.22
<i>Podocarpus falctus</i>	0	0	0.17 \pm 0.59
<i>Olea africana</i>	0	0	0.22 \pm 0.51
<i>Brachyleana hutchinsii</i>	0	0	0.10 \pm 0.28

Percentage (Means \pm SE) with superscript across the row show significantly ($P < 0.05$) different means.

The percentage of various types of tree damaged by wildlife in Hombe Forest Station are shown in Table 2. There were several kinds and mode of game damage impacted on the industrial plantation forests such as debarking, bark stripping,

uprooting, root browsing, branch breaking, trunk breaking, knocking down, felling and throws. Others included trampling, browsing and grazing. *Eucalyptus* spp, *P. patula*, *Casuarina*, *A. mearnsii*, *A. melanoxylon* and, *Brachlaena* suf-

ferred uprooting, root browsing and trunk breaking due to their palatability and mineral nutrient contents. *C. lusitanica* suffered bark stripping, debarking, knocking down, felling and throws. *G. robusta* suffered debarking, branch breaking, truck breaking, knocking down, felling and throws. The close proximity of forest plantation to Mount Kenya ecosystem results in continuous animal raids. Most of the types of game damage impacted to industrial plantation forest were found to be knocked down trees, broken trunk, uprooted trees, root browsing, debarking, bark stripping, broken branches and twigs & leaves browsing. *C. lusitanica* experienced the highest stem damage in form of knocked down stems at 45.7% occurring in site B, followed by broken trunk 33.4%, then finally uprooting 20.9%. Mexican green ash had the highest game damage on broken trunk 72.0% in site A, followed by knocked down stems 21.4% and least uprooting 6.6%. *V. keniensis* the highest game damage impacted was broken trunk 80.0% and least damage was knocked down 20.0% in site A. *C. lusitanica* experienced the highest impact of game damage especially debarking/bark-stripping 74.7%, broken branches 17.8% and browsing 7.5% in site A. The highest game damage for *F. pennsylvanica* was browsing accounting for 74.2%, followed by broken branches at 19.4%, while the

least type of game damage was debarking/ bark stripping accounting for 6.4% in site A. The highest game damage to *V. keniensis* was browsing accounting for 87.7%, followed by broken branches at 8.6%, while debarking/bark stripping was the least type of game damage accounting for 3.7% in site A. In site B, it was found that *C. lusitanica* experienced the highest impact on game damage especially debarking/bark-stripping 73.8%, followed by broken branches 16.4%, while the least type of game damage was browsing 9.8% in site B. The highest game damage for *F. pennsylvanica* was browsing accounting for 76.7%, followed by broken branches at 16.7%, while the least type of game damage was debarking/ bark stripping accounting for 6.6% in site B. In this site, *V. keniensis* did not experience any form of game damage in both site B and site C. Finally in site C, it was found that *C. lusitanica* still experienced the highest impact on game damage especially debarking/bark-stripping 72.6 %, broken branches 19.6% and browsing 7.8% in site C. The highest game damage for *F. pennsylvanica* in this site was browsing accounting for 78.6%, followed by broken branches at 15.5%, while the least type of game damage was debarking/bark stripping accounting for 5.9%.

Table 2. Percentage of various types of tree damaged by wildlife at Hombe Forest Station.

Type of Game Damage	<i>C. lusitanica</i>			<i>F. pennsylvanica</i>			<i>V. keniensis</i>		
	A	B	C	A	B	C	A	B	C
Knocked down	44.2	45.7	43.0	21.4	20.0	28.0	20.0	0	0
Broken trunk	19.2	33.4	37.3	72.0	80.0	72.0	80.0	0	0
Uprooting	36.6	20.9	19.7	6.6	0	0	0	0	0
Root browsing	0	0	0	0	0	0	0	0	0
Debarking/bark stripping	74.7	73.8	72.6	6.4	6.6	5.9	3.7	0	0
Broken branches	17.8	16.4	19.6	19.4	16.7	15.5	8.6	0	0
Browsing	7.5	9.8	7.8	74.2	76.7	78.6	87.7	0	0

The kind and mode of game damage impacted on the industrial plantation forests with the underlying factors for the preference of certain tree species.

4. Conclusions

In this study, all tree species showed signs of damage from wildlife, *Cupressus lusitanica* damage was highest in site C compared to site 2 and 1 (One-Way ANOVA; $F_{(2)} = 16.234$, $P < 0.001$). Other plant species were also damaged but the game damage levels was low. The differences in game among the site may be attributed to higher density of animals observed in

site A compared to the other sites. The major impacts to forest are trunk breaking and uprooting of Eucalyptus, bark stripping, debarking, and knocking down of cypress.

5. Recommendations

In order to sustainably manage the Hombe Forest Station and Mt. Kenya forest ecosystem as a resource of national importance, the following are recommendations on the industrial plantation forest:

The Kenya Forest Service needs to take into account industrial forest plantations fencing to avoid losing all the in-

vestments in establishing, management and protection of plantations. The planting of non-palatable industrial forest plantation tree species like *Fraxinus pennsylvanica* and *Vitex keniensis* needs to be enhanced especially to the game prone areas.

There is need to reduce the levels of game damage to the established industrial plantation forest by wild animals through the establishment, installation and maintenance of wildlife proof barriers electric fences or game moats.

Kenya Forest Service (KFS) to have a comprehensive forest land zonation and mapping for establishment of industrial plantation forest which are ring – fenced to protect the young plantations against game damage.

Abbreviations

KFS	Kenya Forest Service
ANOVA	Analysis of Variance
PSP	Permanent Sample Plot

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Author Contributions

Benjamin Mutuku Kinyili is the sole author. The author read and approved the final manuscript.

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Data Availability Statement

The data is available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

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