

# Effects of Sicklebush (*Dichrostachys cinerea* (L.) wight and Arn.shrub) Encroachment on Floristic and Vegetation Structure in Semi-arid Savannah of Southern Ethiopia

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## Abstract

Anthropogenic drivers in Protected Areas particularly overgrazing in National Parks may enable the spread of native plant species into non-encroached areas, a phenomenon witnessed with sicklebush (*Dichrostachys cinerea* (L.) Weight and Arn. Shrub) in Semi-arid Savannah Plains of Nech Sar National Park (NSNP). This study was conducted in the Savannah Plains of NSNP, to investigate the effects of sicklebush encroachment on native floristic and vegetation structures. Two sicklebush encroached patches, each greater than one hectare and two adjacent non-encroached sites of the same size were selected randomly to establish sampling units. A total of 32 (10m by 10m) plots were established being eight from each of the four encroached and non-encroached sites. Five 1m by 1m quadrats were laid in each plot to collect vegetation data except for aboveground biomass. Aboveground biomass was clipped from 0.25m<sup>2</sup> sub-quadrats of each quadrat. Species composition, richness, diversity, vegetation live cover, vegetation dead cover, bare ground cover and vegetation height and aboveground biomass were compared between encroached and non-encroached sites. A total of 46 plant species were identified in the study area, of which 27 were found only in non-encroached site and 19 were common for both sites, implying that 58.7% of the species were absent in sicklebush encroached sites. Non-encroached sites harboured a total of 18 families and 43 genera, whereas encroached sites harboured only 7 families and 18 genera. There were significant differences ( $p < 0.05$ ) in species richness, species diversity, species composition, vegetation live and dead cover, vegetation height between encroached and non-encroached areas, with non-encroached areas recording higher values than encroached areas. Vegetation height did not show significant difference between the compared sites for the plant growth forms but it did show for few of dominant species. On the other hand, bare ground cover record was high in encroached areas compared to non-encroached areas. This implies that the native plant species of the savannah plains of the study area were under pressure due to sicklebush encroachment unless treated properly in short term.

**Keywords:** bush encroachment, effect, Nech Sar National Park, savannah, sicklebush encroachment

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## 1. Introduction

Ecologically unsustainable anthropogenic activities such as settlement, agriculture, overgrazing deforestation, coupled with climate change and variability, facilitate plant species encroachments, which have been an established problem of savannahs worldwide (Mudzengi *et al.*, 2014). Savannahs are ecosystem with a continuous grass layer intermixed with a discontinuous tree and shrub layer (Van Langeveld, 2003). Although savannahs are globally important biomes for human being and supporting a high diversity of ungulates, now a day it has been suffering from disproportionate increase in woody plants cover (Van Auken, 2000; Wigley *et al.*, 2009; Munyati *et al.*, 2011; Kgosikoma *et al.*, 2012), a phenomenon well documented as bush encroachment.

The problem of bush encroachment on savannah ecosystem has been increasing globally both in terms of total land area cover and severity of degradation (Gillson *et al.*, 2012). Understanding the effects of such events in our case: sicklebush encroachment on the aforementioned vegetation variables will contribute hugely to pull all efforts together to manage and control the encroaching capacity of *D. cinerea*, which in turn contribute to attainment of the 2030 Convention on Biological Diversity target, which was also assimilated as a new target in the Millennium Development Goals.

In Africa, the main encroaching woody species are thorny trees (e.g. *Acacia drepanolobium* Harms ex Sjusted, *A.reficiens* Willd., *A. seyal* Del., *A. tortilis* Willd., *A. mellifera* (Vahl) Benth. *A. nilotica* (L.) Willd. ex Del., *A. karroo* (Vahl) Benth., *Acacia brevispica* Harms, *Acacia senegal* (L.) Willd., *Acacia albida* Del., and *Dichrostachys cinerea* (L.)Wight and Arn.Shrub) (Kraaij and Ward, 2006). These species also tend to have very high levels of phenolic compounds in their leaves, which reduce their digestibility to livestock and wildlife. The combination of thorniness and low digestibility of Acacia trees and other Fabaceae species reduce their accessibility and natural

value to consumers (Jacobs, 2000).

Sicklebush is the common name of *Dichrostachys cinerea* which is a semi-deciduous to deciduous tree/shrub with an open crown (Orwa *et al.*, 2009). It seems possible that two subspecies can be recognized: *Dichrostachys cinerea subspecies africana* and *Dichrostachys cinerea sub species nyassana*. The latter tends to grow larger and has larger and less hairy leaves and leaflets (Orwa *et al.*, 2009, TTPC, 2010). The generic name ‘Dichrostachys’ means ‘2-coloured spike’, and ‘cinerea’ refers to the greyish hairs of the typical subspecies, which is confined to India; from the Greek ‘konis’ and the Latin ‘cineres’.

