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Land use Impact on Vegetation Characteristics in Samburu -Laikipia Landscape Savanna, Kenya

Kirathe, Joseph Nderitu [1, 3, 4], John Maina Githaiga[3], Robert, Mutugi Chira[3] and Daniel I. Rubenstein [2, 4]

[1.] School of Natural Resource, Tourism and Hospitality, Maasai Mara University, Kenya
[2.] Department of Ecology and Evolutionary Biology, Princeton University, USA
[3.] School of Biological Sciences, University of Nairobi, Kenya.
[4.] Mpala Research Centre, Nanyuki, Kenya

Authors contacts: Joseph Nderitu Kirathe,
Maasai Mara University, School of Natural Resource, Tourism and Hospitality.
P.O. Box 861-20500 Narok, Kenya.
E- mail: *jkirathe@gmail.com*

Abstract

The study was conducted to understand the influence of different land-use on vegetation composition and structure in Samburu-Laikipia landscape in Kenya. We used 377,1 km^2 randomized grids to assesses vegetation characteristics. Principal Component Analysis (PCA) was used to determine the underlying vegetation characteristics patterns. Furthermore, we tested the effect of land-use on vegetation characteristics using One Way ANOVA. PCA results reveal that the selected vegetation characters clustered onto two axes explaining 80.2 % variations; Axis one depicted anthropogenic disturbance in Community Conservation Areas (CCAs) and Community Grazing Areas (CGAs) while axis 2 clustered along areas where human impacts are less, in particular Protected Areas (PAs) and Laikipia Ranches(LRs) which also often serve as wildlife conservancies.

Land-use greatly influenced on vegetation characteristics with PAs and LRs showing significantly higher grass cover, percentage perennial grasses, herbaceous layer biomass and grass height. While CCAs and CGAs showed significantly higher abundances and percentages of annual grasses, forbs, shrubs and tree characteristics. Interestingly, with respect to structure and composition there were no strong seasonal differences. Moreover, the findings suggest that human land-use does not automatically lead to universal species reductions or loss. Rather, in some dimensions, especially with respect to woody vegetation and annuals heavy use of the landscape may improve habitat condition and create a landscape mosaic that enhances overall species diversity. The study finds it important to monitor, control and manage the usage of communal areas in fashion that favors a mixture of communities that enhances overall landscape biodiversity.

Keywords: Landscape, vegetation, composition, structure, land-use

1. Introduction

The arid and semi-arid savanna vegetation distribution, structure, and composition depend on climate, topography, soils, geomorphology, herbivore, and fire (Scholes and Archer, 1997; Weber et al., 1998; Adler et al., 2001; Augustine, 2003; van Wilgen et al., 2003). In addition, savanna ecosystems have been shaped by human land-use practices since thousands of years ago (Higgins et al., 1999; Shackleton, 2000; Wittig et al., 2007), and with this process continuing which should not be neglected when trying to predict future impacts of human development (Heubes et al., 2011). Human land-use impact, abiotic, biotic and climate change factors interact, making it difficult to identify, isolate, or quantify the key determinants of savannas and their biodiversity change (Scholes and Archer 1997; Higgins et al., 1999).

Conservation of biodiversity today is increasingly complicated by challenges of understanding the factors shaping vegetation structure and composition that occurs along different land-use types (DeFries, et al., 2005) while shaping the associated animal populations. At landscape level, arid and semi-arid savannas consist of patterns of vegetation types clustered in concurrence with climatic condition and geographical features which create mosaic of patchiness (Augustine, 2003).While topography, weather and climate influence the distribution pattern of animals, vegetation characteristics in terms of quality, quantity, species composition, plant morphology and physiology are the key determinant of wildlife abundance (Harris et al., 2002). Moreover, vegetation variations that change over time and space also tend to be the main driving force shaping variations in biodiversity abundance.

