EUROPEAN ACADEMIC RESEARCH
Vol. VI, Issue 4/ July 2018

ISSN 2286-4822
www.euacademic.org

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

Distribution of *Parthenium hysterophorus* Linn and its Impacts on Biodiversity in Nyando Sub-County, Kisumu County, Kenya

DORCA AUMA MURONO[1]
Department of Plant Sciences
Kenyatta University, Nairobi, Kenya
EMILY WABUYELE
Department of Plant Sciences
Kenyatta University, Nairobi, Kenya
PAUL K. MUORIA
Department of Plant Sciences
Kenyatta University, Nairobi, Kenya
JOHN OTIENO ABUTO
Department of Biochemistry and Biotechnology
Kenyatta University, Nairobi, Kenya

Abstract:

Parthenium hysterophorus Linn has been classified as one of the world's most serious invasive plants. The weed threatens natural and agro-ecosystems in over 30 countries worldwide. Parthenium hysterophorus is a hazardous weed which causes harm to biodiversity, natural plant ecosystems, humans and livestock. In Kenya, the weed was first reported in the early 1970s and has since spread to several parts of the country. Currently, there is no study on the detailed distribution of P. hysterophorus and its impacts on biodiversity in Kenya. Thus, the aim of this study was to evaluate the extent of invasion and impacts of P. hysterophorus on plant species diversity in Nyando Sub-County of Kisumu County. GPS data on the presence of P. hysterophorus was loaded into ArcGPS 9.1 software to develop point

[1] Corresponding author: johnabuto@yahoo.com / johnabuto1979@gmail.com

distribution map. Fifteen transects were randomly established and vegetation surveys conducted. One-way ANOVA was used to determine significant differences in the mean values of vegetation variable data (richness, diversity and density) among various land use types ($p \leq 0.05$). The effects of P. hysterophorus density on species diversity, richness and density of other herbaceous plant species were evaluated by correlation and linear regression analyses. There was a negative correlation between the density of the weed and species diversity ($r = -0.075$, $p = 0.029$) and richness ($r = -0.924$, $p = 0.001$). This shows that where P. hysterophorus density was high, species diversity, and richness was low. Therefore, there is need for increased awareness of P. hysterophorus, its impacts and possible solutions among the local people and relevant stakeholders. Appropriate measures should be taken to control this weed in Kenya.

Key words: *Parthenium hysterophorus*, invasive plants, distribution, diversity, richness, density.

1. INTRODUCTION

Invasive alien species are defined as non-indigenous species that colonize a particular habitat and negatively impact on it ecologically, environmentally or economically [1]. A plant species may become invasive if it can out-compete other species for resources such as nutrients, light, water or food [2]. A number of authors have described the impacts of invasive alien species on agriculture, forestry, fisheries, and other human enterprises and as well as on human health [3-5]. One such invasive alien plant species is *Parthenium hysterophorus* Linn which is widely distributed and belongs to the family Asteraceae or Compositae [6].

Parthenium hysterophorus is an aggressive, annual or ephemeral herbaceous weed of tropical and subtropical regions. The weed is commonly known variously as carrot weed, star weed, fever weed, bitter weed, white top, congress grass and wild feverfew among other names [7]. *Parthenium hysterophorus* has invaded the natural ecosystems throughout the world and in so doing threatened losses in agricultural productivity. The weed has strong potential to spread due to allelopathy and has since invaded a range of habitats in Kenya [8]. According to Evans [9], the distribution of *P. hysterophorus* indicates severe threat for the ecosystem in biodiversity hotspot areas. In Kenya *P. hysterophorus* is thought to have been introduced in the 1970s in coffee plantations in Kiambu County [10, 11]. The weed has since spread to other parts like Nairobi, Lake Victoria basin, Nyeri, Nanyuki, Mwea and Kibwezi where it has been recorded in a range of habitats including drainage trenches, dumpsites, construction sites, residential areas, game reserves and crop fields [8].

Like many locations in Western Kenya, Kisumu County has been invaded by *P. hysterophorus*. In addition to causing hay fever and allergic reactions in human and livestock, *P. hysterophorus* weed has been reported to exert allelopathic effects which suppress growth and establishment of associated plant species and subsequent decrease in forage and habitat for animals [6]. Furthermore, the reduction in species diversity, the spread and subsequent formation of pure stands of *P. hysterophorus* ultimately changes the vegetation structure that inevitably alters both biotic and abiotic interactions [5] and changes in species diversity. In spite of these adverse effects of *P. hysterophorus*, there is limited information regarding its geographical distribution, rate of expansion, socio-economic and environmental impacts in Kisumu County in general and Nyando Sub-County in particular. This study was designed to determine the distribution of *P.hysterophorus* in Nyando Sub-County and generate data on the threat posed by *P. hysterophorus* to native biodiversity and habitats. This will provide baseline for efficient control and management of the weed and enhance socio-economic development in Nyando Sub-County and Kenya in general.

