The habitat use and selection of African elephants (*Loxodonta africana)* in a land use landscape in Kenya, Africa

Ashley Coe

Ashley Coe (Corresponding author)

Montana State University

Bozeman, MT

Email: acoe84@hotmail.com

Phone: 781-953-0298

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Abstract

The objectives of this analysis are (1) to examine how land use and cover types affect the distribution of African elephants in Kenya (2) to determine what land use cover types support larger densities of elephants as a very general indicate of habitat preference.
I found that elephants exist in the highest density (2.09 individuals/ km^2) within Kenyan protected areas. The density was higher within protected areas than in all the other land use types combined (1.59 individuals/ km^2). Outside of protected areas, the elephants preferred (2) savannahs, (3) open herbaceous vegetation, and followed by (4) agriculture land use types. Individuals were absent from closed vegetation, forest plantations, urban areas, or bare areas. Current protected areas do not adequately provide habitat for long-term conservation of elephant populations and biodiversity. The majority of elephant range is not currently protected in designated areas, so it is crucial to species conservation to understand how elephants use human-dominated land outside of protected.

Keywords: habitat selection, conservation, elephant density

Introduction

Currently, the African elephant is listed as vulnerable by IUCN, however, there is wide variation in the population status across its range. The eastern and southern populations account for two-thirds of the total continental population and are increasing at a rate of 4.0% annually (IUCN website). The western and central populations are in decline but are currently recruiting individuals from the eastern/southern populations that will offset that decline. As of the 2007 status report, Kenya had approximately 23,353 – 31,636 individuals (Blanc 2007); mainly, savannah African elephants (*Loxodonta africana africana*) which use the grasslands and woodlands that dominate eastern Africa. There may also be small remnant populations of *Loxodonta africana cyclotis* along the western edge of the region (Blanc 2007).

Elephant habitat in eastern Africa (880,000 km^2) accounts for 26% of the total elephant range in Africa. 30% of the continental range lies within protected area boundaries. The largest elephant populations in eastern Africa are in Tanzania (80% of regional population), Kenya (12% of regional population), and then Uganda (Blanc et al 2007). Sudan has a large part of the proposed range, but little is known about the population sizes in this country.

With elephant numbers increasing regionally in east Africa, further information about elephant land use is important to minimize human-elephant conflict, minimize vegetative damage, and develop sufficient management strategies and protected areas. Currently, very little is understood about how elephants (*Loxodonta Africana*) use and are affected by human-occupied landscapes (Graham 2009). Human-elephant conflict is the most prominent issue affecting elephant conservation in Kenya (Blanc 2007; Graham

2010). Land use planning is critical in preventing spatial land use patterns that will leave crops more vulnerable to raiding by elephants (Graham 2010).

As of 2008, Kenya is in the process of developing a national elephant conservation strategy; therefore, more complete land use data will be important in the creation of the conservation plan. If high densities are concentrated in inadequate confined areas, elephants can have detrimental impacts on vegetation (Agnew 1968; Anderson and Walker 1974; Barnes 1983; Ben-Shahar 1993; Guildemond 2008).

Current protected areas are too small and isolated to give sufficient habitat for long-term conservation (Graham 2009). Also, these inadequate protected areas lead to decreases in biodiversity and vegetative damage as discussed above. Also, the lack of connectivity among protected areas restricts the long distance migrations and movements that are critical for elephant populations (Galanti 2006). Within the continent, protected area management is challenging and controversial (Dickson and Adams 2009) because of opposing interests. The majority of elephant range is not currently protected in designated areas (Blanc 2007), so we must understand how elephants use the human-dominated land outside of protected areas. Also as the elephant range spans the continent and individuals travel long distances, continental conservation is crucial. Currently, there is no broad or continental conservation plan, but the need for one has been discussed (IUCN SSC African Elephant Specialist Group 2008). Only southern Africa range states have collaborated on a regional plan. The following range states currently have isolated state plans Tanzania, Botswana, Namibia, South Africa and Zambia. The majority of the conservation plans rely on external funding sources for implementation (IUCN SSC African Elephant Specialist Group 2008) and are not self-sufficient.

