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Impact Of *Prosopis Juliflora* To Biodiversity And Ecosystem Services In Lake Turkana Ecosystem In Turkana County, Kenya

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Abstract: ***Prosopis juliflora in Kenya has attracted an immense attention as a result of its invasive nature and altering Lake Turkana its natural ecosystems at an alarming rate. This attention has been mainly attributed to the impact this species has on the social, economic and ecological well-being of communities in the infested areas. The purpose of the study assesses the impact of Prosopis juliflora on plant abundance and species diversity; livestock and human health and ecosytem services in Lake Turkana ecosystem in Turkana county. Ecological quantitative data was collected by using cross- sectional survey research design. Quadrat sampling method was used to determine plants population size and density. Sampling plots were laid to collect data from the study area. The main sampling plots of 400 m x 400 m and sub-plots of 25 m x 25 m (225 m2 and square quadrats square quadrats of 5 m x 5 m (25 m2). Diversity index was used to calculate the Diversity index. A sample of 251 of respondents were selected from the target population. Questionnaires and Interview schedules were used to collect data from respondents. Data analyzed by use of descriptive statistics and inferential statistics. Correlation and Regression Analysis will be used to show associations between independent variables and dependent variable. A p-value of < 0.05 level of significance. The findings have established that the sampled study sites in Lake Turkana ecosystem have extremely displayed lower species diversity and species richness and mostly dominated by the same Prosopis species with average species diversity index of D = 0.69. The results have confirmed that the rapid expansive nature of Prosopis juliflora in the Lake Turkana ecosystem has affected the critical ecosystem of Lake Turkana shorelines hence impacting negatively the biodiversity and ecosystem services. P. juliflora species were subjected to ANOVA and the result of the study showed significant differences in plant tree species abundance and species diversity at level of significance (p<0.001). The reduced indigenous plant species distribution, species richness and species diversity is as a result of colonization and aggressive nature of the Prosopis species. The study therefore recommends that, there is need to reversing the trends in biodiversity loss of indigenous plant species and restoration of natural lake Turkana ecosystem by coming up with an integrated approach for effective management of Prosopis species.***

Keywords: ***Prosopis juliflora, plant abundance and species diversity, Lake Turkana ecosystem and ecosystem.***

I. INTRODUCTION

Throughout the history of the world, biological invasions have occurred as humans have been responsible for redistributing species outside their native ranges. Redistribution of the species have been attributed to their economic, environmental and aesthetic values (CBD, 2010). However, when these new species reach new environment without their natural enemies, they tend to grow and become established to the extent of outcompeting the indigenous species (Abdulahi *et al*., 2017). These are Invasive alien species (IAS). Currently, invasive alien species is one of the major challenges that the world is currently struggling with (Shackleton *et al*., 2014). Convention on Biological Diversity (2010) indicates that invasive alien species are all taxonomic groups whose introduction and spread is outside their native ranges. Invasive alien species have profound impacts on the social, economic and ecological well-being of society and the native ecosystems. Along with impacts caused by climate change, overexploitation and habitat loss and fragmentation;

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Invasive alien species have been attributed to the massive loss of biodiversity globally (Niguse and Amara, 2016). Most of the invasive alien species are aggressive invaders especially if the climatic conditions favour them. They dominant the native species easily and successfully out-compete them (El-Keblawy and Abdelfatah, 2014). Further, the negative effects of invasive species are worsened by climate change and human-induced disturbance. Therefore, Invasive alien species have attracted the attention of governments, scientists, policymakers, and many other stakeholders globally on the need for them to be brought under control (CBD, 2010; Harageweyn *et al*., 2013).

Prosopis juliflora (Sw.) DC is one of the invasive species affecting several of the countries in the Sub-Saharan Africa. It is native to the Caribbean, South and Central America (Pasiecznik *et al*., 2001). It belongs to the genus Prosopis; and is one of the species that has been widely introduced to more than 129 countries globally (Shitanda *et al*., 2013). *Prosopis juliflora* is an evergreen, fast-growing tree and highly adapted to dry land ecosystems because of its ability to fix nitrogen and can tolerate poor arid saline soils. Similarly, this species has a high coppicing ability and its extensive root systems allows it to access water deep underground. *Prosopis juliflora* also tends to form impenetrable thickets within a short time and this makes it an aggressive competitor against the native plant community (Pasiecznik *et al*., 2001; Abdulahi *et al*., 2017). Additionally, a study conducted by Shiferaw *et al.* (2004) points out that *P. juliflora* is equipped with some inherent biological characteristics that contributes to its successful invasion in new areas. For instance, they produce many seeds with high percentage of seed germination and it is adapted to wide ecological conditions. A maturre *P. juliflora* tree can reach a height of up-to 12 meters with trunk diameter of 1.2 meters (Pasiecznik *et al*., 2001, Andersson, 2005, Abdulahi *et al.*, 2017). *Prosopis juliflora* has been termed as a "conflict" species because of its ability to render both positive and negative impacts. Some of its numerous benefits include: provision of wood fuel such as charcoal and firewood, livestock feeds, bio-pesticides, soil erosion control and electricity generation as well as provision of building materials and honey production. This tree also helps in improving livelihoods of Arid and Semi-Arid (ASAL) communities by preventing further soil degradation, assisting in land reclamation. These qualities made it an attractive candidate for ASAL rehabilitation programs, and it is one of the reasons that this tree was introduced to the ASALs of Africa (Pasieznik *et al*., 2001).