2. MATERIALS AND METHODS

2.1. Study Area

The study was undertaken in western part of Nyando Sub-County, formerly known as Kadibo Division of Kisumu County (Figure 1). Nyando Sub-County lies between longitude 33° 20' - 35° 20' East and latitude 0° 20' - 0° 50' South. The area covers a total of approximately 163km^2 and a population of about 73,227 persons [12]. The area receives a mean annual rainfall of 1000mm and mean annual temperature of 20°C [13]. The main drainage river channels include river Nyando and Obuso among others. The area is dominated by black soils which develop deep cracks in dry season that allow a lot of rain water to penetrate in the beginning of the rainy season. During the onset of the rainy season, the soils expand, cracks close and water cannot further infiltrate the soil leading to flooding of the plain terrain. In addition, the Sub-County is located on the low ridges where rivers occasionally break into causing loss of property and human life due to flooding [13, 14].

In this study, three sites were chosen for data collection, namely Rabuor, Nyamware and Bwanda regions of Nyando Sub-County (Figure 1). Rabuor is located close to the Nairobi-Kisumu highway and has many shopping centers. Thus many residents of Rabuor are business people while a few are involved in small scale agriculture among other economic activities. Bwanda is located further away from the highway and experiences less flooding as compared to Nyamware, on the shores of Lake Victoria. Residents of Bwanda practice small scale agriculture and trade as main stay economic activity. Many farmers from Bwanda and Rabuor graze their cattle in Nyamware due to the presence of extensive pasture lands, rivers and nearness to the lake. Nyamware is dominated by crop farming and livestock grazing. Due to low amounts of rainfall, most farmers practice irrigation farming. The area experiences flooding due to its location where many rivers break into the lake.

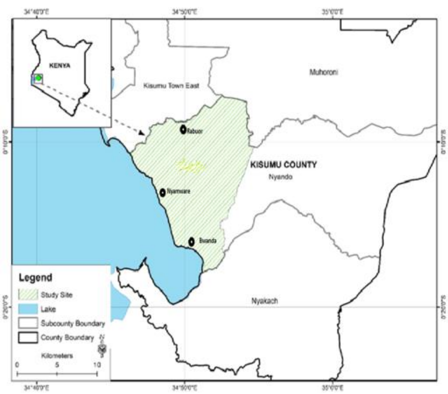

Figure 1: Map of Nyando Sub-County

2.2. Sampling Method

The survey was done from 1st November 2016 to 31st January 2017 in the three sampling sites as described in section 2.1 above. These sites were chosen on the basis of accessibility, variation in location and availability of *P. hysterophorus*. This study consisted of two stages: establishment of spatial distribution of *P. hysterophorus* and sampling for herbaceous plant species.

2.2.1. Distribution of *P. hysterophorus* in Nyando Sub-County

Mapping of *P. hysterophorus* was done to assess its distribution pattern and to characterize the land use types invaded by the weed. A section of the Nairobi-Kisumu highway (between Alendu and Korowe) was used as the main transect and from it six feeder roads (three from each side of the road) measuring approximate distance of 10km were selected. Along each feeder road, stops were made where *P. hysterophorus* was present and geographic coordinates recorded using a hand-held GPS receiver. Locality data on the distribution of *P. hysterophorus* was loaded in to ArcGIS 9.1 software to develop point distribution map.

2.2.2. Impact of *P. hysterophorus* density on herbaceous species diversity

Based on visual observation, five major habitat (land use) types were selected using stratified random sampling method: river bank, residential, pastureland, roadside and cropland [15]. For each land use type, three sampling sites with an area greater than one hectare and covered by *P. hysterophorus* weed were selected. A ten meter (10m) long transect was established in each sampling site and along it, ten quadrats systematically laid where *P. hysterophorus* and other herbaceous plant species were identified, counted and recorded. GPS readings (altitude, latitude and longitude) for each sampling site was taken using GPS channel 12 reader in order to locate the global position of each quadrat as well as the sampling site. Plant species collected from the quadrats were identified in the field; for species that could not be determined in the field, voucher specimen were collected, pressed, dried and transported to the East African Herbarium at the Kenya National Museum for identification.

2.3. Data management and analysis

All the plant species identified in this study were ranked according to their family. Locality data on the presence of *P. hysterophorus* was loaded in to ArcGIS 9.1 software to develop point distribution map. To assess the effect of *P. hysterophorus* density on herbaceous plant community, species richness, diversity, and density of herbaceous species was calculated.