Sicklebush is a woody shrub or tree that may adversely affect native herbaceous species plant vigour, basal cover and species richness (Mudzengi *et al.*, 2014). Reduced litter covers of herbaceous and top hamper were also observed in invaded sites. These observations can be attributed to the fast growth, propagation and propagule pressure that characterize sicklebush, giving it a competitive advantage with respect to acquisition of light, nutrients and other resources. Therefore, these adverse effects on herbaceous species may, in the long term, reduce the grazing capacity of savannahs, making them even more susceptible to alien invaders. Biological invaders of sicklebush change ecosystems as they differ from native species in resource acquisition and/or resource use efficiency. They may also alter the trophic structure of the area invaded, or the disturbance frequency and/or intensity (Vitousek, 1990).

Owing to its strong capacity for natural regeneration, the species has high potential for ravine afforestation, wetlands and other soil conservation purposes on difficult sites even though the negative effect overthrow the positive effects in relation to herbaceous plants. Thorn branch enclosures prevent livestock from straying at night and protect vegetable gardens, cash crops and fodder (Gariné-Wichatitsky *et al.*, 2004; Orwa *et al.*, 2009, GISD, 2015). Medium sized *Dichrostachys cinerea* is preferred food item for browsers such as kudu in savannahs. However, the recent study by Simon (2016) revealed that there is no significant correlation between Greater kudu, other ungulates and the densities of *D. cinerea* in the savannah Plains of Nech Sar National Park.

Nech Sar National Park, although established with the aim of conserving endemic and endangered Swayne’s Hartebeest and ecotourism development, is currently encroached by diversified human drivers (Simon, 2016), of which sicklebush encroachment can be mentioned as top challenge. Being fragmented, the plains are becoming a hostile ecosystem for the wild animals to live, which are supposed to attract tourists from around the world. The grass species perhaps being outcompeted by the woody species may not provide enough forage for the animals. As a result, given time allowing the current condition to continue, the Park may become a place where it cannot provide its services to different biodiversity components in and around its vicinity. The aim of this study was to investigate the effects of sicklebush encroachment on floristic and vegetation structures in the semi-arid savannah plains of Nech Sar National Park that may play a role as a base line information for savannah vegetation management.

## 2. Methodology

**2.1. Study area:** This study was conducted in the savannah plains of Nech Sar National Park southern Ethiopia. The savannah plains cover approximately 200 km<sup>2</sup> out of 514 km<sup>2</sup> of the park. The park is located at about 500 km south of Addis Ababa in the Ethiopian Rift valley (Fig. 1).

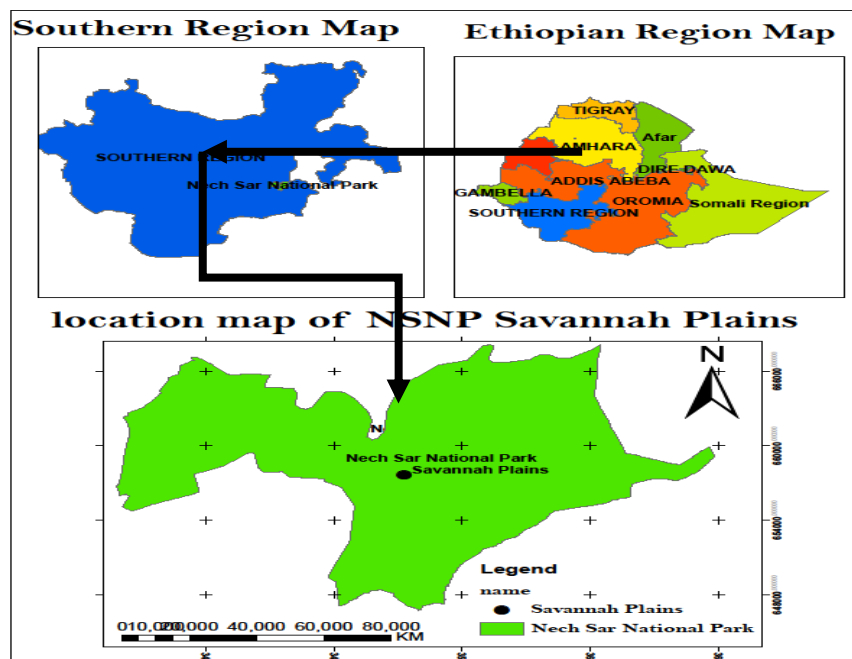


Figure 1: Map of the study area with black dot at the centre showing the location of Savannah Plains.

Geographically, it is bounded at 5051' - 6010'N and 37032' - 37048'E. The plains elevation ranges from 1108 to 1650 m a.s.l at Lake Chamo and the peak of Geda hill, respectively. Overall park area is area cover is 514 km<sup>2</sup> (436 km<sup>2</sup> is terrestrial, 78 km<sup>2</sup> is aquatic and wetland) (Duckworth *et al.*, 1992).