On the other hand, it has been reported that this *Prosopis juliflora species* has had negative impacts on human and animal health. This invasive plant acts as a reservoir of pests, parasites and predators. *Prosopis juliflora* has been found to encourage rats' production by providing a year-round food source. (seeds and flowers). Additionally, a study conducted by muller *et al.* (2017) in Mali, West Africa found out that *Prosopis juliflora* thickets promoted the malaria parasite transmission capacity of African malaria vector mosquitoes. This is because this invasive species is attractive to Anopheles mosquitoes and it provides them with sugar that is critical for their survival. *This P. juriflora* species is also a noxious weed that has caused negative impacts in the infested ecosystems hence causing more harm to human and animal health lives. The species encroaches on the crop and pasture lands which directly impacts crop and livestock production. It also reduces diversity and abundance of biodiversity because of its ability to out-compete them. *Prosopis juliflora* blocks water points and irrigation channels causing water sources to dry up (Haji and Mohammed 2013; Niguse and Amare, 2016; Abdulahi *et al.*, 2017).

In developing nations, the impacts of P. juliflora on livelihoods is mostly felt because a good number of their population are small scale farmers who depend on the natural resources for survival (Andersson, 2005). This has led to contentious issues surrounding this species; some advocate for it to be planted while others call for its total eradication (Haregeweyn *et al*., 2013; Abdulahi *et al*., 2017). The concern about desertification, deforestation and fuel-wood shortage in 1970s and early 1980s, prompted a wave of interventions that sought to introduce *P. juliflora* and other hardy tree species to new environment across the world. For example, in Kenya P. juliflora was introduced to combat desertification and to ensure self-sufficiency of wood products in Baringo, Tana River and Turkana (Lodwar, Kakuma and Lokichoggio) districts (Mwangi and Swallow 2008; Maundu *et al*., 2009; Abdulahi *et al*., 2017; Assen *et al*., 2019). Years later after its introduction, *P. juliflora* has turned invasive and is wreaking havoc in the semi-arid and arid areas of Kenya. Haregeweyn *et al*. (2013) points out that this plant has invaded more than 4 million hectares in Africa. In Ethiopia, it is estimated that *P. juliflora* has invaded around 1.5 million hectares at annual invasion rate of around 50,000 ha/year (GIZ, 2014).

In Kenya, *P. juliflora* is estimated to have invaded one million hectares (Witt, 2010). Mbaabu *et al*., (2019) in their study which was conducted in Marigat Sub-County in Kenya found out that the area coverage of *P. juliflora* in Baringo County in Kenya increased from 882 hectares in 1998 to 18792 hectares in 2016. Additionally, Ng *et al*., (2016a) in their study to map *P. juliflora* within Tarach water basin in Turkana, found out that in this study area; 17100 hectares had been densely covered by this species whereas, 51500 hectares is sparsely covered by *P. juliflora*. Similarly, Muturi *et al*., (2013) also established that an estimate of 3 to 27.7 million hectares of the riverine areas in Turkana are highly susceptible to *P. juliflora's* invasion. Specifically, this invasive species has formed an impenetrable thicket along River Turkwell and River Weiwei and it is further spreading in the floodplains along these rivers making it difficult to access the rivers. Also, the entire shoreline from Kerio Delta to Todonyang around lake Turkana has been immensely covered by *P. juliflora* and has caused profound negative socio-economic and ecological impacts in this very fragile ecosystem (Nadio *et al*., 2020).

Lake Turkana ecosystem has played a very essential role in contribution to the livelihoods of the local community. This ecosystem has been an important grazing grounds especially during dry seasons. Invasion by *P. juliflora* coupled with other factors such as climate change has contributed to frequent food shortages and loss of livelihoods. For instance, a study conducted by Haji and Mohammed (2013) in Dire Dawa, Ethiopia, indicated that livestock income in non-invaded areas was higher compared *to P..juliflora* invaded areas,i.e.112.266 USD and 89.348 USD respectively. This is because *P.*

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juliflora's invasion reduce grass cover of the grazing lands and eventually reduces livestock density. The reduction in livestock density have also been attributed to the high sugar content in the pods of this plant that suppresses the rumen bacterial activity causing permanent impairment on the ability to digest cellulose. The high sugar content in pods also causes dental disfiguration and tooth decay, this reduces the browsing and grazing ability of livestock (Mwangi and Swallow 2005). The leaves of this tree have tannin contents which are poisonous to animals if they over feed on the leaves over a long period of time. Additionally, Masakha and Wegulo, (2015) also noted that households incur economic loss of estimated KES 128,000/per year associated with *P.juliflora's* thorns of which 150 US dollars/year was used to treat livestock ailments caused by *P. juliflora.* Invasion by this plant species has also been reported to have negative impacts on crop production through: reduction of the size of farmlands, competition with crops, wastage of time for clearing land and increment in the cost of labour (Niguse and Amare, 2016).