Density of plant species in each of the sampling sites was computed using the formula:

$$\text{Density} = \frac{\text{Total number of plant species in all quadrats}}{\text{Total number of quadrats used}}$$

Diversity of the plant species per site was calculated using Simpson diversity index:

$$D = 1 - \left(\frac{n(n-1)}{N(N-1)}\right)$$

Where, n = is the total number of organisms of a particular species
N = is the total number of organisms in all species

Effect of *P. hysterophorus* density on species diversity, richness and density of other herbaceous plants was evaluated by correlation and linear regression analyses. In these analyses, *P. hysterophorus* density was considered as explanatory variable and other attributes as response variables. One-way ANOVA, followed by Tukeys HSD test was used to determine significant differences in the mean values of variables of vegetation data (richness, diversity and density) among various land use types ($p \leq 0.05$). IBM SPSS statistical software version 20 was used for all analyses.

3. RESULTS

3.1. Species Composition

A total of 25 herbaceous plant species belonging to 12 families were identified in the three sampling sites. These species include: *Flaveria trinervia, Alysicarpus vaginalis, Clitoria ternatea, Corchorus trilocularis, Corchorus olitorius, Gomphrena celosioides, Tridax procumbens, Euphorbia hirta, Sphaeranthus steetzii, Commelina benghalensis, Xanthium strumarium, Amaranthus spinosus, Alternanthera pungens,* *Cycnium tubulosum, Euphorbia indica, Tribulus terrestris, Datura stramarium, Tagetes minuta, Hygrophila auriculata, Schkuhria pinnata, Hibiscus pandoriformis, Sida acuta, Ipomea aquatic, Centella asiatica* and *Parthenium hysterophorus*. Family Asteraceae had the highest number of species while Orobanchaceae, Zygophyllaceae, Solanaceae, Commelinaceae, Acanthaceae, Convolvulaceae and Apiaceae had the least number of species as shown in Figure 2.

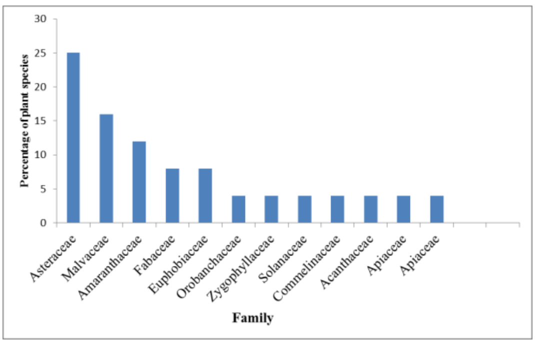

Figure 2: Plant families recorded in study area

3.2. Distribution of *P. hysterophorus* in Nyando Sub-County

Parthenium hysterophorus weed was found to be extensively distributed among the five land use types *viz.*, cropland, river bank, road side, pastureland and residential areas (Figure 3). There was significant variation in the mean density of *P. hysterophorus* among the five different land use types with high density recorded in cropland and roadside while residential areas had the lowest density ($p \leq 0.05$) (Table 1 and Figure 4). The highest densities of *P. hysterophorus* weed were recorded in the roadside and cropland in Rabuor and Nyamware with mean densities of 34.00±0.577 and 26.33±3.18, respectively. The least density (2.33±2.60) was recorded in residential area in Bwanda (Table 1). Similarly, there was a significant variation in the mean density of the weed from the three sampling areas ($p \leq$

0.05). For instance, a comparative analysis of the three sampling sites revealed statistically significant difference in the mean densities of *P. hysterophorus* weed in pastureland, cropland, residential area and river bank ($p > 0.05$). On the other hand, there was no statistical difference in the mean density of *P. hysterophorus* in the roadside among the three sampling sites ($p > 0.05$; one way ANOVA) (Table 1).

Table 1: Mean density of *P. hysterophorus* in different land use types and sites

Sites	Density of *P. hysterophorus*/m^2				
	Roadside	**Pastureland**	**Cropland**	**Residential**	**River bank**
Bwanda	21.67 ± 2.19^{cA}	15.33 ± 2.33^{cB}	20.00 ± 2.65^{bA}	2.33 ± 2.60^{bD}	6.00 ± 2.31^{bC}
Nyamware	25.00 ± 2.52^{bA}	24.33 ± 3.38^{aA}	26.33 ± 3.18^{aA}	9.67 ± 1.86^{aC}	12.33 ± 3.60^{aB}
Rabuor	34.00 ± 0.577^{aA}	18.67 ± 2.33^{bC}	21.33 ± 1.45^{bB}	9.67 ± 1.76^{aD}	6.00 ± 3.21^{bE}

Results were expressed as Mean±Standard Eror of Mean (SEM). Means followed by different lowercase and uppercase superscripts within the same column or row are statistically different ($p \leq 0.05$).

