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Impacts of *Prosopis juliflora* on Abundance and Species Diversity of Forage Species in Turkana County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author NEC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AH and OJ managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study sought to determine the effects of *P. juliflora* on the abundance and relative diversity of other forage species in Turkana County.
Study Design: Ecological data collection entailed cross-sectional surveys across riverine and non-riverine ecosystems.
Place and Duration of Study: The study was undertaken in three sub-counties within Turkana County namely Turkana Central, Turkana West and Turkana South between 15th January to 17th May, 2020.
Methodology: Sampling plots were used to collect plant abundance data from the various parts of the study area. The plots were of three types; main plots of 30 m× 40 m (1200 m^2), sub-plots of 5 m × 2 m (10 m^2) and square quadrats of 1 m×1 m (1 m^2). The sub-plots and quadrats were nested within the main plots which were in turn laid down along transect belts. The transects of width 40 m

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and 400m in length were laid down in two main habitats (riverine and non-riverine) of the three sub-counties. Control plots were also laid in non *P. juliflora sites.*

Results: *Prosopis juliflora* was the most abundant species covering about 63% of the sampled individuals (N=6390). This was followed by Acacia tortilis at 18% while *Acacia mellifera* was the least. There was significant difference in abundance between sites and among counties ($p<0.05$). The Shannon diversity index (H´) in areas with *Prosopis juliflora* ranged between 0.40-1.27 while in areas without *Prosopis juliflora* (or Control) it ranged between 1.5-2.1, indicating high diversity in the areas without *P. juliflora* compared to areas colonized by it. *Prosopis juliflora* was also high in the riverine areas compared to non-riverine areas across the three sub counties. Results show that *Prosopis juliflora* has invaded vast areas especially the riverine ecosystem leading to a decline in the population of key forage species and thus threatening the socio-economic livelihoods of Turkana County.

Conclusion: *Prosopis juliflora* was the most abundant and dominant plant species in both the riverine and non-riverine sites. The study also showed that *P. juliflora* has led to the decreased plant species richness and diversity in the area because of its invasive nature.

Keywords: Prosopis juliflora; invasive shrub; arid and semi-arid lands; arid-land forage; Turkana.

1. INTRODUCTION

Prosopis juliflora is a perennial deciduous thorny shrub commonly found in arid and semi-arid lands (ASALs) but native to South America, Central America and the Caribbean, where it is known as Mesquite or Algarrobo [1]. The plant can grow up to a height of 10 meters tall. *P. juliflora* grows in very dry and harsh conditions where virtually no other trees can grow hence ensuring self-sufficiency in fodder for livestock and food for humans, fuel wood and timber [1,2]. In addition, the species makes the fragile arid and semi-arid environments more habitable, thus mitigating against the impacts of drought, famine and climate change.

Prosopis juliflora was first introduced to Africa in 1822 in Senegal followed by South Africa in 1880 and Egypt in 1900 [3]. The plant was introduced into Kenya in the late 1970s by the National Irrigation Board (NIB), in collaboration with the Finland government to help in solving environmental and energy problems in irrigation schemes within the ASALs [4]. In 1983, the plant was introduced in Marigat in Baringo District during the Baringo Fuel Wood Afforestation Extension Project by the World Bank, Food and Agricultural Organization (FAO) and Government of Kenya (GoK) [5]. The aim of this introduction was to help mitigate desertification and fuel wood shortages in the arid and semi-arid lands (ASALs) [6]. The plant was preferred in this region because of its drought tolerance, resilience, fast growth, source of fodder and fuel wood [5]. Unfortunately, the invasion of the *P. juliflora* species was not managed hence became invasive, causing ecological, economic and social impacts that included reduced pasture production on grazing lands and loss of biodiversity among others. Further planting of the tree was stopped in the early 1990s when its invasive characteristics were noticed [4]. In Turkana County where the study was undertaken, *Prosopis juliflora* was introduced in 1979 by the Government of Kenya (GoK) and Norwegian Agency for Development Cooperation (NORAD) through the Turkana Rehabilitation Project [4]. However, the species has been termed as a nuisance as it continues to invade millions of hectares of rangelands [7].