Prosopis juliflora in Kenya has attracted immense attention from stakeholders such as scientists, policy makers, public, and development agencies among others. This attention has been mainly attributed to the impact this species has on the social, economic and ecological well-being of communities in the infested areas. *Prosopis juliflora* spreads very fast and it is highly adapted to arid and semi-arid areas. Researchers project that this species has the potential of invading more than half of Kenya's land which is classifies as arid and semi-arid (Witt, 2010). *Prosopis juliflora* has caused severe socio-economic impacts in the invaded areas by causing loss of arable lands, grazing fields and even death of livestock. There is also another serious but not often noticeable problem; the loss of biodiversity (both plants and animals) and the ecological impact in the infested areas. This species alters the ecosystem services such as water supply, grazing potential, soil quality and hydrological potential. Native biodiversity has been negatively affected by this plant species in many parts of the world (Mwangi and Swallow, 2005; Maundu et al., 2009; GIZ, 2014; El-Keblawy and Abdelfatah, 2014; Niguse and Amara, 2016).

A study by GIZ (2014) conducted in wetlands of the middle Awash basin in Ethiopia indicated that *P. juliflora* out-competed the native vegetation like grasses and shrubs and displaced the valuable grasses leading to a considerable shift in the vegetation composition. Mwangi and Swallow, (2005) in their study carried out in Baringo, Kenya also reported that *P. juliflora,* tends to smother the growth of the native grasses and is much associated with declining pasture availability in the study area. Similarly, Maundu et al. (2009) revealed in their study conducted in Baringo, Loiyangalani and Garissa districts that the plant diversity was significantly lower within the *P. juliflora* thicket than outside the three study sites. *Prosopis juliflora* has also caused reduction in species richness and basal cover of native herbaceous vegetation. Mureithi et al. (2009) found that cover of understory of herbaceous plant species in plots invaded by *P. juliflora* was less by 27% than in the open areas. The lower total biomass production of the herbaceous species growing under P. juliflora indicates that canopies inhibit production of understory plant species. The inhibition is attributed to the allelopathic effects of *P. juliflora* leaves, shading and competition for moisture and nutrients. Additionally, experimental results of Muturi et al. (2013) indicated that *P. juliflora* litter had strong effect on the germination of the *Acacia tortilis*. *Prosopis juliflora* also alters soil nutrient and composition, alters hydrology and causes loss of access to infrastructure and water sources (Shackleton *et al*., 2014). Even with this reality, few studies have tried to investigate the impacts of *Prosopis juliflora* on biodiversity and ecosystem services around Lake Turkana.

Many studies have focused on the negative impacts of *Prosopis juliflora* on livelihoods and its potential for production of electricity, wood fuel, honey production, and livestock feeds, among others. However, few studies have investigated and quantified how this invasive species is negatively affecting biodiversity and the ecosystem services around Lake Turkana. By determining its impacts on biodiversity and ecosystem services; this study will establish the biodiversity that are seriously threatened by *P. juliflora* invasion and then provide convincing evidence and/or additional information on need for the government(s) and other stakeholders to invest in efficient and effective control methods, and establish proper monitoring programmes to halt further spread of this plant. In addition, also put in place measures to conserve and protect the threatened species. One of the proposed projects in the Turkana County Integrated Development Plan (CIDP) is to reclaim land in areas that have been invaded by this species. Therefore, this study was timely because it would provide insightful evidential based data that would help the responsible stakeholders to prioritize the control and management of this invasive species. The findings of this research study would be very essential in monitoring as well as prevention of further spread of invasive nature of *Prosopis species* into non-invaded areas. Therefore, they would be need for formulation of integrated approaches and effective management strategies that are environmentally sound and cost-effective to be developed. It is against this background that this study was therefore conducted to evaluate the impact of *Prosopis. juliflora* on plant abundance and species diversity, livestock and human health and ecosystem services along Lake Turkana Ecosystem in Turkana county, Kenya.