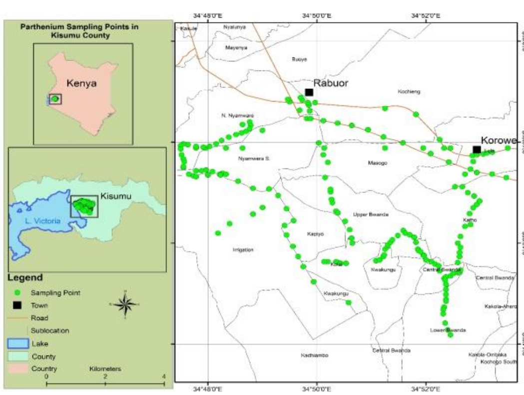

Figure 3: Distribution map of *P. hysterophorus* in Nyando Sub-County.

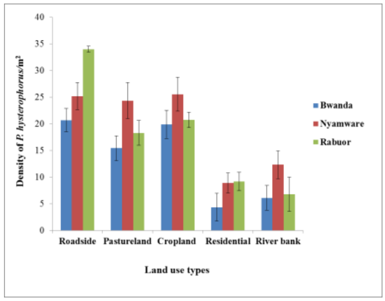

Figure 4: Comparison of mean density of *P. hysterophorus* in the land use types.

3.3. Impact of *P. hysterophorus* density on herbaceous species richness, diversity and density

3.3.1. Impact of *P. hysterophorus* density on species richness

There was a significant negative relationship between density of *P. hysterophorus* weed and species richness (r = -0.924, $p < 0.001$). This implied that an increase in the density of *P. hysterophorus* weed led to the decrease in the number of other plant species in the sampling areas, hence the negative correlation values. Sites which had low density of *P. hysterophorus* had more herbaceous plant species (Figure 5).

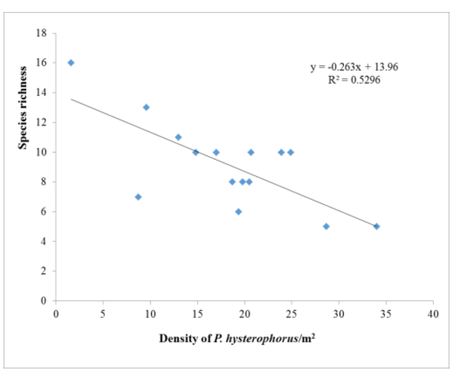

Figure 5: Relationship between *P. hysterophorus* density and species richness.

3.3.2. Impact of *P. hysterophorus* density on species diversity

Species diversity varied significantly among the land use types (F = 8.378, $p < 0.014$). The highest value was recorded along the river banks (0.941±0.118) while the least was recorded in cropland (0.045±0.011). According to the correlation analysis, sites which recorded higher density of *P. hysterophorus* had low diversity in herbaceous plant species (r = -0.075, p= 0.029). Similarly, sites which had lower number of *P. hysterophorus* weed recorded higher diversity in herbaceous plant species (Figure 6).

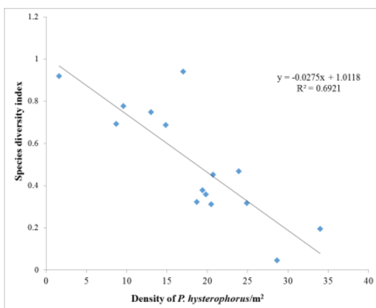

Figure 6: Relationship between *P. hysterophorus* density and species diversity.

3.3.3. Effect of *P. hysterophorus* density on the density of herbaceous plant species

The 25 plant species identified alongside *P. hysterophorus* (section 3.1) have been reported to possess medicinal properties. Out of these plants, three medicinal species namely *Schkuhria pinnata*, *Gomphrena celosiodes* and *Tagetes minuta* were selected for correlation and regression analyses. A scatter plot suggested that an increase in the density of *P. hysterophorus* led to a decrease in the number of *Schkuhria pinnata.* However, a correlation analysis showed that there was no significant relationship between the presence of *P. hysterophorus* and that of *Schkuhria pinnata* (r = 0.392, p = 0.26) (Figure 7).

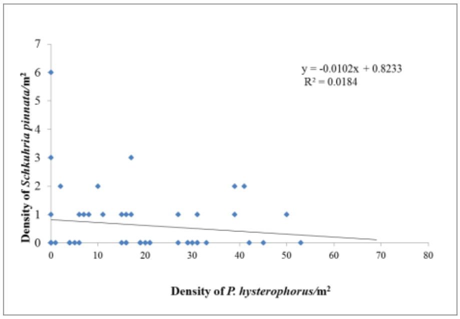

Figure 7: Relationship between *P. hysterophorus* density and density of *Schkuhria pinnata*.