It was purposely introduced in Turkana County to help mitigate desertification, fuel wood and fodder shortages. The plant however turned invasive and has since colonized vast areas of the pastoral rangelands heavily colonizing areas along the water courses especially along River Turkwell, River Kerio and on the western shores of Lake Turkana [8]. The plant has heavily invaded some parts of Turkana County including Letea ward, Songoti ward, Lokangai, Loriu, Kalokol, Lotubai, Katilu, Nanam, Turkwell and Kerio [9].

Previous studies have associated *P. juliflora* invasiveness with reduced diversity of the native plant species growing in the same ecosystem [8]. According to [10] and [11], invasion of alien species is one of the key drivers of biodiversity loss which consequently disrupts the ecological integrity and ecosystem functioning of a place. In 2004, International Union for the Conservation of Nature (IUCN) rated *P. juliflora* among the world's top 100 least wanted plant species because of its invasive nature [12]. From a study done in south Africa, ecosystem services such as water supply and grazing potential mostly in arid areas are clearly affected by Prosopis invasions [13,14,15]. Further negative effects are noted on bird and insect species richness and composition in the Kalahari [16]. Prosopis has been proven to increase the mortality of a keystone tree species for instance the *Acacia erioloba* in the Kalahari Desert [17]. All of these studies have been limited to small areas or single sites and there is a need for more extensive surveys to establish both the nature of the invasions, and the degree of impact that they are having in different habitats. Such information would be necessary for estimating the impacts of *Prosopis* over large spatial areas, and for informing large-scale management strategies. This study therefore aimed at evaluating the impact of *P. juliflora* invasion on forage plant species diversity in Turkana County of Kenya in both riverine and non-riverine areas. This was more so given that this region is a pastoralists' area with a fragile ecosystem of sparse vegetation.

2. MATERIALS AND METHODS

2.1 Study Area

The study was undertaken in the three sub counties of Turkana West, Turkana Central and Turkana South in Turkana County where *Prosopis juliflora* is predominant especially along the riverine regions where the soils are fertile because of alluvial deposition with sufficient moisture. Turkana County falls within the Arid and Semi-arid ecological zone experiencing a mean annual temperature of 29.3ºC and mean annual rainfall of 180 mm [18]. The area has scarce vegetation cover predominated by acacia woodlands [18]. The locals in the county are nomadic pastoralists and depend on livestock for their livelihoods [19].

2.2 Study Design

A cross-sectional survey was used to collect data on the impact of *Prosopis juliflora* on the abundance and species diversity of forage plants. Sampling plots were laid to collect data on plant abundance from the various parts of the study area. The plots were of three types; main plots of 30 m × 40 m (1200 m^2), sub-plots of 5 m × 2 m ($10m^2$) and square quadrats of 1 m×1 m ($1m^2$). The sub-plots and quadrats were nested within the main plots which were in turn laid down along transect belts. The transects of width 40 m and 400m in length were laid down in two main habitats (riverine and non-riverine) of the three sub-counties (Fig. 1). For control purposes, plots were also laid in sites colonized by *P. juliflora* and sites free from *P. juliflora.*

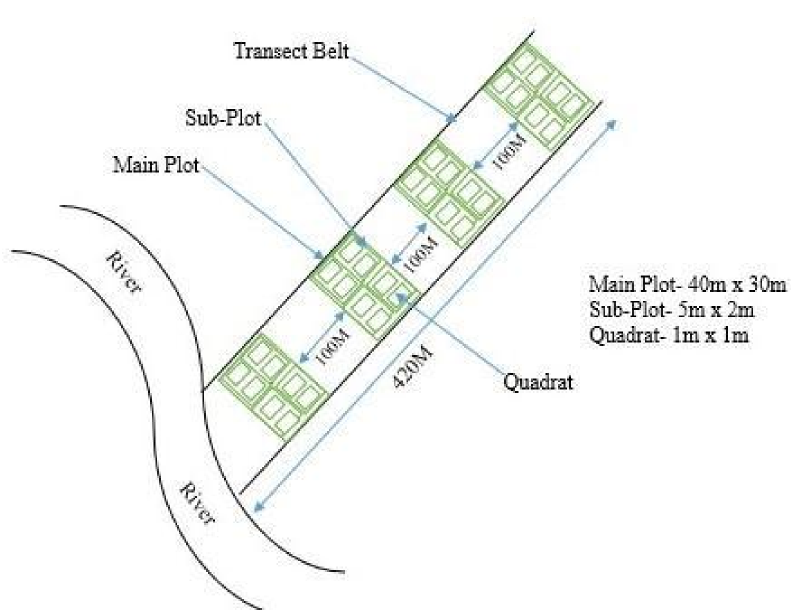

Fig. 1. A schematic diagram showing the laid out transects, main plots, sub-plots and quadrats in a given habitat (not to scale)