II. MATERIALS AND METHODS

A. AREA OF STUDY

The study was conducted in Lake Turkana Ecosystem about 15km from Kalokol Town, in Turkana Central Sub-County in Turkana County. The choice of the area was ideal because of *Prosopis* species abundance altering Lake Turkana Ecosystem and its biological invasive nature along the shores of the Lake. Turkana County is located in northwestern Kenya between latitudes 01°00′ N and 05°28′ N and longitude 34°02′ E and 36°43′ E and is made up of six sub-counties covering an area of approximately 68,680 square kilometers (Ng et al., 2019).

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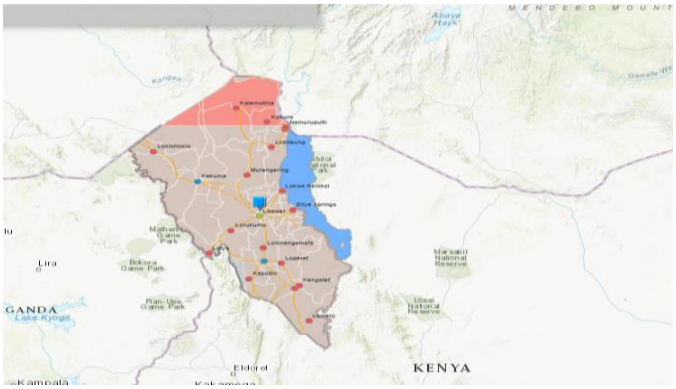

Source:https://www.arcgis.com/apps/Viewer/index.html?appid=14e1bd7eae414d628aba85f150dfb840

Figure 1: A section of the map of Kenya showing Turkana County

B. MATERIALS AND METHODOLOGY

The research study adopted cross- sectional descriptive survey research design along Lake Turkana Ecosystem using both qualitative and quantitative techniques for triangulation purposes. Ecological quantitative data on the impact of *Prosopis. juliflora* on plant abundance and species diversity along Lake Turkana Ecosystem. This study utilized both purposive sampling to select the area of study as a sampling techniques. The choice of the area was purposively selected as study area because of *Prosopis* species abundance altering Lake Turkana Ecosystem and its biological invasive nature along the shores of the Lake. Quadrat sampling method was used to determine plants population size and density. Sampling plots were laid to collect data from the study area. The main sampling plots of 400 m x 400 m and sub-plots of 25 m x 25 m (225 m2 and square quadrats square quadrats of 5 m x 5 m (25 m2). Diversity index was used to calculate the Diversity index. A sample of 251 of respondents were selected from the target population. Questionnaires and Interview schedules were used to collect data from respondents. Data analyzed by use of descriptive statistics and inferential statistics. Correlation and Regression Analysis will be used to show associations between independent variables and dependent variable. A p-value of < 0.05 level of significance. Ecological quantitative data were collected by direct counting of plant species in the habitat and analysis was done as per Sherman (2005); Basistha et. al (2010) and Misra (1968). Simpson's Diversity index was used to calculate the Diversity index.

III. RESULTS AND DISCUSSIONS

A. PROSOPIS SPECIES ABUNDANCE, SPECIES RICHNESS AND DIVERSITY OF LAKE TURKANA ECOSYSTEM AT THE GULF AREA

A total of (N=1,575) of different plant species were sampled from three sampled study sites of Lake Turkana ecosystem at the gulf area of the Lake ecosystem. Out of the three sampled studies, *Prosopis juliflora* was the most abundant (64.2% -Site A; 87.36% -Site B and 86.67%-Site C) followed by *Hyphaene compressa* and the least abundant plant species was *Acacia nubica* as shown in Table 1. The three study sites have four common plant tree species found within the gulf area of Lake Turkana Ecosystem. In terms of density, abundance and frequency, the most densely populated plant species was *Prosopis juliflora* with relative density of 64.10 % and relative abundance of 57.95 (Table 3). The most frequently observed plant tree species from the study area with the highest relative frequency of 29.41 % was *Prosopis juliflora*, followed by *Hyphaene compressa* as shown in Table 3. The indigenous plant trees species with the least relative density and abundance value was observed in *Acacia nubica*.

Species (N= 1,575)	**STUDY SITE A**	**STUDY SITE B**	**STUDY SITE C**	**% of Total No. of Species Site A**	**% of Total No. of Species Site B**	**% of Total No. of Species Site C**
	No. of species	No. of species	No. of species			
Prosopis juliflora	754	311	39	64.2 %	87.36 %	86.67 %
Hyphaene compressa	390	42	05	33.2 %	11.80 %	11.11 %
Acacia tortilis	08	03	01	0.68 %	0.84 %	2.22 %
Indigofera spinose	05	0	0	0.43 %	0 %	0 %
Acacia nubica	17	0	0	1.45 %	0 %	0 %
	N= 1174	**N= 356**	**N= 45**	**Σ 100**	**Σ 100**	**Σ 100**

Table 1: Distribution of plant species in study sites of lake turkana at the gulf area

All the three study sites at Lake Turkana Ecosystem in the gulf area region have extremely displayed lower species diversity and species richness compared to site A that has low species diversity with the same relative abundance and species richness and mostly dominated by the same *Prosopis species* with average species diversity index of D = 0.69. This has reflected the lower species diversity because the bigger the value, the lower the species diversity and species richness in any ecosystem. The abundance of *P. juliflora* species were subjected to ANOVA and the result of the study showed significant differences in plant tree species abundance and species diversity at level of significance ($p<0.001$) as shown in Table 4.