Arid and semi-arid savannas of sub-Sahara Africa have been subjected to land-use changes resulting from rapid human population growth which has led to changes in ecosystems function (Chapin et al., 2000; Sala et al., 2000; Thompson et al., 2005; Que´tier, et al., 2007). These changes have enormous ecological, economic, and social consequences (Plieninger, 2006). Thus, the protection of arid and semi-arid savannas is essential for the protection of biodiversity in order to ensure the availability of natural resources for subsistence and cash income of rural people in the future. Protection can be achieved by reducing human land-use changes through establishment of protected areas (PAs) and creation of community group ranches which are divided into conservation and controlled grazing areas, especially in Samburu-Laikipia landscape. Such areas play a crucial role in protecting semi-arid ecosystems and the biodiversity within their borders, especially by preventing land clearing and by reducing human and other intensive land-use activities not compatible with biodiversity conservation (Bruner et al., 2001**;** Struhasker et al., 2005**;** Clerici et al., 2007). This is due to the fact that ecological and social systems are closely linked and it is important to consider land-use areas with regard to biodiversity protection. Because biodiversity value reaches beyond park and reserves boundaries(Caro et al., 2009), human-dominated communal lands adjacent to protected areas still maintain unique and rich assemblies of species.

The ecological integrity of a PAs strongly depends on the ecological function of the surrounding communal areas (Clerici et al., 2007).In Kenya for example, a country economically reliant on wildlife tourism, wildlife abundance declined 45% outside and 41% inside protected areas from 1977 to 1997 (Western et al., 2009). Ogutu et al., (2011, 2016) attribute wildlife losses in Kenya’s Maasai Mara National Reserve to increasing numbers of human settlements along protected area boundaries which has been accompanied by illegal wildlife harvesting and livestock grazing. Sixty-five percent of Kenya’s wild animals now live outside national parks and reserves (Western et al., 2009), even though >50% of land that once supported wildlife is under agricultural production (Norton-Griffiths & Said, 2010). This calls for urgent need to understand and continually evaluate the impacts of different land-use activities on vegetation structure and composition in arid and semi-arid savannas to help shape actions that foster effective conservation and management practices that will sustain biodiversity.

2. Study area and Methodology

2.1 Study area

The study was conducted between 2009 and 2015 in Samburu-Laikipia landscape located between 36^0 15’-38^0 00’E and 0^0 00’-1^0 00’N covering 15,634 sq.km. The study area included; West gate conservancy, Ngaroni community land and Sessia-Barsalinga community land which are community group ranches in the north; Buffalo Springs and Samburu national reserves both protected areas in the north, Oldonyiro and Kipsing community areas in the south of Isiolo district and Laikipia community group ranches which included Koija, Ilmotiok and Tiamamut group ranches, Olojogi and Mpala cattle ranches both in the south (Figure 1).

