Scientific Research Publishing

American Journal of Plant Sciences, 2021, 12, 1503-1514
https://www.scirp.org/journal/ajps
ISSN Online: 2158-2750
ISSN Print: 2158-2742

Environmental Impacts of Invasive Alien Plant Species on the Biodiversity of the Nyika National Park, Rumphi District, Malawi

Robert D. Kacheche, Maureen Kapute Mzuza*

Department of Geography and Environmental Studies, The Catholic University of Malawi, Chiradzulu, Malawi
Email: *maureenmzuza@yahoo.com, *mkapute@cunima.com

How to cite this paper: Kacheche, R.D. and Mzuza, M.K. (2021) Environmental Impacts of Invasive Alien Plant Species on the Biodiversity of the Nyika National Park, Rumphi District, Malawi. *American Journal of Plant Sciences*, **12**, 1503-1514.
https://doi.org/10.4236/ajps.2021.1210106

Received: August 5, 2021
Accepted: October 15, 2021
Published: October 18, 2021

Abstract

Invasive alien plant species have threatened the integrity of ecosystems and threatened biological integrity throughout the world. In the Nyika National Park, a number of alien invasive plant species have been reported. These invasive alien plants are reported to be very difficult that have caused adverse ecological, economic and social impact. The main objective of this study is to assess the environmental impact of plant invasive alien species in Nyika National Park in order to ascertain means of addressing the possible effects on the biodiversity. This study adopted an exploratory stance in order to answer the hypotheses where purposive and simple random sampling was used. Purposive sampling was only used to the staff of Nyika while simple random sampling was used to collect data from households surrounding Nyika National Park. The results revealed that invasive alien plant species have some ecological impacts of on the biodiversity of the Nyika National Park like change in physical habitats such as loss of native habitats, alteration of ground water regime, drying of rivers, loss of native species and alteration of biomass. The study would therefore be important to policy makers in guiding and development of policies and guidelines governing eradication of invasive alien plant species. The Department of National Parks and Wildlife (DNPW) can form partnership with various stakeholders with a clearly stated intention of developing a relationship, based on collaboration to enhance the control of invading alien plant species and the best management practices.

Keywords

Invasive Alien Species, Biodiversity, Habitat, Native Species, Nyika National Park

1. Introduction

Invasive alien species (IAS) are species that are non-native (or alien) to the ecosystem [1]. Invasive alien species can be defined as any live specimen of a species or lower taxon of animals, plants, fungi, or micro-organisms whose existence in a region outside its natural range has negative impacts on an ecosystem and its services [2]. Invasive species are able to survive, reproduce and spread at an alarming rate across an ecosystem causing detrimental effects in parks, land use changes and give rise to management problems [3]. Introduction of the invasive alien also results in economic problems, environmental and human health damage [4]. Alien invasive species are known to generate substantial costs to the parks and wildlife sector in loss of revenues, in expenses for their control and in lost conservation values and ecosystem services [5]. Exotic species can form the base of many economically important resource management systems such as agriculture, horticulture and forestry [6]. Invasive species tend to be multi-sectoral in their impact, and thus need to be addressed with a multi-sectorial approach.

There are some key features associated with invasive plants which include showing prolific seeding at an early age of first reproduction, have unpalatable foliage, can easily establish in degraded environments, and have an ability to regenerate abundantly from direct seeds, stems or roots [7]). These features make invasive plants good competitors amongst other plant species and allow their survival and abundant establishment [8]. The Millennium Ecosystem Assessment (MEA), an international assessment initiative, has shown strong links between human wellbeing, human security, livelihoods and intangible benefits such as equality and freedom of choice with ecological or ecosystem services. The MEA also highlights that a number of human activities degrade the ecological integrity of ecosystems.

Researchers in Malawi have discovered 31 - 69 invasive plant species and a number of ways have been discovered through which invasive plant species spread in Malawi. Most of the invasive plant species were introduced as ornamental and food species which were brought in to provide economic and recreational gains. For example, most of the exotic species were deliberately planted in the Nyika National Park as a source of timber for economic and recreational gains. This includes, Mexican Pine *Pinus patula*, eucalyptus species and Himalayan yellow Raspberry *Rubus ellipticus* for ornamental and as a source of food. These exotic species ended up colonizing the indigenous habitat and became invasive posing a threat to the reserve hence the need to study their impacts in the Nyika plateau specifically Chelinda camp (**Figure 1**).