SPECIES	**Study Site A**	**Study Site B**	**Study Site C**	**Σn1 (n1-1) N(N-1)** Species Diversity **Site A**	**Σn1(n1-1) N(N-1)** Species Diversity **Site B**	**Σn1 (n1-1) N(N-1)** Species Diversity **Site C**
	No. of species	No. of species	No. of species			
Prosopis juliflora	754	311	39	567,762	96,410	1,482
Hyphaene compressa	390	42	05	151,710	1,722	20
Acacia tortilis	08	03	01	56	06	0
Indigofera spinose	05	0	0	20	0	0
Acacia nubica	17	0	0	272	0	0
	N= 1174	**N= 356**	**N= 45**	**Σn1 (n1-1) 719, 820**	**Σn1 (n1-1) 98,138**	**Σn1 (n1-1) 1,502**
			Diversity	***D= 0.52***	***D= 0.78***	***D= 0.76***

Table 2: Plant species diversity in study sites of lake turkana at the gulf area

Scientific name	Individuals	No. of quadrats the species occur	Density	Frequency	Abundance	Relative Density	Relative Abundance	Relative Frequency	Important Value Index(IVI)
Prosopis juliflora	754	5 out of 5	150	100	150.8	64.10	57.95	29.41	**`151.46**
Hyphaene compressa	390	4 out of 5	78	80	97.5	33.33	37.47	23.53	**94.33**
Acacia tortilis	08	3 out of 5	1.6	60	2.67	0.68	1.03	17.65	**19.36**
Indigofera spinose	05	1 out of 5	1	20	5	0.43	1.92	5.88	**8.23**
Acacia nubica	17	4 out of 5	3.4	80	4.25	1.45	1.63	23.53	**26.61**
	N= 1174		**Σ 234**	**Σ 340**	**Σ 260.22**	**Σ 99.99**	**Σ 100**	**Σ 100**	**Σ 299.99**

Table 3: Primary ecological parameters of lake turkana at the shore line

Analysis of Variance ANOVA of plant species at Site C					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	4850.000	27	179.630	2544.753	<.001
Within Groups	1.200	17	.071		
Total	4851.200	44			
Between Groups	3758.800	27	139.215	1972.210	<.001
Within Groups	1.200	17	.071		
Total	3760.000	44			
Between Groups	2693.900	27	99.774	21.943	<.001
Within Groups	77.300	17	4.547		
Total	2771.200	44			
Between Groups	2907.811	27	107.697	3661.688	<.001
Within Groups	.500	17	.029		
Total	2908.311	44			
Between Groups	2423.244	27	89.750	.	.
Within Groups	.000	17	.000		
Total	2423.244	44			

Table 4a: Analysis of variance of plant tress species at lake turkana ecosystem

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
	Regression	80271.246	5	16054.249	15067.517	<.001[b]
	Residual	41.554	39	1.065		
	Total	80312.800	44			

Table 4b: Linear regression analysis of tree species at lake turkana ecosystem

B. IMPACT OF PROSOPIS SPECIES ON LIVESTOCK, HUMAN HEALTH AND ECOSYTEM SERVICES

RESPONDENT'S DEMOGRAPHIC CHARACTERISTICS

Out of the sampled 251 respondents who participated in the study, 251 questionnaires were properly filled and returned. This represented 100% overall successful response rate which was attributed to use of self-administered questionnaire. Babbie (1990) classified response rates of 50% as adequate, 60% good and 70% very good for analysis hence response rate was considered very good. The research study established the demographic characteristics of the subjected who actively participated in the study. The sampled respondents were 132 males and 119 female respondents, with 52.59% and 47.41% respectively. The study revealed that the majority of respondents were aged between 18 - 35 years with 68.53% while the lowest category was aged between 51 years and above with 4.38 %. Most respondents had no formal education with 36.25 % while majority of them had primary and secondary education highest level of education representing 29.48% and 18.73% while 15.94 % had post-secondary education qualifications of both tertiary and university level of education (Table 5).