As the Park is located within the monsoon region, the Indian Ocean winds bring the main rains during March - May and the Atlantic Ocean winds bring the short rains during September - November. Mean annual rainfall for the last 28 years is 906.1 mm (Simon, 2016). The mean monthly maximum and minimum temperatures are 33.4°C and 15.2°C in the months of March and December, respectively. Most of the centre of the plains consists of gently undulating grassland with a very few scattered single trees or small bushy clumps and rock areas (Duckworth *et al.*, 1992). Wietse (2013) described a geomorphologic pattern in dominant soils as: Vertisols on the plains, Nitisols, Cambisols on moderate slopes and colluvial areas, Leptosols on escarpments, steep slopes, stony outcrops and colluvial areas and Fluvisols next to the Sermelle and Kulfo River. Vertisols were dominant on the plains.

**2.2. Sampling Design:** Sampling design involved were identifying sicklebush encroached and non-encroached adjacent patches. Accordingly, two patches were selected. Each patch has sicklebush encroached area and the adjacent non- encroached area. In each patch, eight 10 m by 10 m plots were laid for encroached area and another eight plots of the same size were established for non-encroached area, which then totally summed to 32 plots. In each plot, five 1m by 1m quadrats (a total of 160 quadrats) were established systematically to collect pertinent data on species composition, species richness, species diversity, vegetation cover, vegetation height. Aboveground plant biomass was clipped from 0.25m<sup>2</sup> sub-quadrats of each quadrat.

**2.3. Data collection:** Vegetation data took into account the peak growth season in the study area. Within each quadrat, percent live cover and height of grass, shrub, herb and climber were recorded. Vegetation cover was estimated visually (Kent & Coker, 1992). We also estimated the percentage cover of each plant species other than the encroaching species, dead vegetation and bare ground. We measured the maximum height of individuals of each species that attained the maximum height for each growth habit.

Aboveground biomass of grass, shrub, herb and climber were clipped from 0.25m<sup>2</sup> sub-quadrats of each quadrat. We clipped the live plant biomass to the ground level using sickle and put all together in paper bags. However, at camping site, the samples were sorted out into different growth habits and each kept in separate labelled paper bags. The bags were sealed, and sun dried until taken to laboratory for further oven drying. For tussock grasses, we sampled plants rooted within the quadrat whereas for stoloniferous species we included only material that is actually present within the vertical planes of the quadrat borders (Mannetje and Jones, 2000). The samples were further oven dried at 40°C for 72 hours and were monitored until constant weight measurement was obtained at 0.1 g precision (Simon, 2016). The first measurement was taken on the 24<sup>th</sup> hour and the second consecutive measurements were taken after 12 hours, which were then reduced to 6 hours, depending on the nature of the sample. The drying was continued this way until we found constant measurements at least for 3 consecutive readings for one sample as adopted from Simon (2016).

**2.4. Data Analyses:** Data were checked for normality, outliers and homogeneity of variances before analyses as proposed by Zuur *et al.* (2010) and found data to violate these assumptions. We therefore used non-parametric

technique (*Kruskal-Wallis H test*) to test for significance differences in measured vegetation variables between encroached and non-encroached areas. We compared percent live cover, height and aboveground biomass of each plant growth habit, cover and height of each species in the quadrat between encroached and non-encroached sites. Since sorting the clipped samples into species level was practically difficult, we did not analyze biomass to the species level. Species richness (S') was taken as the total number of species recorded. Sorensen's similarity coefficients were calculated to compare species similarity between encroached and non-encroached areas. Shannon Diversity Index was computed and compared between encroached and non-encroached sites. Statistical analyses were performed using XLSTAT version 2015.2.01., R (R Core Team, 2015) and Ecological Methodologies, version 7.2 (Krebs, 2011) as appropriate.

$$\text{Percentage Frequency} = \frac{\text{Number of quadrats or plots in which species occurred} \times 100}{\text{Total number of quadrats or plots}}$$

$$\text{Relative abundance} = \frac{\text{Number of individual species} \times 100}{\text{Total number of individuals of all species}}$$

$$H' = \sum(p_i \ln p_i) \quad \text{Where}$$

H' = Shannon-Wiener Diversity Index

P<sub>i</sub> = the proportion of individuals or the abundance of the i<sup>th</sup> species expressed as a proportion of total cover, and ln = natural logarithm.