The conceptual framework mainly analyzes the connections among biodiversity loss, ecosystem service, and society's response to preserve the ecosystem service flow in the Nyika National Park. The invasive species and their impacts are regarded as independent variables. The outcomes of the impact of the plant invasive species these include; environmental and socioeconomic impacts are regarded as dependent variables. Their value depends on the impacts caused by the

invasive species. The outcomes of plant invasive species have resulted into different perceptions towards the management of the plant invasive species resulting into management implications.

2. Materials and Methods

Study Area

The study took place at Nyika National Park (Figure 1). Nyika National Park is situated in the far northern part of Malawi. Nyika National Park is the largest national park in Malawi (S33˚37'59.99"E). The Park has an area of about 1800 km^2 (Van Velden, Wilson, Lindsey *et al.* 2020). About 60 percent of the area is covered by miombo woodland, evergreen forest is around 3 percent and the remaining consist of 37 percent of montane grassland and dambo's, for which the area is best known. Around 1800 plant species have been recorded for the plateau. A large proportion of these being found in the montage grassland and including most of the 33 known endemic species (Species found in Nyika National Park only). Internationally, it is the Nyika's grassland flora that forms its main conservation interest.

This study used quantitative research design where samples were collected purposively and simple random sampling. Purposive sampling was entirely composed of elements that contain the most characteristics, representative or typical

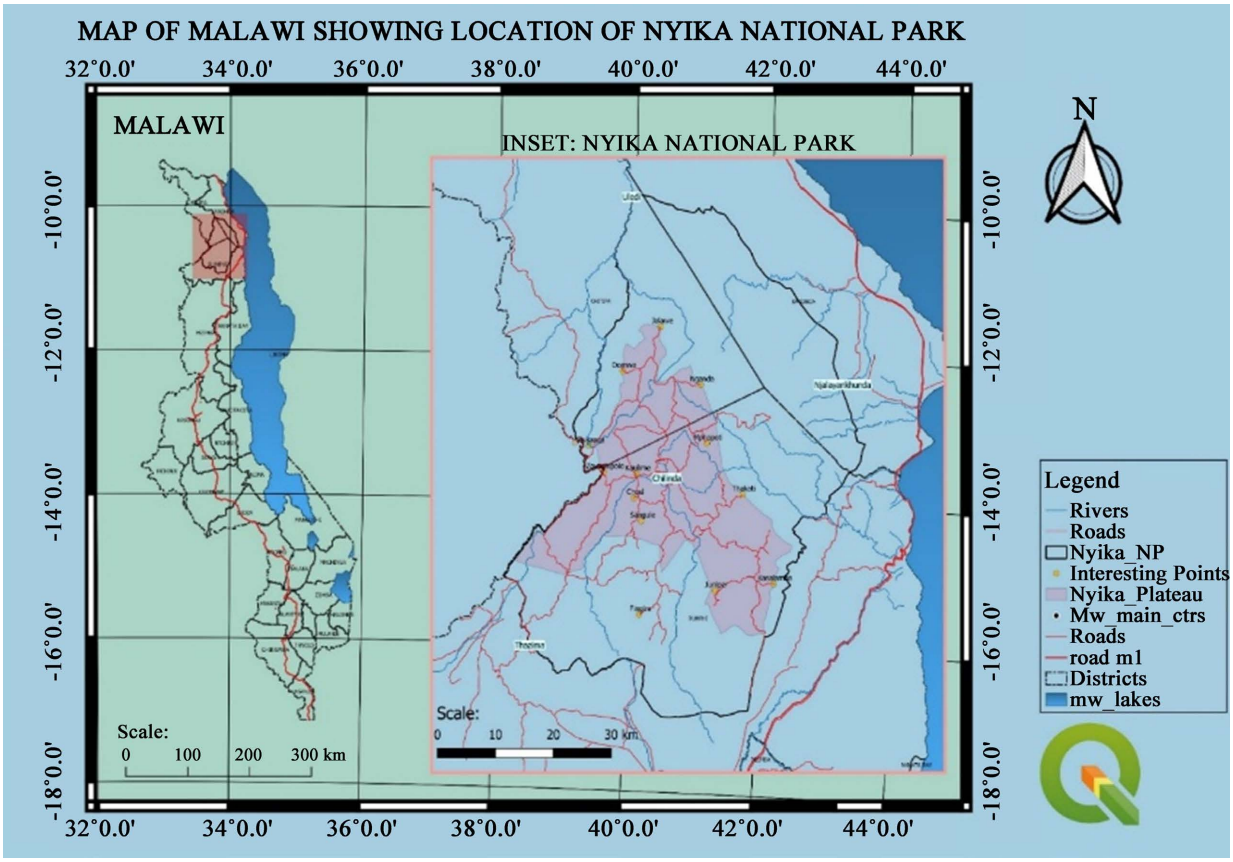

Figure 1. Map of Nyika National Park in Rumphi District, Malawi (Source: NNP, 2021).