Each transect belt had four main plots. Within each main plot, four sub-plots and two 1m^2 quadrats were laid within each sub-plot (Fig. 1). This resulted to a total of 32 main plots, 128 sub-plots and 256 one-meter square quadrats for the entire area. The main plots were laid on the belt transect at a distances of 100 m apart while the subplots and quadrats were randomly placed within the main plots. Within the main plots, all large trees with diameter at breast height (DBH) greater than 10 cm, were identified, counted and their DBH measured using a diameter tape. Within the sub-plots, trees with DBH between 2-10 cm were identified and counted. In the 1m^2 quadrats, all seedlings were identified and counted. Any unidentified tree/plant species in the sampled plots had its leaves and flower specimen collected and preserved as a herbarium specimen for further identification by a taxonomist in the Masinde Muliro University laboratory.

2.3 Species Diversity

Species diversity per ecological area was calculated using the Shannon diversity index

$$H = -\sum_{i=1}^{S} Pi\ In\ Pi$$

where:

H' is diversity index,

P_i is the proportion of (n/N)
In is the natural log
ε summation of the calculations

2.4 Data Analysis and Presentation

Analysis of data was done using the PASWs Statistical Package version 20. Plant diversity was calculated by using the Shannon Wiener diversity index. Analysis of variance (ANOVA) was determined to establish whether there was a difference in plant abundance and diversity between sites and among the sub-counties at 95% confidence interval. The analyzed data was presented using tables, figures and graphs.

3. RESULTS

3.1 Trees Species Abundance

A total of (N = 6390) trees, saplings and seedlings of 19 different species were sampled from the three study sites of Turkana Central, Turkana South and Turkana West. The sampled species were of trees (DBH>10 cm), saplings (DBH 2-10 cm) and seedlings. For the three sub counties cumulatively, *Prosopis juliflora* was the most abundant (63%) of the total species followed by *Acacia tortilis* at 18%. *Acacia melifera,* which was observed in the surveys, was the least abundant with less than 1% of the total species in the area (Fig. 2).

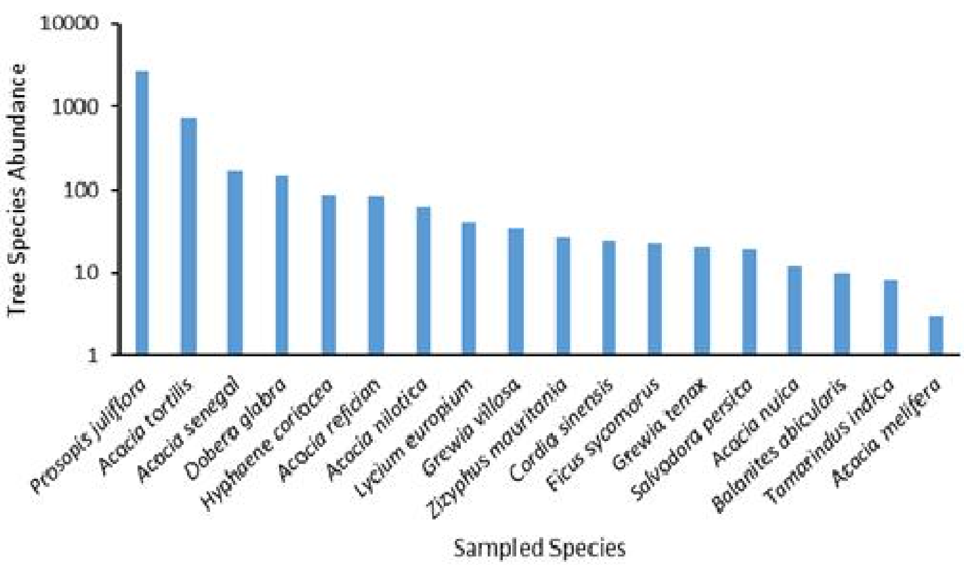

Fig. 2. A ranked abundance of tree species in Turkana Central, Turkana West and Turkana South Sub-Counties