To see the evenness (the pattern of distribution) of plants in the study area, Shannon-Wiener evenness Index (E) was calculated using the equation:

$$E = \frac{H'}{H_{\max}} \quad \text{Where;}$$

E = Shannon-Wiener Evenness Index

H' = Shannon-Wiener diversity Index

H max = lnS = natural logarithm of the total number of species (S) in each site

In reference to the composition of species, Sorensen similarity index (SI) was used to assess the similarity of species between two different sites by using the formula:

$$S_s = \frac{2C}{2C+A+B} \quad \text{Where}$$

S<sub>s</sub> = Sorensen similarity index

A = Number of species that occur in site A (encroached for this case)

B = Number of species that occur in site B (non-encroached for this case)

C = Number of common species that occur in site A and B (Joint occurrence)

Agglomerative Hierarchical Clustering techniques were run in the program R to visualize the plant community structure for the merged data of both encroached and non-encroached plots. Percent live cover abundance values of each plant species was used for plant community analysis. The data matrix contained 32 plots and 46 plant species. The plant community types were named after two or three dominant species selected using the relative magnitude of their mean percent cover abundance values.

### 3. Results and Discussion

#### 3.1. Results

##### 3.1.1. Herbaceous species richness, compositions and diversity

A total of 46 plant species were recorded in the study area, of which 27 species were found in non-encroached sites whereas the remaining 19 species were common for both non-encroached and encroached areas. A total of 18 plant families were recorded in the study area, of which only 7 families belonged to encroached sites regardless of the presence of all in non-encroached plots. The relative abundance of plant species were varying between non-encroached and encroached sites for *Chrysopogon plumulosus* (17.6 vs. 14.2), *Bothriochloa insculpta* (16.1 vs. 8.6), *Abutilon figarianum* (9.7 vs. 16.4) in non-encroached and encroached areas, respectively.

Table 1: Species richness, species diversity, species evenness, and Simpson's diversity index comparison between encroached and non- encroached areas

Variables	Non- encroached	Encroached
Species richness	46	19
Shannon diversity Index (H')	4.69	3.55
Species evenness	0.51	0.24
Simpson's diversity index	0.91	0.89

As seen in Table 1 most of the computed parameters were higher in non-encroached areas as compared to encroached areas. The overall Sorensen's similarity coefficient between non-encroached and encroached areas was computed to be 0.59.

##### 3.1.2. Vegetation live cover, dead cover and bare land

As indicated in figure 2, mean vegetation live cover was remarkably high in non-encroached area whereas bare land showed a reverse trend. Dead cover comparison between encroached and non-encroached areas looked



comparable.

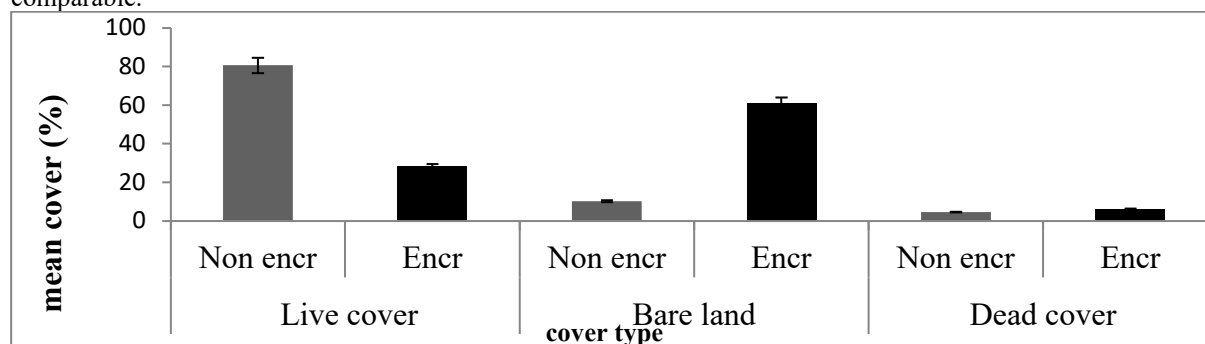


Figure 2: Comparison of mean vegetation live cover, bare land and dead cover between encroached and non-encroached sites. “Non encr” & “Encr” stand for non-encroached and encroached site, respectively.



Figure 3: Pictorial comparison of herbaceous vegetation structure within non-encroached and encroached plots. Native vegetations are much better in non-encroached areas than encroached areas. (Photo: Nov, 2015).

As it can be seen from the table 2, mean cover (%) comparison of common plant species between encroached and non-encroached areas, the mean cover of those common species was high in non-encroached areas as compared to encroached areas except for species such as *Dyschoriste multicaulis*, and *Gomphocarpus phillipsiae*. Table 2: Mean cover (%) comparison of common plant species between encroached and non-encroached sites ( $p < 0.05$ ).