The objectives of this analysis are (1) to examine how land use and cover types affect the distribution of African elephants in Kenya (2) to determine what land use cover types support larger densities of elephants as a very general indicate of habitat preference.

Methods

I acquired elephant counts from World Research Institute from a 1994-1996 census using low-flying aircraft. The number of elephants was aggregated to 5km cells. From the same organization, I acquired land use and land cover data representing the rangeland, urban, agricultural, protected areas, and bare areas. I also incorporated land cover data from Africover.org.

I then overlayed the elephant count numbers on the land use maps. I first conducted a broad analysis using the following 9 general land use categories: isolated crop agriculture, small field agriculture, medium field agriculture, forest plantation, savannah, open herbaceous vegetation, protected areas, urban areas, and bare areas. Using ARCGIS, I summed the number of elephants within each land use type. I also summed the total area of each land use type (m). I then calculated the density of elephants (number of individuals/ km^2) for each land use category. I then preformed this same algorithm for the more detailed land use categories. Table 1 outlines the specific land use type categories within each of the general categories.

The density calculation is interpreted as an indicator of habitat preference. The limitations of this assumption are discussed in the Discussion section below.

##Table 1 approximately here##

Results

Broad results

Elephants exist in the highest density (2.09 individuals/ km^2) within protected areas (Figure 1). The density was higher within protected areas than in all the other land use types combined (1.59 individuals/ km^2). Outside of protected areas, the elephants preferred savannahs and then open herbaceous vegetation (no above ground persistent woody vegetation). They preferred agricultural land types less (Figure 1). They were not present in closed vegetation and forest plantations. This, however, could be compounded by the difficulty of locating individuals via aircraft in dense vegetation. Also, there were no individuals reported in bare areas or in urban areas.

##Figure 1 approximately here##

Protected Areas

The National Parks had the greatest density of elephants (2.34 individuals/ km^2) followed by the national reserves (1.16 individuals/ km^2) , and then the forest reserves (2.34 individuals/ km^2) (Figure 2a). In a Kenyan "National Park," there is complete protection of natural resources and activities are restricted to tourism and research. National reserves, on the other hand, allow other human activities under specific conditions like fishing in marine reserves or firewood collection in terrestrial reserves (Kenyan Wildlife Service 2011).

Rangeland

Elephants occurred in the highest density in open trees and shrubs savannah (2.132 elephants/ km^2) (Figure 2b). They also preferred open to closed herbaceous vegetation on temporarily flooded land (2.02 elephants/km^2) followed by open to closed herbaceous vegetation (1.74 elephants/km^2). No individuals were located in closed vegetation and very few (.025 elephants/km^2) in sparse shrub vegetation.

Agriculture

Within the agricultural cover types, elephants were found in the highest densities in small field- shrubs, rainfed, permanent (AG-SSP) (2.02 elephants/km^2) followed by continuous rainfed small field (cereal) agriculture (AG- SC) (1.03 elephants/km^2) (Figure 2c). AG-SSP includes vegetation with more structural variety and cover than AG-SC. Also, there is a temporal component integrated in with AG-SC, however, AG-SSP retains its characteristics. Elephant density was not linearly related to crop intensity (Figure 3). The density of elephants was greater at 60% and 100% than at 15% and 90%.

Figure 2 approximately here##

##Figure 3 approximately here##

Urban Areas

As expected there was no elephants sited in or near the urban areas. Previous research as found that female elephants especially avoid human settlements (Harris et al 2008).

Bare Areas

There were no elephants sited in bare areas. As the area lacks close water and vegetation for protection or forage, it is expected that these areas would also be devoid of elephants.