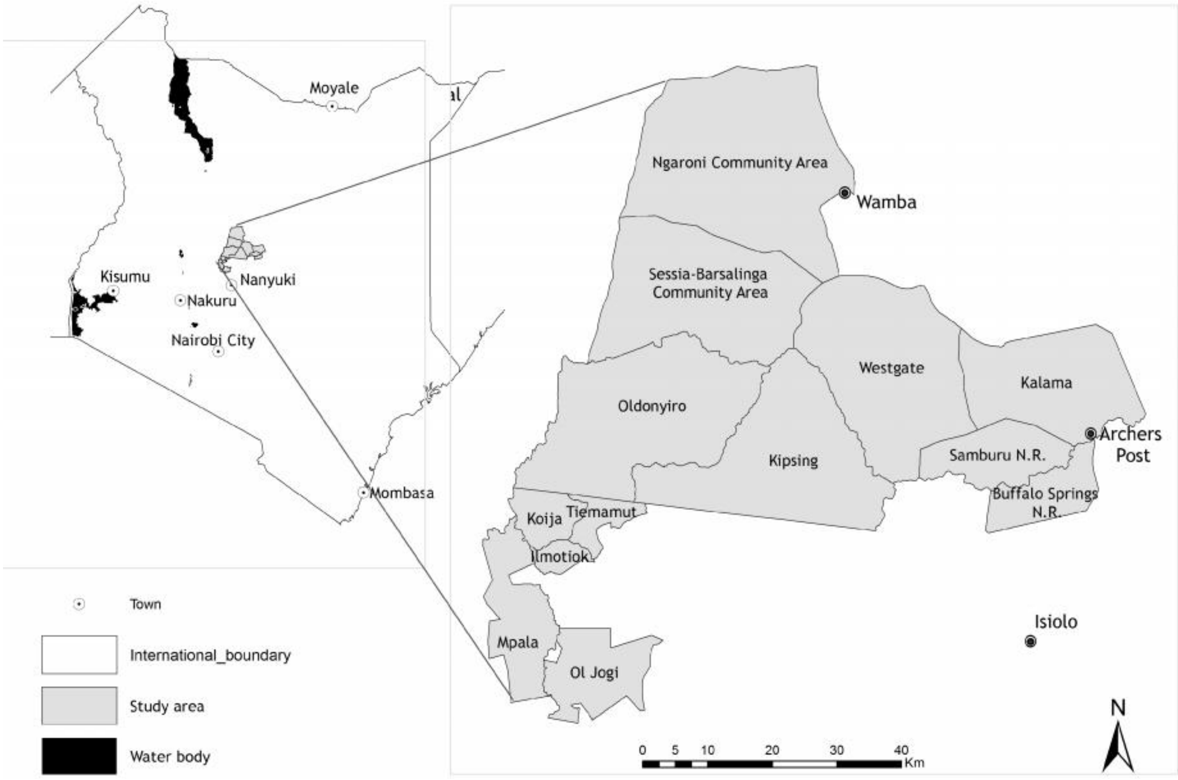

Figure 1: Map of Kenya showing the location of study area and study sites

On this landscape there is wide variation in seasonal rainfall, largely affected by altitude and the fact that the Samburu- Laikipia landscape lies on the lee ward side of both the Aberdares range and Mt. Kenya. Study sites located in the south (Laikipia) receive more rainfall ranging between 400-750 mm per annum (County Government of Laikipia, 2018) than areas in the north around Archers post and Wamba town where yearly rainfall averages around 250 mm per annum (County Government of Samburu, 2018). The climate is hot and dry during the day with cool nights with mean annual temperature ranges between 16^0C to33^0C (SNR, 2003; County Government of Samburu, 2018; County Government of Laikipia, 2018).The vegetation communities fall under the 'ecological zone V' consisting largely of bush and wooded grassland (Pratt et al., 1966),. The systems include an alternating savannah mosaic that includes *Acacia*-grasslands and *Acacia*-*Commiphora*s crubland sand large areas of *Acacia tortilis* wooded grasslands with a ground cover of perennial and annual grasses (Pratt et al., 1966).

We sampled vegetation within the four dominant land-use types prevalent in Samburu-Laikipia landscape. These included; I) Laikipia commercial cattle ranches (LRs) with controlled number of livestock and that often serve as wildlife conservancies. Those included in the study were Mpala Ranch and Oljogi Ranch; II) Community conservation areas (CCAs) in Laikipia, Samburu and Isiolo; III) Community grazing areas (CGAs) which includes community grazing areas in Laikipia, Samburu and Isiolo; and IV) Protected areas (PAs) which included Buffalo Springs and Samburu National Reserves. All these land-use types have varying degrees of human activities uses (Fig. 2).