Plant Species	Non- encroached		Encroached		P-values
	Mean cover	Std. Dev	Mean cover	Std. Dev	
<i>Abutilon figarianum</i>	8.51	7.13	2.09	2.29	0.003
<i>Barleria homoiotricha</i>	0.31	0.89	0.05	0.2	0.502
<i>Brachiaria deflexa</i>	0.44	0.81	1.1	1.76	0.286
<i>Bothriochloa insculpta</i>	15.6	13.76	1.06	2.00	<0.0001
<i>Commelina schweinfurthii</i>	0.11	0.27	0.05	0.14	0.591
<i>Chrysopogon plumulosus</i>	17.11	15.71	1.81	2.81	<0.0001
<i>Digitaria macroblephara</i>	1.93	2.98	10.7	1.35	0.158
<i>Dyschoriste radicans</i>	7.11	8.28	0.87	1.26	0.007
<i>Dyschoriste multicaulis</i>	0.39	0.88	0.63	6.18	0.158
<i>Gomphocarpus phillipsiae</i>	0.39	0.48	0.26	0.45	0.368
<i>Indigofera sp.</i>	4.86	3.43	0.39	0.38	<0.0001
<i>Justicia matammensis.</i>	3.29	7.78	1.78	2.75	0.743
<i>Lintonia nutans</i>	1.5	2.06	0.78	1.03	0.969
<i>Otostegia sp.</i>	1.78	2.78	0.04	0.15	0.006
<i>Rhynchosia minima</i>	3.94	2.78	0.84	5.47	0.000
<i>Sehima nervosum</i>	2.34	5.47	0.05	0.14	0.074
<i>Sida alba</i>	0.41	0.74	0.04	0.12	0.138
<i>Tephrosia sp.</i>	2.06	2.23	0.43	0.72	0.014
<i>Triumfetta flavescens</i>	9.26	6.17	0.33	0.74	<0.0001

Figure 4 showed the mean cover comparison of different plant growth habit between encroached and non-encroached areas. In all growth forms the mean cover showed significant difference between the two compared areas ( $p < 0.05$ ).

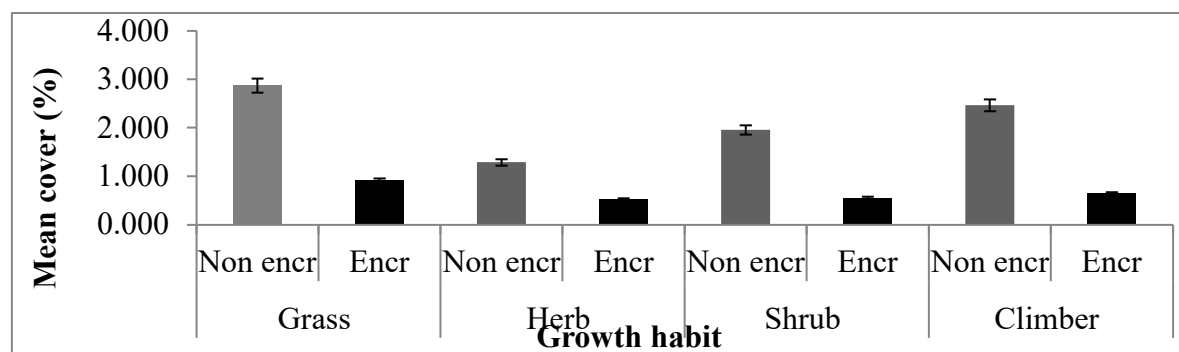


Figure 4: Comparison of mean vegetation cover between encroached and non-encroached areas in the savannah plains of NSNP. “Non encr” and “Encr” stands for non-encroached and encroached sites, respectively.

### 3.1.3. Aboveground plant biomass

Mean aboveground plant biomass of the study area was 343.9 gm<sup>-2</sup>, being 258.4 in non-encroached and 85.5 in encroached areas. The result in table 3 indicated that mean aboveground biomass showed significant differences for grass, herb and climber whereas it was not or shrub (p<0.05) between non-encroached and encroached sites.

Table 3: Mean aboveground plant biomass (gm<sup>-2</sup>) comparison of different plant growth habits between encroached and non-encroached areas in the savannah Plains of NSNP (p<0.05).

Growth form	Non-encroached		Encroached		P-values
	Mean biomass(gm <sup>-2</sup> )	Std.dev	Mean biomass(gm <sup>-2</sup> )	Std.dev	
Grass	152.79	124.2	49.25	20.99	0.001
Herb	86.25	62.6	28.5	16.1	0.003
Shrub	19.3	29.09	5.32	12.1	0.155
Climber	21.1	23.5	2.43	5.29	0.002

### 3.1.4. Vegetation height

Table 4: Mean height (cm) comparison of common plant species between encroached and non-encroached sites (p<0.05).