attributes of the population [9]. Purposive sampling was only used to the staff of Nyika National Park due to their vast knowledge about the impacts that invasive plant species have caused within the park. Besides that, the households surrounding Nyika National Park was selected using simple random sampling. The households were included in the study because plant invasive species have great negative impacts to them for instance they reduce water quality and quantity, the invasive plant species have direct impacts on agricultural productivity as well as costs associated with invasive species control efforts. In addition to that invasive plant species have caused loss of traditional food and medicinal plants. The study mainly focuses on two camps (Thanzima and Chelinda). The results obtained were generalized to the rest of the population. The study used triangulation data collection where primary, secondary and tertiary data were collected. Primary data was collected through administered questionnaire, interview and direct observation while secondary and tertiary data was collected through reviewing of existing maps, reports, books, internet and journals.

Data was coded and entered into SPSS Computer package. It was then summarized using descriptive statistics such as percentages, frequencies and presented using graphs, tables and charts. After processing, data was then analyzed using inferential statistics such as chi square and at 95% confidence level using analytical methods in SPSS computer package version 20.0. Chi square test is the sum squared difference between observed and the expected data divided by the expected data in all possible categories [10]. Chi square test was used to obtain levels of significance for the non-parametric data and used to analyze the following variables: Knowledge of the invasive species, invasive species effect on beneficial plants and on the supply of other ecological goods and services, views of the respondents on the eradication of invasive species and species form. The null hypothesis was rejected because the calculated value was greater than the critical value [10]. Species use, source of invasive species, species distribution, and species abundance was analyzed using descriptive statistics such as frequencies.

3. Results and Discussion

Interpretation of the results was based on the questionnaires distributed to staff of Nyika National Park and people surrounding the park. Data and information in this study was analysed and discussed in accordance with the research objectives.

3.1. Response Rate

A total of 20 questionnaires were distributed to Thanzima and Chelinda camps within Nyika National Park. Each respondent was required to respond to one questionnaire. The next step was to screen, sort out and analyse the questionnaires by the researcher. The details of the returned questionnaires show that out of 20 questionnaires sent out, all were completed and returned (**Figure 2**). Therefore, this shows that 100% of the respondents (65% male and 35% female) completed and returned the questionnaires (**Figure 2**).

The findings also revealed that out of 20 questionnaires sent (30%) of respondents were primary school leavers, (60%) were secondary school leavers and (10%) had a university degree (Figure 3). This shows that respondents of all levels of education participated in the study (Figure 3).

3.2. Spatial Distribution of Plant Invasive Species in Nyika National Park

A total of 11 invasive plant species were observed within the Nyika National Park (NNP). The distribution of invasive plant species varied within Thanzima and Chelinda Camps. The observed invasive plant species were Bracken fern, *Lantana camara*, Rubus, Black wattle, *Pinus patula*, Himalayan raspberry, Acacia dealbata-Silver Wattle, Eucalyptus Camaldulensis—Blue gum and Sida acuta-Herb. The most common four invasive plant species were *Pinus patula*, Blackern fern, Rubus and Black Wattle. Amongst the list of the top four dominant plant invasive species identified was *Pinus patula*. This is in line with the report by [11] which stated that *Pinus patula* is the greatest invader of the afro-montane forests amongst the pine as it is able to produce viable seeds.

According to respondents (95%) indicated that invasive plant species were

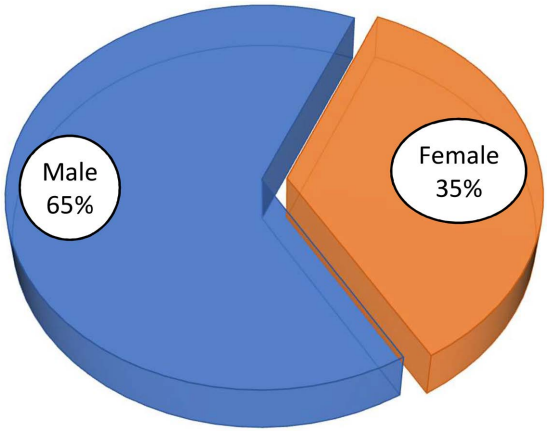

Figure 2. Gender of respondents involved in the study.