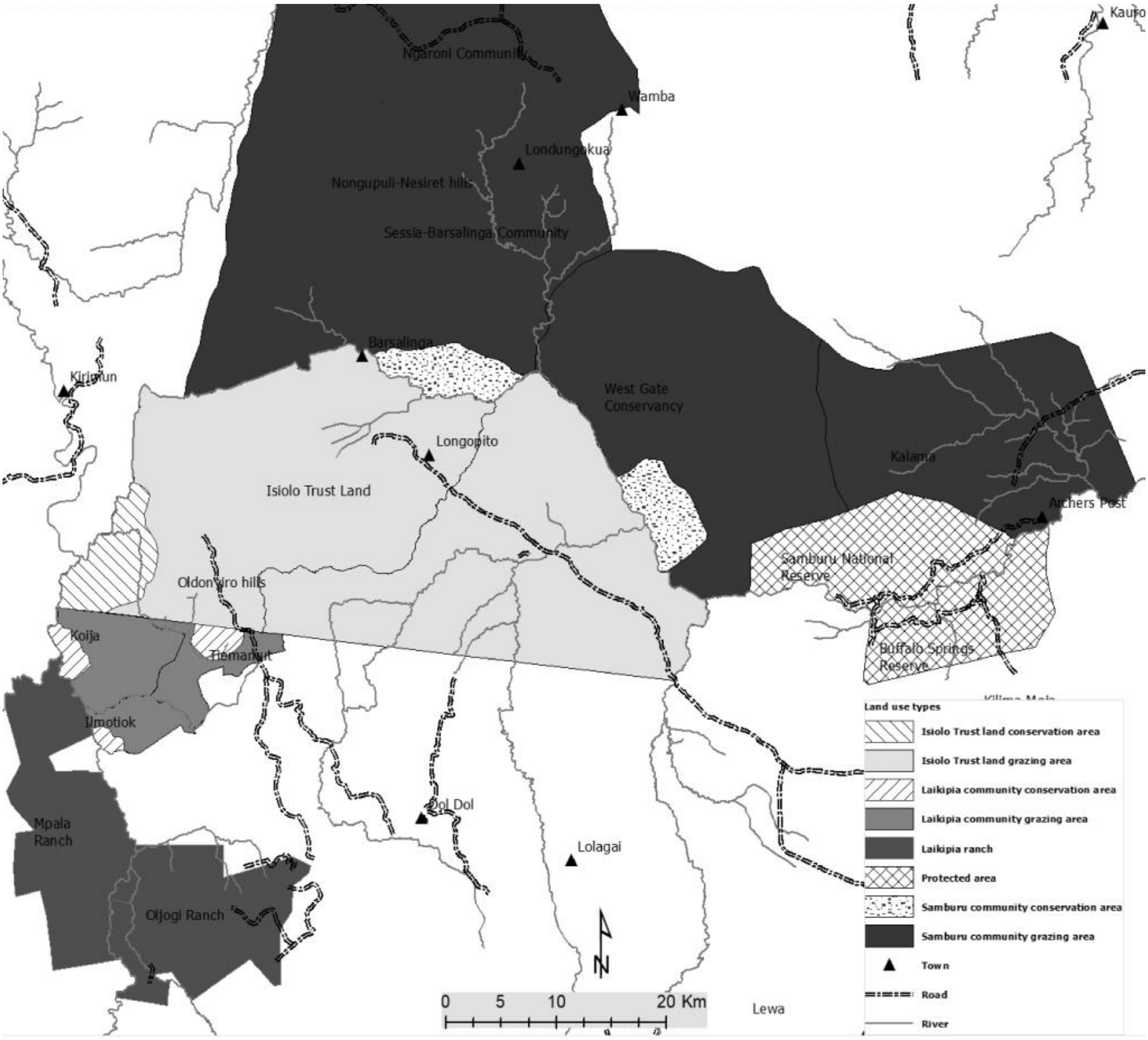

Figure 2: Land-use types occurring in Samburu-Laikipia landscape

2.2 Vegetation surveys

To understand vegetation structure and composition, 1 km random grids were established using ARCGIS (ESRI, 2015) totaling 377 grids depending on different vegetation type and spreading across different weather seasons. For every random vegetation grid, 100m transect running down slope was conducted from the center of the grid to evaluate trees and herbaceous layer characteristics. Ten sampling points, 10 m apart along the transect were determined where 10 wielding rods were inserted on1-meter pin frame. Grass or forbs touching the pin were keyed to species and counts were made to estimate percent cover, species diversity, percent perennial and annual grasses. This was repeated every month to capture herbaceous layer spatial-temporal variations in each vegetation type. Grass and forbs height were measured using a meter rule to the nearest cm while herbaceous layer biomass was estimated by clipping grass in four by 0.5m^{2}quadrat per transect. The clipped grass was dried and weighed until no further weight loss.

Tree and shrub plants density were determined from counts of 5 meters on both sides of the transect while canopy cover was measured using line intercept method along the 100 m transect. In addition, tree height was also determined using a tape measure with an extension pole.

2.3 Data analysis

Collected data were summarized and tested for normality using the Kolmogorov-Smirnov test, and data for grass height, forbs height, tree and shrub density, herbaceous layer biomass and forbs density were normalized using log10 (x +1) transformation (McDonald, 2014). While proportion and percentage data were normalized using log it transformation (Ashton, 1972).Species diversity was calculated using Shannon-Weaver index ($H' = -\Sigma pi \ln pi$) where *pi* represents the proportion occurrence of a species. We performed a Principal Component Analysis (PCA) to determine the underlying patterns of the vegetation data in the different land-uses. Differences in vegetation composition and structure between land-use were tested using One-way Analysis of Variance (ANOVA), at 5% level of significance using JMPRO Version 14 Statistical Package (SAS Institute Inc., 2018). When models showed significant differences, differences among the means were compared using post-facto Student t-test LSM test (Kramer, 1956; Tukey, 1953).