Plant species	Non- encroached		Encroached		P-values
	Mean height	Std. Dev	Mean height	Std. Dev	
<i>Abutilon figarianum</i>	16.51	13.28	12.54	15.95	0.157
<i>Barleria homoiotricha</i>	0.68	1.91	0.37	1.50	0.551
<i>Brachiaria deflexa</i>	3.00	5.63	3.65	4.36	0.396
<i>Bothriochloa insculpta</i>	25.13	14.76	3.01	4.23	<0.0001
<i>Commelina schweinfurthii</i>	0.35	0.75	1.00	2.73	0.766
<i>Chrysopogon plumulosus</i>	24.44	15.80	7.97	9.19	0.000
<i>Digitaria macroblephara</i>	6.25	8.13	4.60	8.10	0.358
<i>Dyschoriste multicaulis</i>	0.81	1.53	0.26	1.05	0.170
<i>Dyschoriste radicans</i>	7.23	5.65	2.84	3.41	0.010
<i>Gomphocarpus phillipsiae</i>	3.80	4.88	2.23	3.41	0.259
<i>Indigofera sp.</i>	13.29	8.09	5.20	5.35	0.002
<i>Justicia matammensis.</i>	5.44	7.73	4.54	3.57	0.510
<i>Lintonia nutans</i>	7.80	8.79	7.17	7.34	0.969
<i>Otostegia sp.</i>	5.40	6.36	0.26	1.05	0.002
<i>Rhynchosia minima</i>	9.00	4.76	4.00	4.89	0.002
<i>Sehima nervosum</i>	3.58	6.26	0.66	1.89	0.092
<i>Sida alba</i>	1.41	2.72	0.34	0.92	0.193
<i>Tephrosia sp.</i>	5.37	4.39	1.37	2.11	0.003
<i>Triumfetta flavescens</i>	8.84	6.86	1.51	2.63	0.000

As from table 4, mean height of dominant plant species between encroached and non-encroached showed no significant difference (majority of them) and others showed significance difference (p<0.05) in that the mean vegetation height depends on specific species in the area.

Table 5 indicated that the mean vegetation height between encroached and non-encroached site showed no significant differences among growth forms. However, mean height of dominant plant species showed significant difference (almost half of them) (p<0.05) except for species like *Lintonia nutans*, *Commelina schweinfurthii* and *Barleria homoiotricha* (etc.) between encroached and non-encroached sites (Table 4).

Table 5: Mean height (cm) comparison of different growth habits between sicklebush encroached and non-

encroached areas ( $p < 0.05$ )

Growth form	Non-encroached		Encroached		P-values
	Mean	Std. Dev	Mean	Std. Dev	
Grass	5.34	2.57	4.44	3.41	0.142
Herb	2.51	1.06	2.21	1.10	0.291
Shrub	4.28	2.29	3.34	3.11	0.07
Climber	4.84	2.29	4.00	4.89	0.163

### 3.1.5. Plant Community types

Based on mean percent live cover abundance value of each species four plant community types were identified from the hierarchical cluster analysis (Fig. 5). These were *Dyschoriste radicans-Chrysopogon plumulosus* community (Community type 1), *Bothriochloa insculpta-Triumfetta flavescens* Community (Community type 2), *Justicia matammensis-Abutilon figarianum* Community (Community type 3) and *Dyschoriste radicans-Digitaria macroblephara* Community (Community type 4).