3.3.3. Effect of *P. hysterophorus* density on the density of herbaceous plant species

This study revealed that an increase in the population of *P. hysterophorus* led to a decrease in the number of *Gomphrena celosiodes* weed as indicated in Figure 8. However, results of the correlation analysis showed that population of *P. hysterophorus* did not significantly influence that of *Gomphrena celosiodes* (r = -0.032, p = 0.93) (Figure 8). Similar results were also noted in the relationship between the density of *P. hysterophorus* and that of *Tagetes minuta*; where an increase in the population of *P. hysterophorus* led to a decrease in the population of *Tagetes minuta*. However there was a significant positive correlation between *P. hysterophorus* population and that of *Tagetes minuta* (r = 0.675, p = 0.0322) (Figure 9).

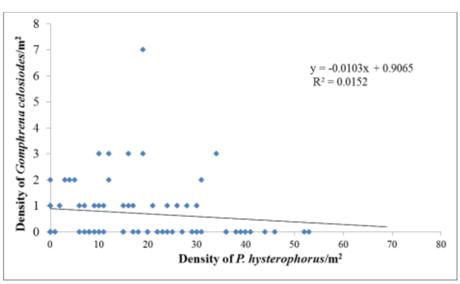

Figure 8: Relationship between *P. hysterophorus* density and density of *Gomphrena celosiodes*.

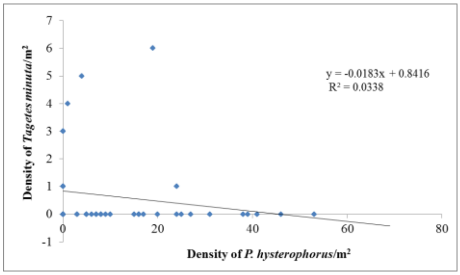

Figure 9: Relationship between *P. hysterophorus* density and density of *Tagetes minuta*.

4. DISCUSSION

4.1. Spatial distribution of *P. hysterophorus*

The current study shows that most parts of Nyando Sub-County have been invaded by *P. hysterophorus*. This weed was mainly found in cropland, roadside, residential area, pastureland and along rivers. These findings are consistent with those of [16], who reported a higher degree of *P. hysterophorus* invasion in roadside, cropland and pastureland in Tanzania. A study carried out by Karki [17] in Nepal reported high densities of *P. hysterophorus* along roadsides, industrial areas and non-cultivated farmland. Oudhia [18] also reported similar patterns of invasion in a phytosociological study of the weeds of the rainy season in Raipur in India where he found *P. hysterophorus* dominating the vegetation.

The increased invasion of *P. hysterophorus* in Nyando Sub-County might be attributed to favorable conditions for seed dispersal. This is because Nyando Sub-County is associated with flooding, increased animal movement and movement of machinery. Crawley [19] reported that periodic disturbance in the form of floods disperse seeds, prepare them for germination and provide seedbed thus promoting invasion of new territory. The dispersal mechanism of *P. hysterophorus* which is mainly through flooding, animal dung, animal movement, wind and movement of machinery facilitate the rapid spread of *P. hysterophorus* from one place to another [20].

Auld *et al.* [21] stated that local dispersal of *P. hysterophorus* seeds occur by wind and water while motor vehicle, machinery, crop and pasture seeds are responsible for long distance dispersal. The rapid spread of *P. hysterophorus* might also be as a result of high reproductive potential, enormous seed bank and short life cycle [22]. In addition, the seeds of *P. hysterophorus* weed have been reported to remain viable for a long time and survive under very harsh environmental conditions [23]. Due to its allelopathic effects, Riaz and Javaid [24] postulated that this weed lacks natural enemies and thus inhibits the germination and growth of other plant species. Moreover, levels of invasion might have also been favored by human activities as evidenced by feeder roads which were away from the highway and agricultural areas having fewer densities of *P. hysterophorus* weed. This might be because the areas are less disturbed [25].

4.2. Impact of *P. hysterophorus* density on diversity, richness and density of herbaceous plant species

A total of 25 herbaceous plant species belonging to 12 families were recorded in the study area. This is in consonance with study of Ortega *et al.* [26] who reported high densities and dominance of different invasive exotic plant species in Montana, USA. This is due to their better establishment success than their indigenous counterparts. Globally, several studies have revealed the aggressiveness of *P. hysterophorus* weed. Similar trend was observed in the current study where species diversity, richness and density decreased significantly with the increase in *P. hysterophorus* density. For instance, sites which recorded higher density of the weed had the lowest plant species diversity and richness. Similarly, sites which had lower number of *P. hysterophorus* recorded higher plant species diversity and richness. This can be attributed to the fact that *P. hysterophorus* weed grows faster, has a short life cycle, greater reproductive ability, competitive ability and allelopathy that makes it a successful invader of non-native habitats [27]. This is in line with findings of Dalip [22] who reported that *P. hysterophorus* weed easily occupied new locations and often substituted native plant species resulting in a serious damage to biodiversity.