3. Results

3.1 Relationship between land use on vegetation structure and composition

Principle Component Analysis (PCA) biplot shows that Axis 1explains 54.1 % of the overall vegetation composition based on characteristics of forbs, trees and shrubs as well as some annual grasses and forbs and separates low impact human impact areas such as Protected Areas (PAs_ and Laikipa Ranches (LRs) from Community Areas irrespective of whether they were designated as conservation areas (CCAs) or grazing areas (CGAs).

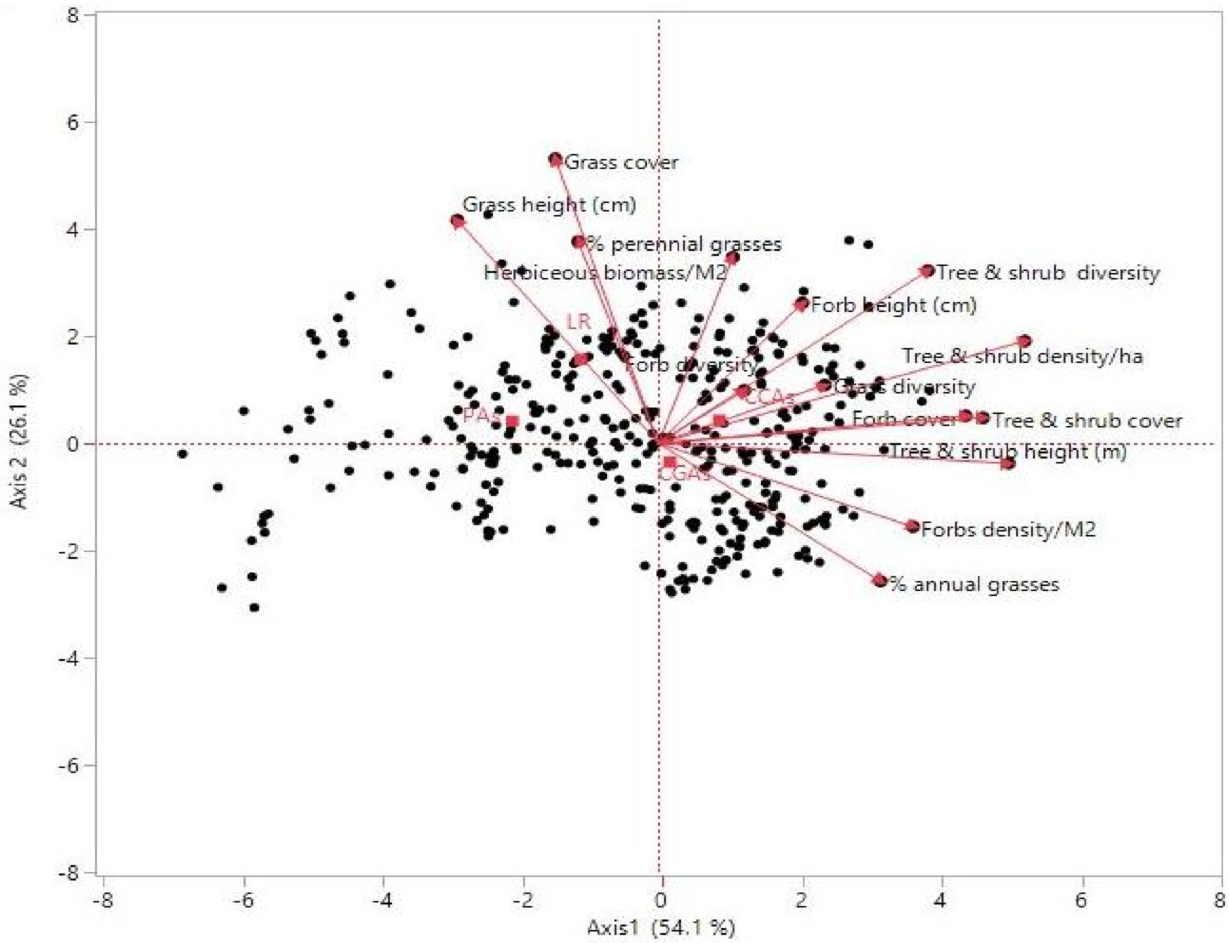

Figure 3: Principal Component Analysis biplot of measured vegetation variables from the 4 Land use types in Samburu-Laikipia landscape. CCAs represent Community Conservation areas, CGAs represent Community Grazing Areas, LRs represent Laikipia Commercial Ranches and PAs represent Protected Areas.

Axis 2 explains an additional 26.1% of these vegetational features, but does so by separating all land use types that purport to provide some degree of wildlife protection (PAs, LRs and CCAs) from those that are heavily impacted by human use (CGAs). While Axis1 is characterized by features associated with trees, shrubs and forbs, Axis 2 is mostly characterized positively by features associated with perennial grass cover, height its relative abundance and herbaceous biomass. but negatively with respect to abundance of annual grasses and forbs, two vegetation types often preferentially used by livestock. (Figure 3). Clearly, land-use type is strongly related to vegetation structure and composition on Samburu-Laikipia landscape.

3.2 Land-use impact on vegetation composition and structure

When details of vegetation structure and composition are compared across both land use types and time using One-Way ANOVA some striking patterns emerge (Table 1). In the dry season, LRs and PAs are characterized by significantly higher values of grass cover, grass height, percent perennial grasses and herbaceous layer biomass than either of the community areas. Only with respect to grass cover did community conservation areas differ from community grazing areas during the dry season (Table 1). When compared to Protected areas (PAs) or Laikipia Ranches (LRs), CCAs and CGAs maintained significantly higher abundances of forb cover, forb height, tree and shrub densities, and heights, as well as the relative abundance of annual grasses (Table 1).With respect to plant diversity, grass diversity was high in LRs, CCAs, and PAs while forb, tree and shrub diversity was highest in CGAs, CCAs.