3.2 Tree Species Diversity and Richness

3.2.1 Tree species diversity and richness in Turkana Central Sub-county

In Turkana central, among the tree species with DBH > 10 cm; *Prosopis juliflora* was the most abundant with about 69.6% (n = 374) of the individuals in the riverine region and 82.3 % (n = 79) of the total species in the non-riverine region. *P. juliflora* also was the most abundant among the saplings DBH (2-10cm) and seedlings (DBH < 2cm). This comprised of 59% (n = 154), 41% (n = 149) in the riverine and 85% (n = 79), 97% (n = 33) in the non-riverine respectively (Table 1). The second most dominant species in the riverine and non-riverine areas was *Acacia tortilis.* Other dominant trees but confined to the riverine areas included *Hyphaene coriacea*, *Zizyphus mauritania* and *Ficus sycomorus.* These species are important for the pastoralists as they are among the good fodder species for their browsing goats. Other than *Acacia tortilis*, the last four mentioned species showed very low numbers of seedlings (i.e. DBH<2cm) in the riverine areas and non in the non-riverine areas. This means that their regeneration was very poor, and particularly in the non-riverine areas where a whopping 97% of the seedlings on the habitat floor were *Prosopis juliflora*. The latter colonised the entire open landscapes and the understorey of growing saplings and trees that were found in the dry none riverine areas.

3.2.2 Tree species diversity and richness in Turkana west Sub-county

The pattern of tree species distribution in Turkana West was similar to that in Turkana Central. Here among the trees (DBH > 10 cm), *P. juliflora* was again the most abundant at 84.5% (n = 463) of the total individuals in the riverine region but third in the non-riverine region with only 17% (n = 18) of the total abundance. *P. juliflora* also was the most abundant among saplings of DBH (2-10 cm) and seedlings of DBH < 2 cm which comprised of 90.4% (n = 322) and 56.6% (n = 158) in the riverine respectively. An interesting observation in the non-riverine areas was that *Acacia reficiens* was the most abundant species among the saplings (DBH 2-10 cm) and seedlings (DBH < 2 cm) while *Acacia tortilis* was dominant for the large trees (DBH > 10cm), (Table 2). The high number of seedlings of *Acacia reficiens* compared to *P. juliflora* could suggest that the former may be only species that may counteract the dominance of the invasive *P. juliflora* in this region.

3.2.3 Tree species diversity and richness in Turkana South Sub-county

Among the trees (i.e. DBH >10 cm) in Turkana South, *P. juliflora* was the most abundant with about 52% (n = 344) of the total tree species in the riverine region but its population declined from the riverine habitat towards the non-riverine habitat where the other species dominated. *P. juliflora* was also the most abundant species among the saplings and seedlings of all tree species in both the riverine and non-riverine sites (Table 3).

3.2.4 Tree species abundance, diversity and richness in the control Plot

In the sites without *Prosopis juliflora* (Control), there were no specific most abundant species in both the riverine and non-riverine regions. Generally, the big trees (DBH >10 cm in the riverine region) ranged between 3.2% to 24.9%, 1.1% to 23.4% for the saplings and 1% to 35% for the seedlings. In the non-riverine sites, among the big trees, *Acacia tortilis* had the highest percentage at (22%) followed by *Acacia senegal* at 18%. *Ficus sycomorus* was the least at 12%. Among the saplinggs and seedlings, there was no specific abundant species as most ranged between 20-27% (Table 4).

The abundance of *P. juliflora* in the three sub-counties were subjected to ANOVA and the results showed significant difference in abundance between the riverine and non-riverine sites across the sub counties (F =5.857, p = 0.006). *P. juliflora* abundance did not significantly vary in the riverine sites across the three sub-counties (p = 0.06). The abundance of *P. juliflora* did not also vary in the non-riverine sites across the three sub-counties (p =0.06).

3.3 Species Distribution

3.3.1 Tree species distribution in the riverine sites

The study results showed that *Prosopis juliflora* was more abundant in both the riverine and non-riverine sites. In the riverine sites, the *P. juliflora* population was high close to the river banks and reduced as the distance from the riverbanks increased (Fig. 3). The opposite was the case with population of the other species which was low in areas close to the riverine but increased as the distance from the riverbank increased (Fig. 3).