In Ethiopia, Ayana *et al.* [28] noted that within a few years of introduction of *P. hysterophorus* weed into Awash National Park, there was a decline of 69% in stand density of herbaceous species. The reduction of species richness and diversity with increasing density of *P. hysterophorus* has been well elaborated by Navie *et al.* [29]. These authors also reported that *P. hysterophorus* takes the form of a rosette during the early stages and requires suitable area to establish. The rosette spreads rapidly near the ground and interferes with the emergence of other seedlings through allelopathy. The stem elongates later and branches at the apex. Together with its high growth rate, the weed becomes competitive and develops the ability to exclude the growth of other species [29].

Gomphrena celosiodes, Xanthium strumarium, Alternanthera pungens and *Tagetes minuta* were the most dominant herbaceous species as they were present in most of the sampling sites. This might be because the plants have strong competitive vigor with *P. hysterophorus* and are also prolific producers of light seeds which are easily blown by wind. In addition, these species produce many thorny bracts that easily attach on human clothing and hairs of animals thus ensuring their dispersal and dominance in Nyando Sub-County [25]. On the other hand, plant species such as *Alysicarpus vaginalis, Clitoria ternatea* and *Corchorus trilocularis* were less dominant in many sampling sites. This might be attributed to the negative effects of *P. hysterophorus* invasion as a result of its allelopathic properties and competitive replacement [30]. According to Gilfedder and Kirkpatrick [31] and Gentle and Duggin [32], the abundance of individual native threatened plant species are negatively correlated with the weed species that have invaded their habitat. The decline in species diversity and richness with successive increase in the *P. hysterophorus* infestation level is an indicator that the community heterogeneity has significantly and negatively been affected. This might be related to rapid dispersal by animals and other human activities. The current results are in agreement with the findings of McFadyen [33] and Chipendale and Paneta [34] who reported a total habitat change in native Australian grassland, open woodlands, river banks and flood plains.

The present study found a negative relationship between density of *P. hysterophorus* weed and density of medicinal plant species namely, *Tagetes minuta, Gomphrena celosioides and Schkuhria pinnata*. This would imply that these species are not equipped with the versatile characteristics that *P. hysterophorus* weed has and as a result they cannot withstand strong competition with it. These results support the work of Shabbir and Bajwa [35] who reported a decline in *Artemisia scoparia, Tribulus terrestris* and *Cannabis sativa* in Pakistan due to increase in *P. hysterophorus* density. Similarly, Mahadevappa *et al.* [36] reported that *P. hysterophorus* had become a curse for the natural herbs in Chhattisgarh plains of India.

In a study on the impact of alien species in India, MacDonald *et al.* [37] found that alien plant invaders shade out indigenous species and reduce their recruitment. The present study gives strong evidence to show that *P. hysterophorus* negatively affected the density of other herbaceous flora by inhibiting their recruitment and regeneration possibly due to increased allelopathic influence. Tadele [38] and Mulatu [39] reported that *P. hysterophorus* releases phytotoxin substances into its immediate environment which highly inhibits germination and growth of several plant species. This is because allelochemicals released from *P. hysterophorus* are capable of changing the physiochemical characteristics of the soil by affecting the moisture content, temperature, pH, organic matter, carbon, nitrogen, phosphorous and soil microbial activity [38, 39].

From this study, it can be postulated that an increase in *P. hysterophorus* invasion may lead to changes in the structure and species composition of vegetation thereby affecting the availability of resources. When an alien plant species invades, the nature of the resources that are available and the spatial and temporal patterns of resource availability can all be altered [27]. Rice and Emery [40] also reported a change in the structure and composition of native plant community due to introduction of an exotic plant species. Some of the plant species identified alongside *P. hysterophorus* are used by the Luo Community in Kenya as herbal medicine. For instance, the leaves of *Tagetes minuta* are used to treat wounds, nematodes and ticks infestation in livestock [41], while *Gomphrena celosiodes* has been used to cure skin diseases, jaundice and malaria [42]. The extracts of *Schkuhria pinnata* are used as an arbotifacient and contraceptive [43]. Thus, changes in the density and structure of the indigenous vegetation undoubtedly have a negative ramification on the human communities that depend on them.

5. CONCLUSION

A total of 25 herbaceous plant species belonging to 12 families were identified in the study area with family Asteraceae having the highest number of species. There was a statistically significant variation in the mean density of *P. hysterophorus* among the five land use types with high densities recorded in cropland while residential areas had the least density. Species richness, diversity and density of other herbaceous flora were found to decrease with the increase in density of *P. hysterophorus*. This could be attributed to the rapid rate of invasion and expansion of this weed as a result of its allelopathic properties. This study demonstrated that ecosystems in Nyando Sub-County are threatened by *P. hysterophorus* weed which is widely distributed. The outcome of this survey includes the realization that *P. hysterophorus* weed is an emerging threat to the Kenyan ecosystem and a problem of national significance that requires urgent attention. Thus, there is need for increased awareness on *P. hysterophorus*, it impacts and possible solutions among the local community and relevant stakeholders.