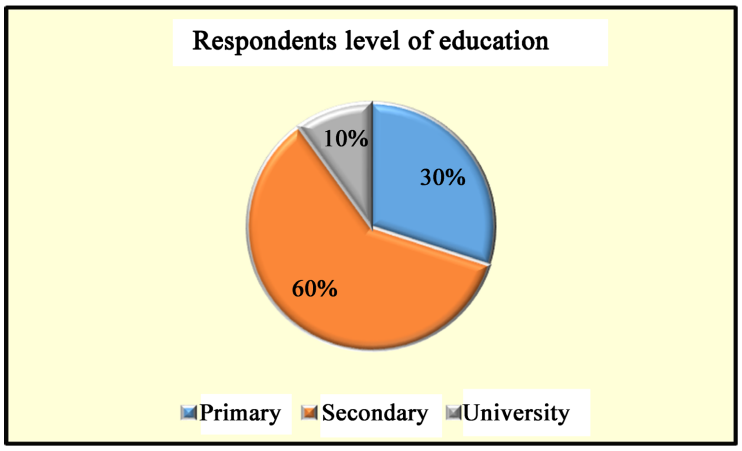

Figure 3. Level of education of respondents.

found to be more abundant at Plateau of the NNP (Figure 4).

The study found that the identified invasive species were of exotic origin and some are native. The invasive alien plant species had a significant representation in terms of spatial distribution across the park. However, it was observed that the species distribution varied with the Nyika plateau having a higher proportion of the invasive species (Figure 4). This could be as a result of previous efforts to get rid of the invasive species on other sides of the NNP. It is evident that more effort be concentrated to the side having higher distribution of the invasive species and lessons from methods used to remove the invasive species on the other parts of the NNP be applied on the Nyika Plateau. It has been noted that blacken fern covers almost the entire Chelinda Camp and most respondents reported higher concentration of invasive species on the Chelinda Camp (Figure 5).

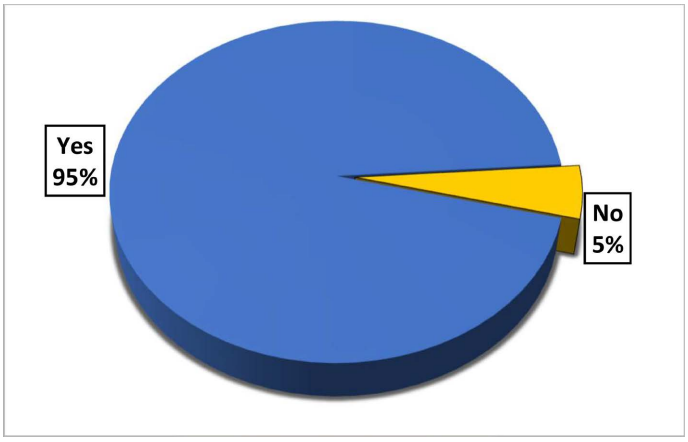

Figure 4. Respondents knowledge about places within NNP where invasion is common.

Figure 5. Abundance of Bracken fern on Nyika Plateau.

Results show that the invasive species have a higher spatial distribution on the Nyika Plateau (Figure 5). Furthermore, it has been found that species utilisation, altitude and climate could be contributing to the variation in spatial distribution (Figure 5). This is in line with [12], who mentioned that invasive species spatial distribution is subject to altitude, soil, and species utilization. It is becoming a serious problem looking at it with focus on the Nyika Plateau side. There is a probability that the invasive species can with time reduce the diversity as they increase in abundance and take over more area. This is in relation to results obtained by [11] on distribution of invasive alien plant species in a mid-sized city in the Czech Republic, central Europe. Results indicate a great amount of variation. The species cover of invasive plant species decreased with increasing proportion of urban greenery and distance from the city centre, but increased with habitat richness; road margins, rural sites, and railway sites were richest in invasive plant species.

3.3. Ecological Impacts of Invasive Plant Species on the Biodiversity

Respondents were also asked to mention if there are any ecological impacts of invasive plant species on the biodiversity of the Nyika National Park. (95%) of the respondents said that there are ecological impacts and (5%) of respondents said that there are no any ecological impacts of plant invasive species on the biodiversity of the Nyika National Park (Figure 6). The main effects recorded were change in physical habitats such as loss of native habitats (40%), alteration of ground water regime (5%), alteration of surface water (15%), drying of rivers (5%), loss of native species (5%), alteration of biomass (5%), loss/decrease of native species through competition for food (5%), loss/decrease of native species through competition for habitat (5%), harbours pathogens which lead to loss of native species (5%) and decrease in growth rate of native species (10%) (Figure 6).