Characteristics	**CATEGORIES**	**FREQUENCY (%) N=251**
Gender of respondents	**Male**	132 ***(52.59%)***
	Female	119 (**47.41%*)***
	18-24	88 ***(35.06%)***
	31-35	84 **(33.47%*)***
	36- 50	68 (**27.09%*)***
	51 & Above	11 **(4.38%*)***
Occupation of the respondent	No education	91 **(36.25%*)***
	Primary level	74 (**29.48%*)***
	Secondary level	47 (**18.73%*)***
	Tertiary College	31 **(12.35%*)***
	University level	09 **(3.59%*)***

Table 5a: Demographic characteristics of the sampled respondents

The survey revealed that 53.39 % of respondents were married compared to 21.11% 0.5% who were single and 8.37 were widowed. Majority of the respondents living at the gulf area of Lake Turkana Ecosystem were fish traders with 37.45%, 17.13 % were civil servants and the rest while fish daily laborers with fisher folk community at the lake representing a total of 29.48%.

Marital Status of respondent	**CATEGORIES**	**FREQUENCY (%) N=251**
	Single	53 (**21.11%*)***
	Married	134 **(53.39%*)***
	Separated/Divorced	43 **(17.13%*)***
	Widowed	21 **(8.37%*)***
Occupation of the respondent	Pastoralism	40 **(15.94%*)***
	Civil servant	43 **(17.13%*)***
	Trader (Fish trader)	94 **(37.45%*)***
	Daily Laborer	44 **(17.53%*)***
	Others	30**(11.95%*)***

Table 5b: Marital status and occupation characteristics of the sampled respondents

From the study, the respondents reported some economic benefits of *P. juliflora*. According to fisherfolk community around the shores of Lake Turkana, *Prosopis* pods have the highest economic value of 62.15% followed by fencing poles with 49.80% with lowest value derived from fuelwood (fuel and energy conservation) and charcoal production with 74.50% (Table. 6). Majority of the respondents appreciated the positive impact of the Prosopis species. Respondent reported that the *P. juliflora* pods could be used for livestock fodder and most of them appreciated the availability of fuelwood and charcoal for their daily subsistence and sale as a source of income to support the families (Table 6).

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	Highest Value	High	Moderate	Low Value	Very Little
	Frequency (%) N=251	Frequency (%) N=251	Frequency (%) N=251	Frequency (%) N=251	Frequency (%) N=251
Construction Pole	2 (*0.80%*)	12 (*4.78%*)	131(*52.19%*)	83(*33.07%*)	23(*9.16%*)
Fencing poles	9(*3.59%*)	125(*49.80%*)	93(*37.05%*)	5(*1.99%*)	0(*0.0%*)
Prosopis Pods for livestock	15(*5.98%*)	156(*62.15%*)	73(*29.08%*)	5(*1.99%*)	2(*0.80%*)
Fuelwood (Fuel and energy conservation)	02(*0.80%*)	06(*2.39%*)	57(*22.71%*)	154(*61.35%*)	32(*12.75%*)
Charcoal production	2(*0.80%*)	21(*8.37%*)	17(*6.77%*)	187(*74.50%*)	24(*9.56%*)
Food for Humans	0(*0.0%*)	0(*0.0%*)	01(*0.40%*)	05(*1.99%*)	245(*97.61%*)

Table 6: Ranking of the economic effects and economic value of prosopis species

The sampled respondents pointed out the negative effects of *Prosopis species* on human health and livestock health. The negative effects of *Prosopis* including but not limited to: The sharp, strong and poisonous thorns of *Prosopis species* produces poisonous substances which is lethal to humans causing serious inflammation and limbs amputations to human body. The dense *Prosopis* thicket in the lake has favored the mosquito habitat and becomes the breeding grounds for mosquitoes. The high incidences of malaria occurrence were associated with *Prosopis species* with 50.0% (Table 6). Over 94 % of respondents have agreed that, the eating of hard pods of *Prosopis* has been confirmed to the disfiguration of livestock' jaws. *Prosopis* has affected the ecosystem services by blocking key paths and roads used by both humans and livestock; The rapid expansion of the invasive alien species has also threatened grazing grounds territory for agro pastoral farming. This could lead to deterioration of livestock health hence affecting their production as shown in Table 7. *Prosopis* species invasion has impacted negatively the ecosystem services including infrastructure, blockage of water courses (hydrological cycles) and drainage systems have been altered by the invasive alien species. There was massive penetration of *Prosopis* into lake shores areas of the lake to the deep waters making fishing very difficult to the fisher folk community. The pricking by thorns of *Prosopis* has led to economic loss to motor vehicles and motor bikes tires (Table 8).