ACKNOWLEDGEMENTS

We would like to acknowledge the following Kenya National Museum staff for their valuable contribution towards this research study: Mr. Augustine Baraza for collection and identification of plant specimen and Mr. Dickens Odeny for developing distribution map of the study area.

REFERENCES

[1] Schoonover JR. Assessing genetic differentiation among populations of the invasive plant *Impatiens glandulifera* in Maine. Honors Thesis; 2010 pp. 1-30.

[2] Weidenhamer JD, Callaway RM. Direct and indirect effects of invasive plants on soil chemistry and ecosystem function. Journal of Chemical Ecology 2010; 36: 59-69.

[3] Patel S. Harmful and beneficial aspects of *Parthenium hysterophorus*: an update. 3 Biotech 2011; 1: 1-9.

[4] Kushwaha VB, Maurya S. Biological utilities of *Parthenium hysterophorus*. Journal of Applied and Natural Sciences 2012; 4: 137-143.

[5] Saini A, Aggrawal NK, Sharma A, Kaur M, Yadav A. Utility potential of *Parthenium hysterophorus* for its strategic management. Advances in Agriculture 2014; 2014: 1-16.

[6] Bagchi A, Raha A, Mukherjee P. A complete review on *Parthenium hysterophorus* Linn. International Journal of Recent Advances in Pharmaceuticals Research 2016; 6: 42-49.

[7] Joshi D. Alien invasive species: a global threat to biodiversity. The Katmandu Post 23 December; 2001.

[8] Wabuyele E, Lusweti A, Bisikwa J, Kyenune G, Clark K, Wayne D, McConnachie J, Wondi MA. Roadside survey of the invasive weed *Parthenium hysterophorus* (Asteraceae) in East Africa. Journal of East African Natural History 2014; 103: 49-57.

[9] Evans HC. *Parthenium hysterophorus*: a review of its weed status and the possibilities for biological control. Biocontrol 1979; 18: 89-98.

[10] Njoroge JM. Tolerance of *Bidens pilosa* L. and *Parthenium hysterophorus* L. to parquat (Gramooxone) in Kenya. Kenya Coffee 1991; 56: 999-1001.

[11] McConnachie AJ, Strathie LW, Mersie W, Gebrehiwot L, Zewdie K, Abdurehim A, Abrha B, Araya T, Asaregew F, Assefa F, Gebre-Tsadik R, Nigatu L, Tadesse B, Tana T. Current and potential geographic distribution of the invasive plant *Parthenium hysterophorus* (Asteraceae) in Eastern and Southern Africa. Weed Research 2010; 51: 71–84.

[12] KNBS. Kenya National Bureau of Statistics: Kisumu County statistical abstract; 2015 pp. 1-80.

[13] KCIDP. Kisumu County Integrated Development Plan: First County integrated development plan 2013-2017. Kenya vision 2030; 2013 pp. 1-285.

[14] KEDDP. Kisumu East District Development Plan. Ministry of State for Planning National Development and vision 2030. Office of Prime Minister Republic of Kenya. 2008-2012 plan; 2008.

[15] Mueller-Dombois, Ellenberg H. Aims and methods of vegetation ecology. John Wiley and sons, New York; 1974.

[16] Kilewa R, Rashid A. Invasion and distribution of *Parthenium hysterophorus* weed in Kyerwa District in Kagera region, Tanzania. International Journal of science and research 2015; 4: 921-924.

[17] Karki D. Ecological and socio-economic impacts of *Parthenium hysterophorus* L. invasion in two urban areas in Nepal. Master of Science thesis (Botany). Tribhan University, Kathmandu, Nepal; 2009 pp. 1-91.

[18] Oudhia P. Phytosociological studies of rainy season wasteland weeds with special reference to *Parthenium hysterophorus* L. in Raipur district India. Asian Journal of Microbiology, Biotechnology and Environmental Sciences 2001; 3: 89-92.

[19] Crawley MJ. Biodiversity. In: Crawley, MJ (edition) Plant Ecology, Blackwell Science Limited, Germany; 1997.

[20] Lusweti A, Wabuyele E, Ssegawa P, Mauremootoo JR. Invasive plants of East Africa (www.keys.lucidcentral.org/keys/v3/plants.htm); 2011.

[21] Auld BA, Hosking J, McFadyen RE. Analysis of the spread of tiger pear and *Parthenium hysterophorus* weed in Australia. Australian Weeds 1983; 2: 56-60.