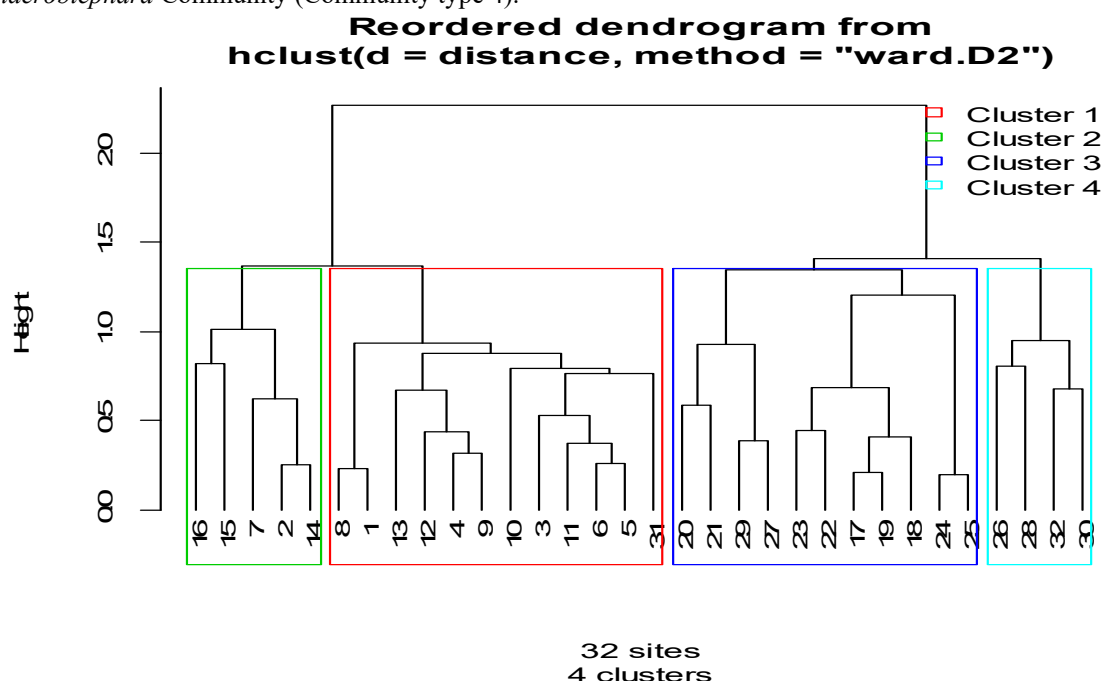


Figure 5: Dendrogram showing plant community types of the study area

Table 6: Diversity index values of different Communities in the study area

Community	Species richness	Shannon index	diversity	Evenness	Remark (figure 5)
1	23	2.53		1.49	Non-encroached
2	15	2.14		1.7	Non-encroached
3	11	2.08		1.45	Encroached
4	7	1.68		1.42	Encroached

From table 6 it is understandable that diversity index values of different community showed decreasing order from non-encroached to encroached sites.

### 3.2. Discussion

In this study a total of 46 plant species were identified. Of these, 27 (58.8%) were absent in encroached sites. On the other hand, only 19 species (41.3%) were common for both sites. The results indicated that all plant species recorded in encroached areas were also identified from non-encroached areas. This may indicate that *D. cinerea* encroachment was affecting the species richness and composition of the savannah plains of NSNP in particular and that of the rift valley system in general. Our result concurs with previous researches (Mudzengi *et al.*, 2014) in reporting the negative effect of sicklebush encroachment on species richness and composition in the savannah ecosystems. Similarly, Sirami and Monadjem (2012) reported that there is significant decrease in species richness associated with shrub cover increase, which was also complemented in our study.

The effects of *D. cinerea* encroachment in species richness decline, particularly to that of herbaceous species observed in this study can be explained in terms of its competitive advantage over the other species. The same justification has been drawn before (Jacoby *et al.* 1982; Mudzengi *et al.*, 2014). It is not only species richness and

composition that was negatively affected by sickle bush encroachment, but also the species diversity as encroached areas exhibited lower species diversity indices (both Shannon-Weiner diversity Index and Simpson's Index) than the non-encroached areas. This is in agreement with Mudzengi *et al.* (2014) and Ayana (2007).

Family-wise, Poaceae exhibited low species richness in encroached areas compared to non-encroached areas whereas Fabaceae showed small difference. From conservation point of view, plants under Poaceae are a key species to grazers on the plains. Most of plant species belonging to the family Fabaceae are often adapt to changes in environment condition. This is due to rapid growth that enables them to overcome potential competitors, adaptability to a wide range of sites, soil types, and ability to coppice (NAS, 1994 cited in Melese Mariyo, 2003). The global reviews of woody plant encroachment suggest that the most damaging species transform ecosystems by using excessive amounts of resources, notably, water, light, and oxygen (Dirkx *et al.*, 2008). Thus, dense stands of woody trees and shrubs in savannahs can rapidly reduce abundance and diversity of herbaceous plants (Joubert *et al.*, 2008).

Our results showed that mean vegetation live cover was high in non-encroached area as compared to encroached areas. Tolsma *et al.* (1987) also reported less than 10% ground cover in *D. cinerea* thickets. Our result showed 52.4% more cover in non-encroached sites compared to encroached sites, which implies the severity of the encroachment status and its effect on other plant species. Bare land analysis followed the reverse trend for the above explanation. On the other hand the condition for dead vegetation cover was in different between the compared sites. The dominance of *D. cinerea* in the Nech Sar Savannah Plains results in decreasing vegetation cover. Jacoby *et al.* (1982) also reported the same condition.

Dense monoculture thickets that are formed by *D. cinerea* can result in a decrease in grazing capacity through loss of grass cover. The reduced abundance of herbaceous species and other ground layer species in our study could also be due to the negative impacts of increased *D. cinerea* canopy cover. Our results revealed that dead vegetation cover was higher in encroached areas. Similar conclusion was made by Xiong and Nilsson (1999). Els (1995) also come up with, the often large differences in litter inputs from invader plants relative to native species lead to reduced decomposition rate and dramatically alters the nutrient cycle in savannah ecosystem. According to Christian (2010) water consumption and evapotranspiration rate by encroachers may be far more than grasses and other herbaceous. Hence, it is expected that encroached area will lose much more water from the soil than an open savannah leading to desertification. As the dead cover was higher under the canopy of sicklebush encroached sites in the study area, we also propose similar scenario.