Table 1. Trees species abundance and diversity in Turkana Central riverine and non-riverine regions

	Turkana central		**Riverine**						**Non-riverine**					
S. No	**Species SCD in each ecological area**	**Type (F=Forage, NF=Non forage)**	**N**	**(DBH >10cm)%**	**N**	**(DBH 2-10 cm) %**	**N**	**DBH <2 cm)%**	**N**	**(DBH >10 cm)%**	**N**	**(DBH 2-10cm)%**	**N**	**DBH <2cm)%**
01	*Prosopis juliflora*	NF	364	69.6	154	59.0	149	41.2	79	82.3	29	85.3	33	97.1
02	*Acacia tortilis*	F	79	15.1	54	20.7	166	45.9	5	5.2	2	5.9	1	2.9
03	*Dobera glabra*	F		-		-		-		-		-		-
04	*Balanites orbicularis*	F		-		-		-	5	5.2	2	5.9		-
05	*Acacia senegal*	F		-		-		-	2	2.1	1	2.9		-
06	*Acacia melifera*	F		-	1	0.4		-	2	2.1		-		-
07	*Ficus sycomorus*	F	21	4.0	1	0.4		-		-		-		-
08	*Cordia sinensis*	F		-		-	5	1.4	1	1.0		-		
09	*Tamarindus indica*	F		-		-		-		-		-		-
10	*Hyphaene coriacea*	F	36	6.9	18	6.9	19	5.2		-		-		-
11	*Salvadora persica*	F	3	0.6	5	1.9	1	0.3	2	2.1		-		-
12	*Lycium europium*	F		-	22	8.4	19	5.2		-		-		
13	*Zizyphus Mauritania*	F	20	3.8	6	2.3		0		-		-		
	Species richness			**6**		**8**		**6**		**7**		**4**		**2**
	Shannon diversity			**1.01**		**1.24**		**1.11**		**0.76**		**0.57**		**0.13**

Table 2. Trees species abundance and diversity in Turkana West riverine and non-riverine regions

	Turkana West					Riverine						Non-riverine		
S. no	**Species SCD in each ecological area**	**Type (F=Forage, NF=Non forage)**	**N**	**(DBH >10 cm%)**	**N**	**(DBH 2-10 cm%)**	**N**	**DBH <2 cm%)**	**N**	**(DBH >10 cm%)**	**N**	**(DBH 2-10 cm%)**	**N**	**DBH <2 cm%)**
01	*Prosopis juliflora*	NF	463	84.5	322	90.4	158	56.6	18	17.5	12	26.7	16	25.4
02	*Acacia tortilis*	F	35	6.4	9	2.5	85	30.5	-	-	1	2.2		0.0
03	*Acacia nilotica*	F	-	-	-	-	-	-	38	36.9	7	15.6	16	25.4
04	*Acacia reficiens*	F	-	-	-	-	-	-	30	29.1	22	48.9	31	49.2
05	*Acacia nuica*	F	-	-	-	-	-	-	11	10.7	1	2.2	-	-
06	*Dobera glabra*	F	-	-	-	-	-	-	-	-	-	-	-	-
07	*Balanites abicularis*	F	1	0.2	-	-	-	-	-	-	-	-	-	-
08	*Acacia senegal*	F	33	6.0	10	2.8	26	9.3	6	5.8	2	4.4	-	-
09	*Grewia villosa*	F	13	2.4	15	4.2	-	-	-	-	-	-	-	-
10	*Grewia tenax*	F	-	-	-	-	-	-	-	-	-	-	-	-
11	*Cordia sinensis*	F	2	0.4	-	-	-	-	-	-	-	-	-	-
12	*Tamarindus indica*	F	-2	-	-	-	-	-	-	-	-	-	-	-
13	*Hyphaene coriacea*	F	1	0.2	-	-	10	3.6	-	-	-	-	-	-
	Species richness			**7**		**4**		**4**		**5**		**6**		**3**
	Shannon diversity			**0.62**		**0.42**		**1.02**		**1.44**		**1.30**		**1.06**