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
The sharp, strong and poisonous thorns of *Prosopis* has poisonous substances	05(*1.99%*)	08(*3.19%*)	12(*4.78%*)	104(*41.43%*)	122(*48.61%*)
The thorns of *Prosopis* has blocked the route pathways in the Lake	10(*3.98%*)	16(*6.37%*)	25(*9.96%*)	93(*.0%*)	107(*37.05%*)
Thorns of *Prosopis* are lethal to humans causing serious inflammation.	35(*13.94%*)	36(*14.34%*)	13(*5.18%*)	75(*29.88%*)	92(*36.65%*)
The pricking by thorns of *Prosopis* might lead to amputation of limbs	21(*8.37%*)	24(*9.56%*)	47(*18.72%*)	75(*29.88%*)	82(*32.67%*)
There are several cases of amputations of limbs caused by *Prosopis*	22(*8.77%*)	15(*5.98%*)	55(*21.91%*)	88(*35.06%*)	71(*28.29%*)
The pricking by thorns of *Prosopis* might lead to even to death	18(*7.17%*)	63(*25.10%*)	69(*27.49%*)	45(*17.93%*)	56(*22.31%*)
The dense *Prosopis* thicket in the lake favors mosquito habitat	55(*21.91%*)	18(*7.17%*)	26(*10.36%*)	92(*36.65%*)	61(*24.30%*)
High incidences of malaria occurrence is associated with *Prosopis species*	14(*5.58%*)	15(*5.98%*)	89(*35.46%*)	68(*27.09%*)	65(*25.90%*)
Prosopis has blocked key paths and roads used by both humans and livestock,	11(*4.38%*)	18(*7.17%*)	33(*13.15%*)	104(*41.43%*)	85(*33.86%*)
Eating of hard pods of *Prosopis* causes disfiguration in livestock' jaws	02(*0.80%*)	05(*1.99%*)	08(*3.19%*)	116 (*46.22%*)	120(*47.81%*)
The high sugar content of *Prosopis* pods causes tooth decay of livestock	10(*3.98%*)	12(*4.78%*)	19(*7.57%*)	88(*35.06%*)	122(*48.61%*)
The hard seeds of *Prosopis* lodging in between gums and teeth leads to gums inflammation	06(*2.39%*)	13(*5.18%*)	15(*5.98%*)	116(*46.22%*)	101(*40.24%*)
Declining of livestock health and even death is as result of eating pods	09(*3.59%*)	13(*5.18%*)	40(*15.94%*)	68(*27.09%*)	121(*48.21%*)
Feeding of *Prosopis* Pods leads to starvation in livestock.	13(*5.18%*)	89(*35.46%*)	107(*42.63%*)	24(*9.56%*)	18(*7.17%*)
Prosopis juliflora has affected fishing routes and fishing landing sites	11(*4.38%*)	16(*6.37%*)	11(*4.38%*)	126(*50.20%*)	87(*34.66%*)
The pricking by thorns of *Prosopis* has led to economic loss to motor vehicles and motor bikes tires	12(*4.78%*)	15(*5.98%*)	56(*22.31%*)	113(*45.02%*)	55(*21.91%*)

Table 7: Impact of prosopis species on human health and livestock health

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Prosopis invasion has affected water resources and hydrological cycles	12(*4.78%*)	90(*35.86%*)	106(*42.23%*)	25(*9.96%*)	18(*7.17%*)
Prosopis invasion has affected road infrastructure	15(*5.98%*)	12(*4.78%*)	34(*13.55%*)	127(*50.60%*)	54(*21.51%*)
Prosopis invasion has blocked watercourses and altered drainage systems	13(*5.18%*)	89(*35.46%*)	108(*43.03%*)	22(*8.77%*)	19(*7.57%*)
Prosopis invasion has interfered fishing pathways used by	14(*5.58%*)	13(*5.18%*)	47(*18.73%*)	120(*47.81%*)	57(*22.71%*)

fishermen folks					
Prosopis juliflora has affected fishing routes and fishing landing sites	13***(5.18%)***	12***(4.78%)***	40***(15.94%)***	157***(62.55%)***	29***(11. 55%)***
Prosopis juliflora has favoured fish breeding grounds	11***(4.38%)***	16***(6.37%)***	41***(16.33%)***	113***(45.02%)***	70***(27. 89%)***
Prosopis Pods has affected livestock production due to deterioration of livestock health	06***(2.39%)***	07***(2.79%)***	52***(20.72%)***	94***(37.45%)***	92***(36. 65%)***
Prosopis invasion has reduced livestock grazing lands	11***(4.38%)***	16***(6.37%)***	27***(10.76%)***	144***(57.37%)***	53***(21. 12%)***
Prosopis invasion has threatened native plant species	06***(2.39%)***	17***(6.77%)***	51***(20.32%)***	131***(52.19%)***	46***(18. 33%)***
Prosopis invasion has affected land use change	17***(6.77%)***	10***(3.98%)***	23***(9.16%)***	128***(51.00%)***	73***(29. 08%)***
Prosopis invasion has affected lakeshore and wetlands making fishing more difficult	05***(1.99%)***	11***(4.38%)***	47***(18.73%)***	96***(38.25%)***	92***(36. 65%)***
Prosopis invasion is associated with loss of grazing territory	10***(3.98%)***	18***(7.17%)***	26***(10.36%)***	154***(61.35%)***	43***(17. 13%)***

Table 8: Impact of prosopis juliflora on the ecosystem services

The three sampled study sites of the Lake Turkana ecosystem showed low diversity index (D) of 0.69 due to reduced diversity of plant species within the area. The reduced species diversity and high abundance of one dominant plant species in the area colonized by *Prosopis juliflora* could suggest the negative influence of *Prosopis juliflora* on the regeneration and establishment of other native species (Clement *et. al*, 2020). The high abundance and density of *Prosopis species* could be associated with extreme reduction of indigenous plant species that have become threatened overtime leading to low species diversity index.