Mean cover of *B. insculpta*, *C. plumulosus*, *T. flavescens* and *A. figarianum* showed significant difference between encroached and non-encroached areas whereas others did not. The negative correlation of herbaceous plants coverage, with *D. cinerea* is a real challenge for conservation efforts of the park. Simon (2016) made the same conclusion concerning the problem of bush encroachment in the savannah plains of Nech Sar National Park. This is not only from foraging point of view, but also from point of view of ecotourism development. An increase in woody plant density within savannahs may have negative impact on conservation, ecosystem functions, tourism and on livelihoods of the local communities (Trollope; 1980, Oba *et al.*, 2000; Smit, 2004; Asner *et al.*, 2004; Britz and Ward, 2005; Gemedo *et al.*, 2006; Wigley *et al.*, 2010) in general. Although there are positive contribution of encroaching species such as legumes in soil fertility, these impacts will not overweigh negative impacts such as loss of biodiversity (Parr *et al.*, 2012), rangeland degradation, reduced grazing capacity, injuries to livestock and wildlife due to thickets prickling (Lange *et al.*, 1997).

In dealing with further effect of *D. cinerea*, aboveground vegetation biomass was included as a parameter. Estimates of aboveground biomass production of a given site are an important aspect in assessing wildlife habitat, forage availability, and ecological relationships and processes (Catchpole and Wheeler, 1992) cited in Eric (2013). Having this link in mind, the mean aboveground plant biomass of the study area was 343.9 gm<sup>-2</sup>, being 258.4 in non-encroached and 85.5 in sicklebush encroached plots, showing significant difference between encroached and non-encroached areas. This was true for grass, herb and climber but not for shrub. Grass contributed 58.7% of the overall mean plant biomass, of which 44.4% was in non-encroached plots and 14.3% in encroached plots. This shows that bush encroachment affects biomass production of grass species which is very important from grazing point of view. On the other hand, herb and climber contribute 33.4% and 6.8% of the aboveground biomass, respectively. The low aboveground plant biomass in sicklebush encroached site is also complemented by various studies (e.g. Dean and Macdonald, 1994; Jacobs, 2000; Smit, 2004).

Mean vegetation height between encroached and non-encroached site showed no significant differences in terms of growth habits. However, this was not the case for individual species. For example *B. insculpta*, *C. plumulosus*, *T. flavescens*, *Indigofera sp.*, *Otostegia sp.*, *D. radicans*, and *R. minima* showed significance difference whereas the rest did not. Bush encroachment, since it lowers grazing capacity, affects plant height and, this reduces wildlife abundance (Dean and Macdonald, 1994; Jacobs, 2000; Smit, 2004), is a global concern. One indicator for savannah degradation is a decrease in vegetation height (Tobler *et al.*, 2003) although the height of the vegetation was comparable except for individual species as pointed earlier.

In the disturbed ecosystem the effect is not only at plant growth form or at species level, but it may go further



to the community level (Hoffman and Zeller, 2005). In the identified communities, species with higher mean cover values are those that were easily observed repeating themselves in associations. Thus, the identified groups are more or less coincides with the natural associations that one can observe while crossing the park. There was variation in species richness, species evenness and species diversity among community types that may emanate from encroachment. Changes of habitat structure and complexity have been reported to be associated with changes in community structure and species richness in the ecosystem (Hoffman and Zeller, 2005).

Sicklebush dominated areas that were in community 3 and 4 showed lower species richness, Shannon diversity index and species evenness compared to community 1 and 2. In contrast, the community type 1 and 2 exhibited higher species number and diversity. The result was consistent with other studies which reported that savannah ecosystems which shift to bush encroachment may bring about changes in species composition and a total biome shift (e.g. Higgins *et al.*, 2000, Bond *et al.*, 2003; Ludwig *et al.*, 2004; Bond *et al.*, 2005; Sankaran *et al.*, 2005; Govender *et al.*, 2006) and lose their ecosystem functioning and services.

#### 4. Conclusions

*D. cinerea* is a native woody shrub or tree that maximizes its biological advantage to encroach savannah ecosystems. It adversely affected native grass, herb and climber species of the savannah plains of the park. The dominance of *D. cinerea* in the savannah plains of NSNP had negative effect on the herbaceous and other understory vegetation composition, species richness, diversity, cover, aboveground plant biomass and structure of the community as a whole. The results revealed that these parameters were remarkable different between encroached and non-encroached sites, being low in encroached areas. Moreover, with the existing trend of increasing *D. cinerea* density, we projected that the negative effect would be stronger and could have negative effect on future efforts of both conservation and tourism development. An increasing pressure of humans and cattle will continue in threatening savannah plains enhancing the fast growing patches of *D. cinerea* if not controlled properly and it cannot be suitable conservation point of view.

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