Often the onset of rains changes the structure and composition of vegetation. This was not the case in our study. During the wet season, the highest levels of grass cover, height and relative abundance of perennial grasses continued to be found in LRs and PAs. Similarly, forb cover and height as well as tree and shrub density cover, height along with percent annual grasses remained high during the wet season in the CCAs and CGAs (Table 1).

4. Discussion

The different land-use areas examined in this study showed significant differences in vegetation structure and composition. Based on vegetation characteristics, the land-use types can be separated into two major types. One as depicted by the first axis of the Principal Component Analysis reveal that CCAs and CGAs mainly exhibit high abundances of forbs, trees, shrubs and annual grasses. This suggests that community land use reduces the relative abundance of perennial grasses and the layer of herbs which are more common in PAs and LRs as depicted by the second principal component. However, diversity of various plant forms seemed to vary less predictably among the land-use types. The findings show that disturbance impact on plant communities, composition and structure differently (Skarpe, 1990; Ogutu, 1996) which is important aspect in understanding distribution and abundance of biodiversity in arid and semi-arid savanna.

Our study on vegetation characteristics across different land-uses types in Samburu-Laikipia landscape suggest that that human disturbance play a key role in shaping vegetation communities, much like Nacoulma et al., (2011) have observed in Burkina Faso.Though it is generally accepted that topography, edaphic and moisture variation affect structure and composition in savannas (Witkowski and O'Connor, 1996; Williamset al., 1996), the loss of woody vegetation due to herbivory, fires, droughts, diseases, and other human disturbances also play important roles in shaping the vegetation in arid and semi-arid savanna ecosystem (Scholes and Archer 1997; Higgins et al., 2000;van Wilgen et al., 2003). CCAs ought to have low levels of human disturbance as they are protected by local communities. CCAs, however, have had a history of disturbance and are often used as community dry season grazing reserves (pers. observ.). Even though CCAs do not retain the same level of perennial grass cover, grass height as PAs and LRs, they contain more of these vegetation types than in CGAs. In this way community conservancies, which are expanding under the auspice of Northern Rangeland Trust (NRT) to surround protected areas and ranches in Samburu-Laikipia landscape are helping increase wildlife habitats (Watson *et al*., 2010; NRT, 2017) are becoming very important for biodiversity conservation.