Table 3. Trees species abundance and diversity in Turkana South riverine and non-riverine regions

	Turkana South					**Riverine**						**Non-riverine**		
S. no.	**Species SCD in each ecological area**	**Type (F=Forage, NF=Non forage)**	**N**	**(DBH >10 cm (%)**	**N**	**(DBH 2-10 cm (%)**	**N**	**DBH <2 cm (%)**	**N**	**(DBH >10 cm (%)**	**N**	**(DBH 2-10 cm (%)**	**N**	**DBH <2 cm (%)**
01	*Prosopis Juliflora*	NF	344	52.2	199	66.8	152	54.7	50	54.3	21	60	39	97.5
02	*Acacia Tortilis*	F	136	20.6	63	21.1	95	34.2	5	5.4	3	8.6		-
03	*Dobera glabra*	F	115	17.5	15	5.0	14	5.0		-		-		-
04	*Balanites abicularis*	F		-		-		-		-	2	5.7		-
05	*Acacia Senegal*	F	19	2.9	18	6.0	8	2.9	35	38.0	6	17.1	1	2.5
06	*Grewia Villosa*	F	5	0.8		-	2	0.7		-		-		-
07	*Grewia tenax*	F	18	2.7		-	2	0.7		-		-		-
08	*Cordia sinensis*	F	14	2.1		-	1	0.4		-	1	2.9		-
09	*Tamarindus indica*	F	6	0.9	2	0.7		-		-		-		-
10	*Hyphaene coriacea*	F	1	0.2		-	2	0.7		-		-		-
11	*Salvadora persica*	F	1	0.2	1	0.3	2	0.7	2	2.2	2	5.7		-
	Species richness			**10**		**6**		**9**		**4**		**6**		**2**
	Simpson diversity			**1.35**		**0.97**		**1.11**		**0.94**		**1.25**		**0.12**

Table 4. Trees species abundance and diversity in riverine and non-riverine sites without *Prosopis juliflora* (control)

Control(Sites without *Prosopis*)			Riverine						Non-riverine					
S. no	**Species SCD in each ecological area**	**Type (F=Forage, NF=Non forage)**	**N**	**(DBH >10 cm%)**	**N**	**(DBH 2-10 cm%)**	**N**	**DBH <2 cm%)**	**N**	**(DBH >10 cm%)**	**N**	**(DBH 2-10 cm%)**	**N**	**DBH <2 cm%)**
01	*Acacia melifera*	F	140	24.9	44	5.5	20	10.0	-	-	-	-	-	-
02	*Acacia senegal*	F	-	-	-	-	-	-	35	18.3	90	20.7		
03	*Acacia tortilis*	F	-	-	188	23.4	71	35.3	42	22.0	118	27.1	39	40.6
04	*Balanites orbicularis*	F	28	5.0	60	7.5	7	3.5	25	13.1	15	3.4		
05	*Cordia sinensis*	F	92	16.4	116	14.4	13	6.5	34	17.8	94	21.6	19	19.8
06	*Dobera glabra*	F	72	12.8	112	13.9	39	19.4	-	-	-	-	-	-
07	*Ficus sycomorus*	F	18	3.2	3	0.4	-	-	24	12.6	12	2.8	-	-
08	*Grewia villosa*	F	80	14.2	88	11.0	15	7.5	-	-	-	-	-	-
09	*Hyphaene coriacea*	F	18	3.2	17	2.1	5	2.5	-	-	-	-	-	-
10	*Salvadora persica*	F	36	6.4	68	8.5	16	7.8	29	15.2	106	24.4	38	39.6
11	*Tamarindus indica*	F	60	10.7	96	12.0	13	6.5	-	-	-	-	-	-
12	*Zizyphus mauritania*	F	18	3.2	9	1.1	2	1.0	-	-	-	-	-	-
	Species richness			**10**		**11**		**10**		**6**		**6**		**3**
	Simpson diversity			**2.08**		**2.11**		**2.0**		**1.77**		**1.60**		**1.05**