Discussion

I found that elephants occurred in the greatest densities in protected areas. Density varies linearly with the degree of protection. The more strictly protected areas, National Parks, had the largest density of individuals. The least regulated protected area, forest reserves, had the smallest density of individuals. In strictly regulated areas, there is less chance of human-elephant encounters, which elephants tend to behaviorally avoid (Harris et al 2008; Graham 2009).

A more detailed study of the land surrounding the protected areas is very important to African elephant conservation, as little is understood about African elephant use of human-occupied land types (Graham 2009). Also, multiple recent publications emphasis the importance of areas surrounding protected areas for the longevity of the species and ecosystem dynamics within the protected areas (Cushman in review; Hansen et al 2011a; Hansen et al 2011b).

The limited use of agricultural areas is also expected. There is little cover in agricultural fields and a high potential for human-elephant conflict. A large human-elephant conflict issue that is growing in number of incidents is crop raiding. The smaller agriculture land uses are more susceptible to crop raiding (Graham 2010). In this analysis, I found that the smaller agriculture fields were indeed more heavily used than larger agricultural fields and other types of agricultural fields. As the small field agriculture is often used as a food source (Graham 2010), individuals could be using

these areas more than other sizes of agriculture that is not as commonly used for a food source. In a recent analysis of crop-raiding potential, the spatial arrangement of land uses is very important. The smaller agriculture lands and larger crop fields are more susceptible to crop raiding if they are adjacent to "daytime elephant refuges," habitat in which elephants can hide undisturbed during the daytime (Graham 2010). Unfortunately, this analysis did not have adequate data to identify daytime refugees and analyze the spatial arrangement and relationship among patches.

Another predictor of the occurrence of crop raiding is percent of area cultivated (Sitati et al 2003). At the broad spatial scale, the extent of cultivation predicated the occurrence of crop raiding. More intensely cultivated lands experienced higher frequency of crop raiding incidents (Graham 2010). In this analysis of percent of cultivation, I did not find a conclusive relationship between density of use and crop intensity.

Within the rangeland cover type, the tree and shrub savannah supported the largest density of elephants (2.13 elephants/ km^2); followed closely by open to close herbaceous vegetation on temporarily flooded lands (2.01 elephants/ km^2). Unfortunately, the land use cover type data maps did not contain data on the availability of water. The proximity of water is a large determining factor on elephant habitat selection and use (Graham 2008). If water is abundant and within close proximity, then elephants seem to select for high vegetative cover that still allows for easy movement (Blanc et al 2007). It can be assumed that there was temporarily high availability of water on the temporarily flooded lands. During these times, the high vegetation and abundance of water in the open herbaceous vegetation makes the habitat ideal for elephants; however, there is not a

temporal component in this analysis to examine the use of the rangelands at hydrological different seasons.

Limitations of the Analysis

Density is only a loose indicator of habitat preference. It cannot be assumed that because the individual is using land use type A at the moment observed that it prefers it to the other types. The individual may merely be passing through the habitat, for example. However, the replication of observation over the 2-year period at random times throughout the year helps to reduce the misrepresentation. Elephants prefer to move short distances per day (Harris et al 2008), so each individual may not have equal access to all habitat types at every moment. Also, water availability is a strong determinant in elephant choice of habitat and is not a variable explicitly controlled for in this model.

Originally, I had intended to incorporate a temporal component, but there was not appropriate abundance data available. Previous studies found that there was great variation in diurnal land use by elephants (Chiyo et al 2005; Hoare 1999). Of the monitored elephants, individuals spent more time at night than during the day in land use types that presented a high risk of human caused mortality (Graham et al 2009). There also is seasonal variation in movement patterns and land use based upon hydrological seasons: wet (November – March) versus dry (April – October) (Harris 2008). Elephants also undertake long distance migrations to help find resources when limited or scarce (Thouless 1996). Therefore, habitat use temporally varies across the range.