Table 1: Vegetation characters for sample grids across different land-use types (mean ± Standard error) and significant levels from one-way ANOVA. Where; *P< 0.05, **P< 0.01,***P< 0.001and NS = Not significant; Mean difference is indicated with superscript alpabet

		Dry season			
Land-use type	**CCAs**	**CGAs**	**LR**	**PAs**	
Vegetation character					**ANOVA**
% Grass cover	40.97 ± 2.03^{b}	33.91 ± 1.51^{c}	62.76 ± 2.40^{a}	41.44 ± 1.89^{b}	$F_{3,249} = 26.22$***
Grass diversity	0.65 ± 0.02^{b}	0.61 ± 0.01^{c}	0.66 ± 0.02^{a}	0.49 ± 0.02^{d}	
Grass height (cm)	9.51 ± 0.92^{b}	10.02 ± 0.57^{b}	19.78 ± 1.58^{a}	15.54 ± 1.12^{a}	$F_{3,249} = 20.11$***
Forb cover	22.03 ± 1.88^{a}	20.25 ± 0.97^{a}	7.98 ± 1.23^{b}	5.85 ± 0.45^{b}	$F_{3,246} = 60.51$***
Forb diversity	0.64 ± 0.04^{b}	1.25 ± 0.25^{a}	0.48 ± 0.04^{b}	0.35 ± 0.03^{c}	
Forb height (cm)	25.77 ± 2.68^{a}	21.14 ± 1.13^{a}	17.04 ± 1.52^{a}	19.86 ± 1.86^{a}	$F_{3,249} = 1.71$NS
Forb density (ha)	1925.74 ± 305.83^{a}	$2081.73 \pm 1.54.60^{a}$	1675.99 ± 1.40^{a}	1001.29 ± 127.82^{b}	$F_{3,211} = 14.12$***
Herbaceous layer biomass/m^2	640.58 ± 80.60^{c}	502.67 ± 31.45^{d}	1779.81 ± 1.79^{a}	648.49 ± 65.64^{b}	$F_{3,249} = 37.97$***
Tree & shrub diversity	0.42 ± 0.03^{a}	0.29 ± 0.02^{b}	0.30 ± 0.03^{b}	0.25 ± 0.02^{b}	
Tree & shrub density/km^2	293.98 ± 30.43^{a}	242.55 ± 19.20^{b}	140.65 ± 17.99^{b}	82.99 ± 8.37^{c}	$F_{3,249} = 15.64$***
Tree & shrub cover	27.39 ± 2.41^{a}	27.08 ± 1.33^{a}	21.84 ± 2.58^{b}	16.86 ± 2.01^{c}	$F_{3,247} = 9.82$***
Tree and shrub height (cm)	2.58 ± 0.17^{a}	2.79 ± 0.11^{a}	2.59 ± 0.18^{a}	2.01 ± 0.18^{b}	$F_{3,249} = 5.94$***
% Annual grasses	45.54 ± 3.27^{b}	53.73 ± 1.86^{a}	20.47 ± 1.91^{c}	22.84 ± 2.39^{c}	$F_{3,243} = 38.02$***
% Perennial grasses	48.84 ± 3.61^{c}	40.87 ± 1.82^{d}	63.41 ± 3.03^{a}	59.35 ± 3.73^{b}	$F_{3,245} = 10.61$***
	Wet season				
% Grass cover	49.53 ± 2.56^{b}	44.73 ± 1.79^{b}	65.46 ± 4.12^{a}	50.43 ± 4.01^{b}	$F_{3,126} = 7.04$***
Grass diversity	0.88 ± 0.17^{a}	0.65 ± 0.03^{b}	0.69 ± 0.03^{b}	0.51 ± 0.02^{c}	
Grass height (cm)	12.78 ± 2.55^{c}	9.57 ± 0.71^{d}	23.34 ± 2.08^{a}	19.41 ± 1.81^{b}	$F_{3,126} = 8.24$***
Forb cover	27.62 ± 3.48^{a}	18.43 ± 1.06^{a}	9.42 ± 1.85^{b}	8.62 ± 1.57^{b}	$F_{3,122} = 24.21$***
Forb diversity	2.37 ± 0.88^{a}	1.18 ± 0.32^{b}	0.39 ± 0.06^{c}	0.34 ± 0.05^{c}	
Forb height (cm)	26.12 ± 3.24^{a}	24.32 ± 1.18^{b}	18.23 ± 2.81^{c}	14.64 ± 2.53^{d}	$F_{3,126} = 3.73$*
Forb density (ha)	2011.53 ± 462.21^{c}	3754.77 ± 506.36^{b}	1803.38 ± 347.47^{b}	4022.96 ± 852.94^{a}	$F_{3,82} = 2.21$ NS
Herbaceous layer biomass/m^2	439.68 ± 73.45^{c}	917.84 ± 187.59^{b}	2847.31 ± 621.43^{a}	1248.83 ± 291.45^{b}	$F_{3,126} = 2.30$ NS
Tree & shrub diversity	0.42 ± 0.06^{a}	0.20 ± 0.02^{c}	0.28 ± 0.05^{b}	0.16 ± 0.05^{c}	
Tree & shrub density/km^2	237.46 ± 34.02^{a}	188.38 ± 21.60^{b}	139.28 ± 29.19^{c}	69.91 ± 15.02^{d}	$F_{3,126} = 4.54$**
% Tree & shrub cover	35.02 ± 4.18^{a}	30.75 ± 2.66^{a}	21.66 ± 3.76^{a}	13.94 ± 3.28^{c}	$F_{3,112} = 6.29$***
Tree and shrub height (m)	2.59 ± 0.24^{a}	2.88 ± 0.22^{a}	1.89 ± 0.33^{b}	1.48 ± 0.41^{c}	$F_{3,126} = 5.72$**
% Annual grasses	39.29 ± 5.47^{a}	38.88 ± 3.04^{a}	18.94 ± 3.37^{b}	22.63 ± 3.89^{b}	$F_{3,104} = 16.94$***
% Perennial grasses	46.87 ± 5.33^{c}	31.38 ± 2.58^{d}	67.67 ± 6.73^{a}	69.03 ± 6.18^{b}	$F_{3,104} = 8.56$***