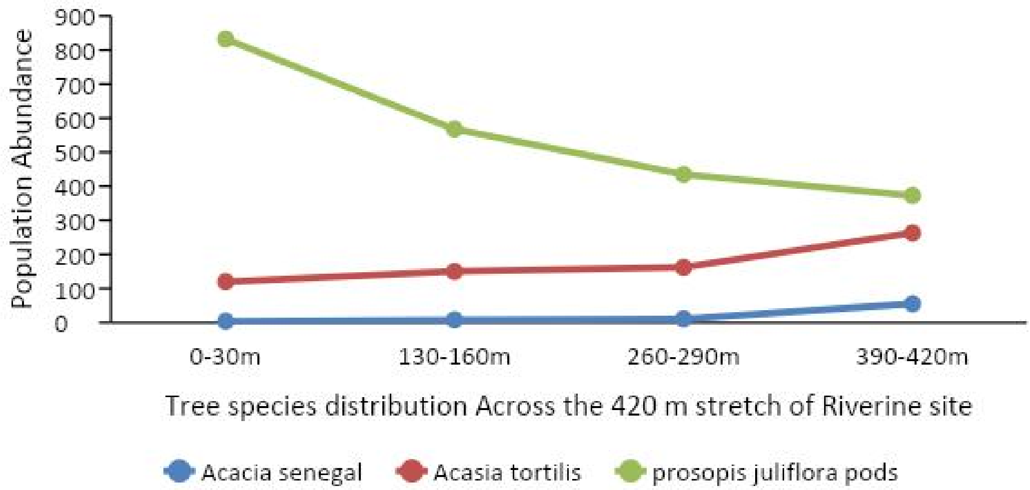

Fig. 3. Representative of tree species distribution in the riverine sites of Turkana County

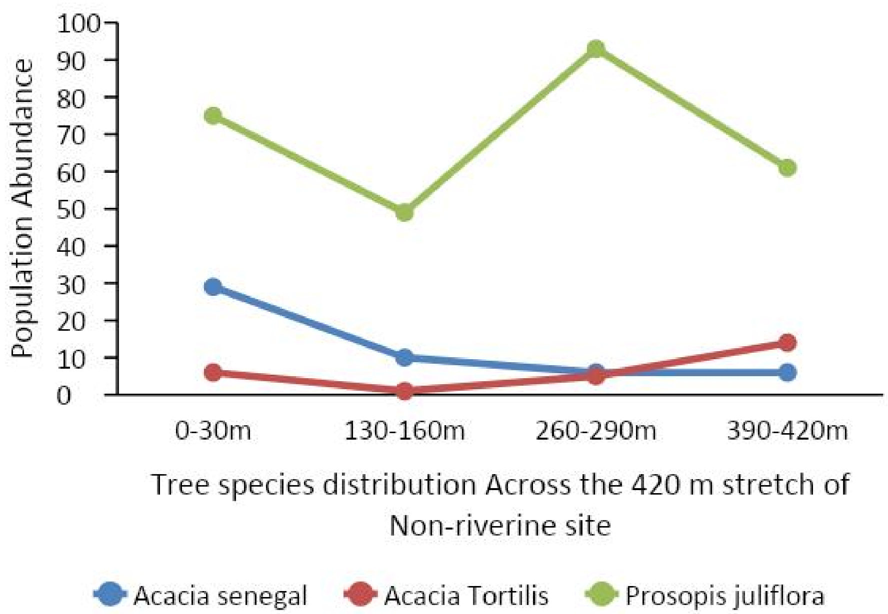

Fig. 4. Tree species distribution in the Non-riverine sites of Turkana County

3.3.2 Tree species distribution in the Non-riverine sites of Turkana County

In the non-riverine sites, the population of *Prosopis juliflora* was evenly distributed across the area which was the cases with the other species as shown by the selected species (Fig. 4). It was also noted that population of all the species were much lower in the non-riverine sites as compared to the riverine sites.