The findings have confirmed that the high abundance of *Prosopis juliflora* to the Lake Turkana ecosystem at the gulf area was widespread distribution within the Lake Turkana ecosystem. This could have contributed by many several confounding factors due to its better ecological adaptability with successful mechanism of seed dispersal and spread to the Lake Turkana ecosystem. The results have confirmed that the reduced indigenous plant species distribution, low species diversity and richness due to colonization of direct selectional pressures ecosystem by the *Prosopis* species. The high spread and rapid growth of *Prosopis species could be* associated with its colonization selection pressure and ability to produce numerous seed production at very higher rate compared to indigenous tree species. *Prosopis juliflora* has allelopathic effects that hinder the growth of the native plant species.

The findings have confirmed that *Prosopis species* was the most densely populated plant species with the highest population and the relative density followed by *Hyphaene compressa* species and lastly by *Acacia nubica* with their ecological parameters. This could clearly explain the typical ecological adaptability characteristic of *Prosopis juliflora* of rapid growth and spreading habit of colonizing Lake Turkana ecosystem. The high abundance and density of *Prosopis juliflora* is attributed to its massive ecological adaptability and its widespread distribution. The results have confirmed that *Prosopis species* was able to outcompete native plant species for limited resources with such ecological habitat and conditions. Lake Turkana ecosystem within the gulf area region seemed to be highly susceptible to *P. juliflora's* invasion. Pasiecznik *et. al.* (2001) cited land use changes, competitive ecological advantages and the climate change as the most confounding factors that has influence high invasion rate. The *Prosopis* species seemed to have fitted into the lake ecosystem as well as the dryland agroforestry systems.

Ellstrand and Schierenbeck (2000) found out that the invasive alien species have the ability to decrease native species abundance as well as changing the community structure (Hejda *et al.,* 2009) and alter genetic diversity (Gaertner *et al.,* 2009). The findings are in concurrence with results of Clement *et.al* (2020) who reported that *Prosopis* possess its invasive potential due to its massive seed production throughout the season and mode of seed dispersal by livestock and water. The high spread and rapid growth of *Prosopis species could be* associated with its colonization selection pressure and ability to produce numerous seed production at very higher rate compared to indigenous tree species. Ellstrand and Schierenbeck (2000) found out that the invasive alien species have the ability to decrease native species abundance as well as changing the community structure (Hejda *et al.,* 2009) and alter genetic diversity (Gaertner *et al.,* 2009). *Prosopis juliflora* has allelopathic effects that hinder the growth of the native plant species. The findings are in concurrence with results of Clement *et.al* (2020) who reported that *Prosopis* possess its invasive potential due to its massive seed production throughout the season and mode of seed dispersal by livestock and water. Ecosystem function is based upon land health, effective water cycles, the flow of nutrients and minerals, and biological diversity. The loss of biological diversity in terms of species and ecosystem depletion in terms of loss land use change, infrastructural loss, hydrological water cycles and essential supporting services, habitat and loss of grazing lands. Prosopis juliflora is notorious for heavily colonizing water courses especially along the rivers, shorelines and floodplains (Muturi et al., 2013). Shackleton *et al.* (2014*) Prosopis juliflora* also alters soil nutrient and composition, alters hydrology and causes loss of access to infrastructure and water sources. The findings are in agreement with Dejene (2018) who reported that adequate supply of biodiversity and healthy ecosystem services increases resilience to economic shocks and environmental change, including impacts of climate change.

IV. CONCLUSIONS

The findings have confirmed that *Prosopis species* was the most densely populated plant trees species with the highest population at the gulf area of Lake Turkana ecosystem. This *Prosopis* species has altered the ecosystem supporting services such as water supply, grazing territories potential, road pathways and water hydrological cycles in the area. This could be attributed to its typical rapid ecological adaptability and colonization selective pressure that leads to widespread distribution in the invaded area. The high abundance and its widespread distribution to Lake Turkana ecosystem would have detrimental effects to the lake natural ecosystem, greater biodiversity loss of native plant species and altering of the ecosystem services.

V. RECOMMENDATIONS

The study recommends that there is need of understanding the negative implications and the adverse effects of the invasive nature of *Prosopis species* and develop effective management strategies that would bolsters eradication efforts to address its invasion rate and ecological adaptability to such ecosystems. There is need for formulation of integrated policy framework and effective management strategies of *Prosopis species* that are environmentally sound and cost-effective based on evidenced based empirical information.

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