Despite the limitations of this analysis, the initial objectives were achieved. The objectives of this analysis are (1) to examine how land use and cover types affect the distribution of African elephants in Kenya (2) to determine what land use cover types support larger densities of elephants as a very general indicate of habitat preference. In order to more fully accomplish objective one, the development of a control landscape with limited anthropogenic land use cover types would be useful. The distribution of elephants on the current land use landscape could then be compared to the distribution on the earlier landscape to evaluate how anthropogenic land uses affect the distribution of elephants. Again, however, appropriate data prevented the creation of the control landscape.

Table 1. Broad land use cover type (LUCT) categories and the detailed categories within each broad category

General LUCT categories	Detaled LUCT categories
Forest plantations	forest plantations closed herbaceous vegation
savannah	shrub savannah trees and shrubs savannag
open herbaceous vegetation	open to very open shrubs with herbaceous open to closed herbaceous vegetaion general open
urban	
bare areas	
protected areas	national park national reserve forest reserve
isolated crops in natral vegetation	
small fields	continuous rainfed small field (cereal) shrubs- small fields, rainfed perm. tea
medium field agriculture	rainfed herbaceous

Figure Captions

Figure 1. The number of elephants (normalized by 1000) and the density of elephants (individuals/km^2) for 9 broad categories of land use in Kenya.

Figure 2. The density of elephants (individuals/ km^2) in the protected areas, rangelands, and agricultural land use categories

Figure 3. The density of elephants (individuals/ km^2) in agricultural land use with different crop intensities