The study observed that annual grass diversity, forb cover, forb diversity, forb density, percentage annual grasses; shrub and tree cover, density and height were higher in both CCAs and CGAs in both dry and wet season. On the other hand, PAs and LRs experienced high levels of perennial grass cover, and height as well as dense layers of herbaceous cover year-round. Both findings were contrary to expected patterns. The formation of this dichotomous matrix is likely the result of heavy grazing pressure on CCAs and CGAs compared to PAs and LRs, thinning the perennial grass layer, thus creating many different microhabitats favoring the growth of annual grasses, forbs, shrub, and tree species (Olsvig-Whittaker *et al*., 1993; Shackleton, 2000; Banda *et al*., 2006). Though these vegetation components dominating CCAs and CGAs are associated with increased human activities, they increase biodiversity by creating diverse mosaic of habitats. Moreover, such woody vegetation fosters basic subsistence for local communities and provide economic resources (Gandiwa, 2011) that are central to their livelihood welfare.

5. Conclusions

Our results show that land-use has an effect on vegetation structure and composition in Samburu-Laikipia landscape. However, these effects need not always be considered negative, since forbs, shrub and tree have increased under human disturbances (CCAs and CGAs) in this landscape. These findings suggest that human land-use does not automatically lead to the overall degradation of savanna habitats. By generating a mosaic of habitats, they may improve vegetation conditions at the landscape level. However, these results need to be applied with caution as during prolonged dry season, the loss of most of the ground cover, even if dominated by annuals grasses, and are vulnerable to soil erosion leading to nutrients depletion.

The observed heterogeneity of vegetation structure and composition in the Samburu-Laikipia landscape due to different land-use types appears to be sustaining the areas biodiversity but the mosaic may be fragile. This calls for a need to monitor, and if necessary control, the level of human activities in arid and semi-arid savanna if livestock numbers and natural resource use unbalances the mosaic and leads to biodiversity loss. Such monitoring and possible control can only be achieved if the local communities are involved in both monitoring and decision making.

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