4. DISCUSSION

4.1 Tree Species Abundance

The high abundance of *Prosopis juliflora* in the riverine and non-riverine sites of Turkana County concur with the findings reported in other regions of Kenya like Baringo and Marigat [5]. The dominance of *Prosopis Juliflora* in the three sub counties has led to reduction of forage species which are beneficial to livestock production. The high spread and growth of *P. juliflora* in the ASAL areas was attributed to its ability to withstand the hardy conditions of the region [5,20]. The plant's ability to produce many seeds all year round is also a factor behind its high regeneration and abundance [20]. A single mature tree is estimated to produces approximately 630,000 to 980,000 seeds per year [21]. The high percentage of seed germination, successful mechanisms of dispersal and adaptability to a wide range of ecological conditions are among the driving factors to its widespread distribution and abundance [22]. Several studies have reported that Prosopis juliflora suppresses the growth of Acacia spp as it suppresses the other native species [3,23]. This suggests that Prosopis was able to out compete native plants for limited resources, such as light and water [24,25]. The peculiar phenomenon seen in Turkana west where Acacia species outnumbered Prosopis could be attributed to the stringent measures put in place to preserve the indigenous species and only allowing the locals to use *Prosopis* as firewood in the Kakuma refugee camp [26].

4.2 Species Richness and Diversity

This domination by one species at the expense of all the other fodder species is likely to be driven by several processes that include allelopathy often observed with tree [23,26]. It is this one factor of over domination of the regeneration of dryland ecosystems in Turkana by *Prosopis juliflora* that remains the biggest threat to the socio-ecology of this region. This concerning threat is further indicated by four species (*Dobera glabra, Balanites orbiculari, Grewia villosa, Grewia tenax* and *Tamarindus indica*), which although common in the past, were completely absent in both the riverine and non-riverine areas.

This indication of reduced diversity in the areas colonized by *P. juliflora* could suggest the negative influence of *P. juliflora* on the regeneration and establishment of other native species in the region. This asserts the findings of [27] and [28] which showed that invasion of *Psidium guajava L* against selected native tree species in Kakamega Tropical Forest is key driver of biodiversity loss consequently disrupting the ecological integrity and ecosystem functioning of a habitat. This is also the case in Turkana County where introduction of *Prosopis juliflora* with the intention of rehabilitating the area has led to the reduction of species diversity of other plants that initially existed in the area.

For instance, before the introduction of *P. juliflora*, there existed tree species like *Acacia mellifera*, *Balanites orbicularis, Balanites orbicularis, Cadaba rofundifolia, Commiphora Africana, Dobera glabra, Doum palm, Euphorbia magnicapsula, Grewia bicolour, Grewia tembensis, Hyphaene coriacea, Lawsonia inermis, Salvadora persica, Tamarindus indica, Ximenia caffra* which are have gone locally extinct since the introduction of *Prosopis juliflora*. The results concur with the other findings that associated *P. juliflora* species with reduced species diversity [8,11].

The plant has become invasive because of its massive seed production throughout the season and its mode of dispersal, which is mainly through livestock and water [29]. *Prosopis* has also been reported to smoother plants underneath because of its canopy which is thicker than those of other arid plant species like *Acacia* [25]. It is also believed that *Prosopis juliflora* has allelopathic effects that hinder the growth of the native plant species [30,31]. Research in other areas around the world have shown that *Prosopis* is more superior to the native plant species in terms of competition for the limited resources [24,32].

4.3 Species Distribution

The abundance of *Prosopis juliflora* was higher in the riverine sites as compared to the dry non-riverine areas mainly because of sufficient water for growth as well as high soil nutrition as a result of siltation within such sites [33,34]. In Turkana, most of the enriched nutrient soils that causes siltation are carried by the Turkwel River from the upland farming region in West Pokot [35]. Given this siltation, and the general trend of increased abundance of *P. juliflora* from the riverine areas towards the drier zone, it is likely that more infestation and colonization of the streams that drain into the Turkwel River will be infested with *P. juliflora*. The high *Prosopis juliflora* abundance in the riverine areas is also attributed to the fact that these areas are the convergent zone for most agents of dispersal mainly livestock and water [32,36].

5. CONCLUSION

The abundance of *P. juliflora* population was high close to the river banks and reduced as the distance from the riverbanks increased. In the non-riverine sites, the population of *Prosopis juliflora* was evenly distributed across the area which was the cases with the other species. The abundance of *Prosopis juliflora* was higher in the riverine sites as compared to the dry non-riverine areas mainly because of sufficient water for growth as well as high soil nutrition The study established high diversity of *Prosopis juliflora* in the study area in both the riverine and non-riverine sites for trees and seedlings. Species diversity was low in areas colonized by the invasive plant as compared to areas which were not colonized and acted as control plots. This is an indication that the invasive plant greatly contributed to the decline in diversity of the essential forage plants.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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