Figure 1

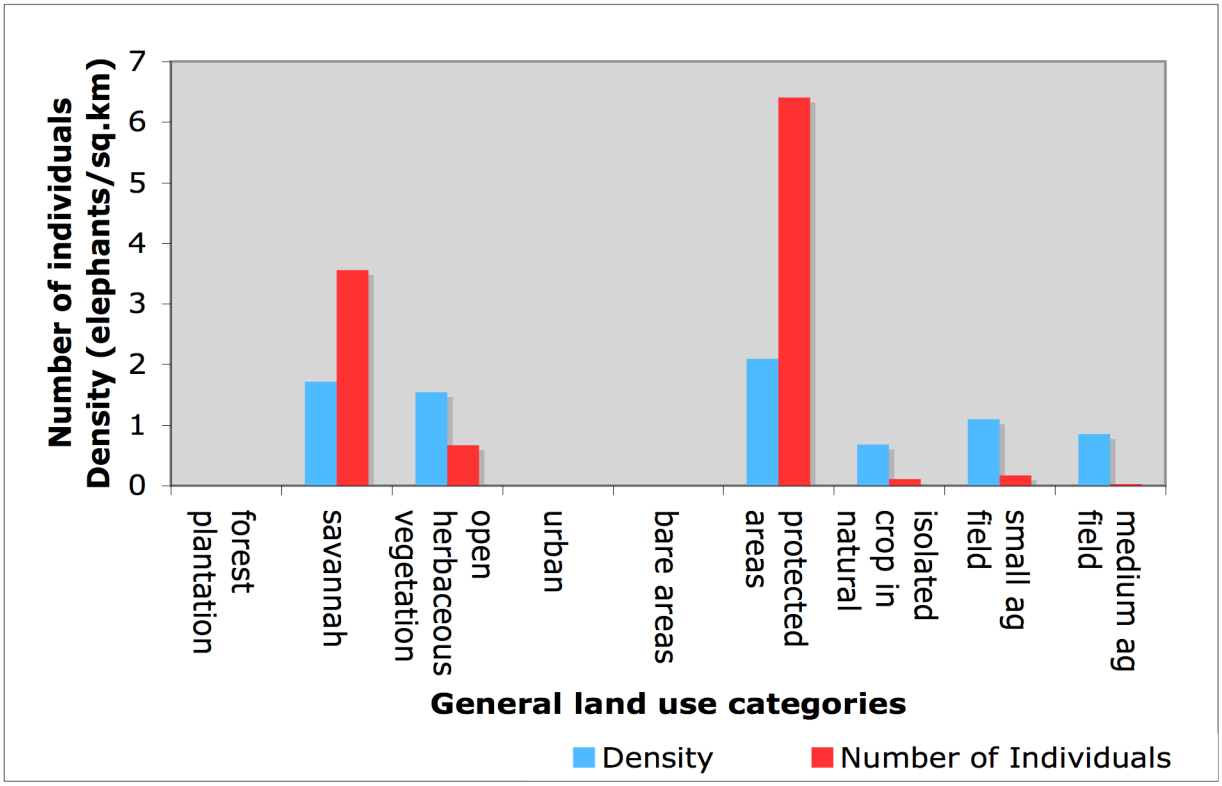
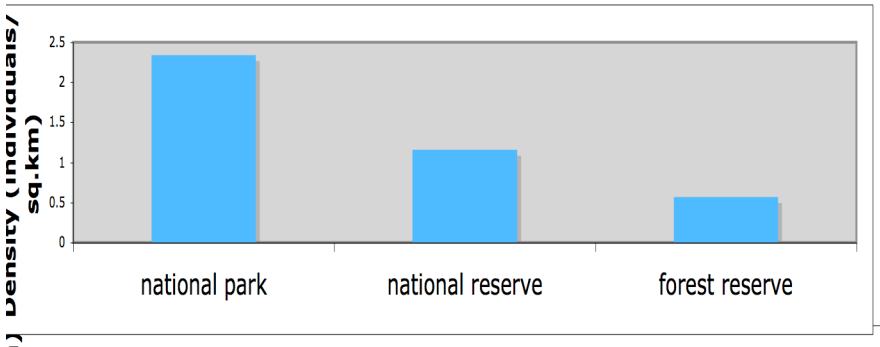
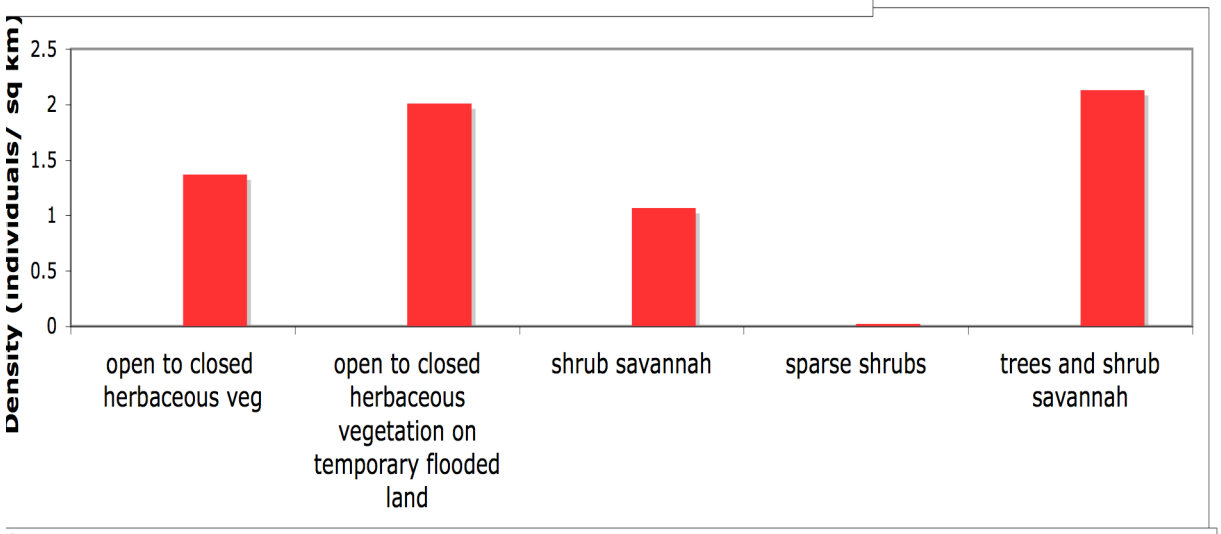