[22] Dalip K, Junaid A, Surat S. Distribution and effect of *Parthenium Hysterophorus* L. in Mehari Sub-watershed of Rajouri Forest Range. International Journal of Scientific Research 2013; 2: 304-306.

[23] Willams JD, Groves RH. The influence of temperature and photoperiod on growth and development of *Parthenium hysterophorus* L. Weed Resource 1980; 20: 47-52.

[24] Riaz T, Javaid A. Invasion of hostile alien weed *Parthenium hysterophorus* L. in Wah Cantt, Pakistan. The Journal of Animal and Plant Sciences 2009; 19: 26-29.

[25] Wise RM, Wilgen BW, Hill MP, Schulthess F, Tweddle D, Chabi-Olay A, Zimmermann HG. The economic impact and appropriate management of selected invasive alien species on the African Continent. Council of Scientific and Industrial Research (CSIR) report; 2007.

[26] Ortega YK, Pearson DE, McKelvey KS. Effects of biological control agents and exotic plant invasion on Deer Mouse populations. Ecological Society of America 2004; 14: 241-253.

[27] Grice AC. The impacts of invasive plant species on the biodiversity of Australian range lands. The Rangeland Journal 2006; 28: 1-27.

[28] Ayana E, Ensermu K, Teshome S. Impact of *Parthenium hysterophorus* L. (Asteraceae) on herbaceous plant biodiversity of Awash National Park, Ethiopia. Management of Biological Invasions 2011; 2: 69-80.

[29] Navie S, McFadyen R, Panetta F, Adkins S. The biology of Australian weeds *Parthenium hysterophorus* L. Plant Protection Quarterly 1996; 11: 76–88.

[30] Timsina B. Impact of *Parthenium hysterophorus* L. invasion on soil and plant species composition of Grasslands of Central Nepal. M.Sc. Dissertation, Central Department of Botany, Tribhuvan University, Kathmandu, Nepal; 2007.

[31] Gilfedder L, Kirkpatrick JB. Germinable seed and competitive relationships between a rare native species and exotics in a semi-natural pasture in the Midlands, Tasmania. Biological Conservation 1993; 64: 113-119.

[32] Gentle CB, Duggin JA. Interference of *Choricarpia leptopetala* by *Lantana camara* with nutrient enrichment in mesic forests on the Central Coast of New South Wales. Plant Ecology 1998; 136: 205-211.

[33] McFadyen RC. Biological controls against Parthenium weed in Australia. Crop Protection 1992; 11: 400-407.

[34] Chippendale J, Panetta F. The cost of *Parthenium* weeds to the Queensland cattle industry. Plant Protection Quarantine 1994; 9: 73-76.

[35] Shabbir A, Bajwa R. *Parthenium* invasion in Pakistan - a threat still unrecognized. Pakistan Journal of Botany 2007; 39: 2519-2526.

[36] Mahadevappa M, Das TK, Kumar A. Parthenium: a curse for natural herbs. Paper presented in the National Research Seminar on "Herbal Conservation, Cultivation, Marketing and Utilization with Special Emphasis on Chhattisgarh, The Herbal State". Raipur, Chhattisgarh, India: Srishti Herbal Academy & Research Institute (SHARI); 2001.

[37] Macdonald IAW, Thébaud C, Strahm WA, Strasberg D. Effects of alien plant invasions on native vegetation remnants on Mascarene Island, Indian Ocean. Environmental Conservation 1991; 18: 51-61.

[38] Tadele T. Allelopathic effects of *Parthenium hysterophorus* extracts on seed germination and seedling growth of *Eragrostis tef*. Journal of Agronomy and Crop Sciences 2002; 188: 306-310.

[39] Mulatu W, Gezahegn B, Solomon T. Allelopathic effects of invasive alien weed *Parthenium hysterophorus* L. compost on lettuce germination and growth. African Journal of Agricultural Research 2009; 4: 1325-1330.

[40] Rice KJ, Emery NC. Managing microevolution: restoration in the face of global change. Frontiers in Ecology and the Environment 2003; 1: 469-478.

[41] Maema LP, Mahlo MM, Potgieter MJ. Ethnomedicinal uses of exotic plant species in Mogalakwena Municipality of Waterbeg District, Limpopo Povince South Africa. International Journal of Traditional and Complementary Medicine 2016; 1: 17-27.

[42] Mansour FA, Gogahy K, Philipe AB, Camara–Cesse M, Francois G, Innocent KK, Joseph AD, Mireille D. Anti-inflammatory and antioxidant effects of ethanol extracts of *Gomphrena celosiodes* (Amaranthaceae) in Winstar Rats. Journal of Pharmaceutical, Chemical and Biology 2016; 4: 503-511.

[43] Lewu FB, Afolayan AJ. Ethnomedicine in South Africa: the role of weedy species. African Journal of Biotechnology 2009; 8: 927-934.