Number of individuals
Density (elephants/sq.km)
7
6
5
4
3
2
1
0
forest plantation
savannah
open herbaceous vegetation
urban
bare areas
protected areas
isolated crop in natural
small ag field
medium ag field
General land use categories
Density
Number of Individuals

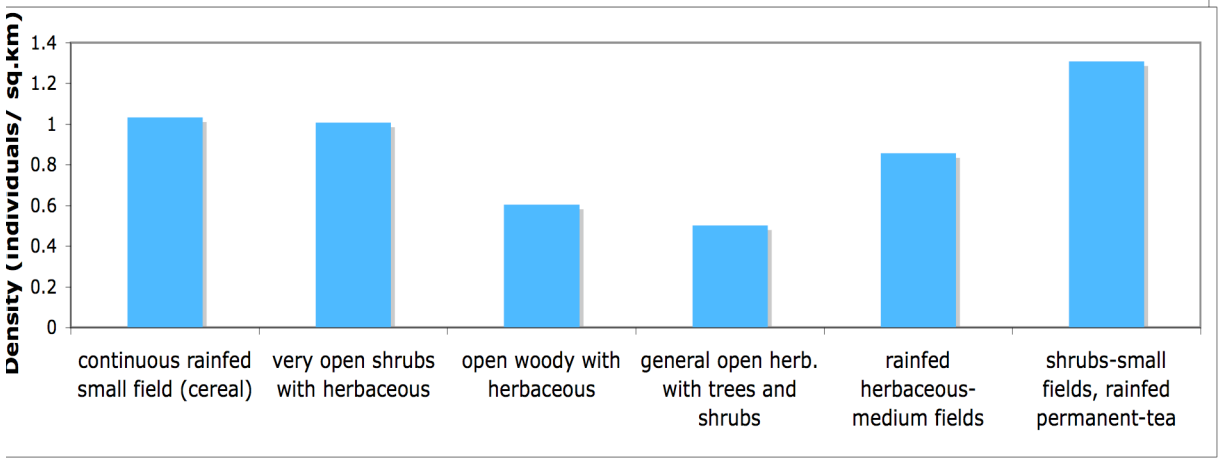
Figure 2



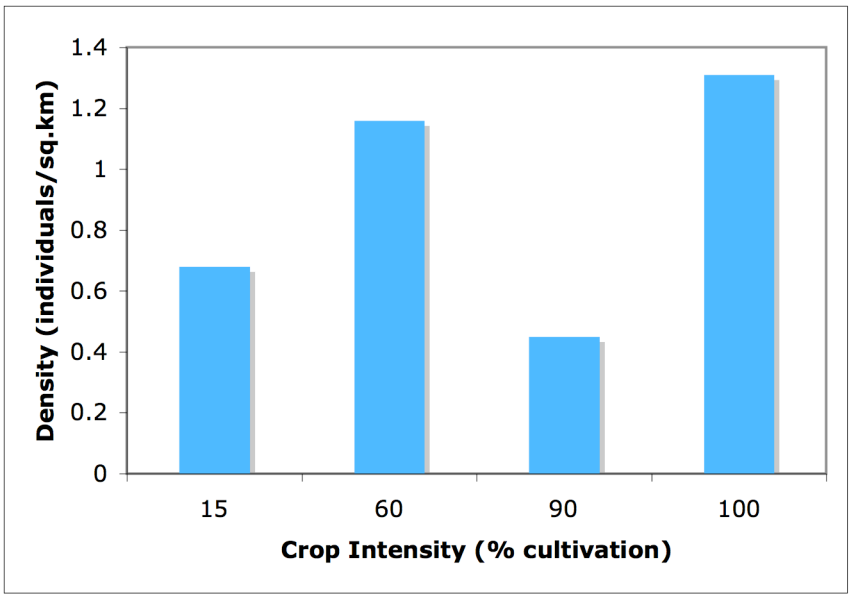
(a) Protected areas



(b) rangeland



(c) agriculture



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