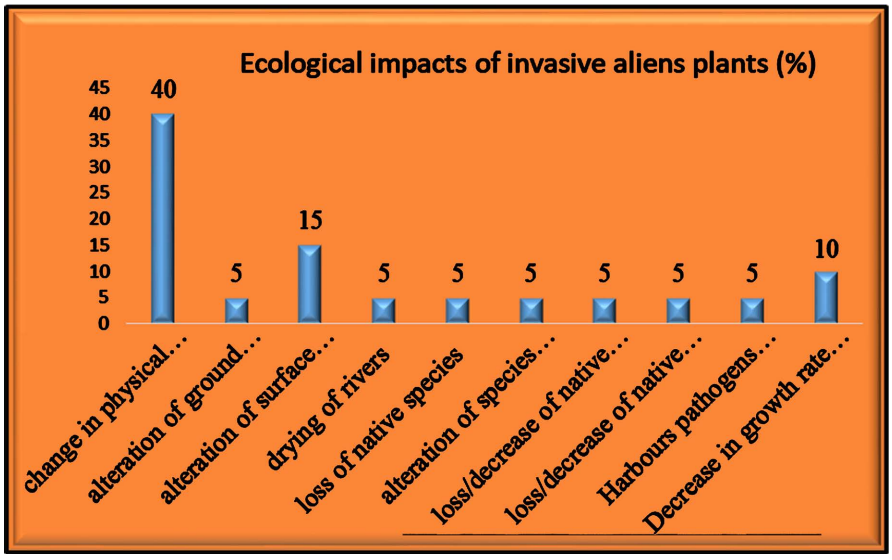

Figure 6. Ecological impacts of invasive alien plant species in the Nyika National Park.

These losses affect the livelihood of the people surrounding the park. Most families directly depend on the products from the park for their survival.

Findings indicate a high concentration of the invasive alien plant species on the Nyika Plateau (Figure 5). *Pinus patula* was explained to be planted around 1950's by Colonial Development Corporation (CDC). The difference in abundance of plant invasive species in the park is due to management prescriptions that were carried in the Nyika National Park. These invasive alien plant species were observed to be more aggressive and covered almost the entire park (Figure 5 and Figure 6).

The invasive species in the NNP have therefore had significant impact in terms of reduction of native species. Although other respondents (5%) indicated that there are no ecological impacts of invasive alien species (Figure 6), this could be explained as they don't know any negative effects of these invasive species. The grass more especially on the plateau has been occupied by blacken fern which is expected to impact negatively on the species population which will result to decrease in native species through competition for food and habitat in the NNP since micro-climates are also bound to change (Figure 6).

This will also bring an effect negatively on the water catchment areas in the NNP and therefore biodiversity in general. Nyika National Park supply water to Lunyina, North Rukuru and Rumphi rivers. The results gave us enough evidence to reject the null hypothesis that invasive species do not have negative impact on the ecology of the NNP. These results agreed with [13] who discovered that various invasive plant species are known to decrease local plant species diversity. Although invasive plant species diminish diversity, they rarely cause plant eliminations [13] but increase ecosystem productivity and alter the rate of nutrient cycling [14], and hence impact on ecosystem services like impeding water uses and affecting human well-being [15] [16].

3.4. Impact of Invasive Plant Species on the Environment

The majority (95%) of the respondents acknowledged to know what invasive species are and most of them were able to give examples such Brackern fern, Rubus and *Pinus patula*. Some of these plant invasive species are native and others brought by tourists. *Pinus patula* was introduced in 1950's for timber making by the Colonial Development Corporation (CDC). The majority of respondents (75%) say that there are significant changes in climate in Nyika National Park mainly rainfall and temperature while (25%) of respondents say that there are no any significant changes in terms of rainfall and temperature (Figure 7).

Respondents (85%) say that these significant changes in climate in Nyika National Park have been observed more than 10 years, (5%) of respondents say that the changes have been observed more than 20 years while 10% of respondents say that they are not sure of the years they started observing these changes (Figure 8).

According to the findings we can infer that the invasive plant species have an impact on the environment of the NNP. The findings give us enough evidence to

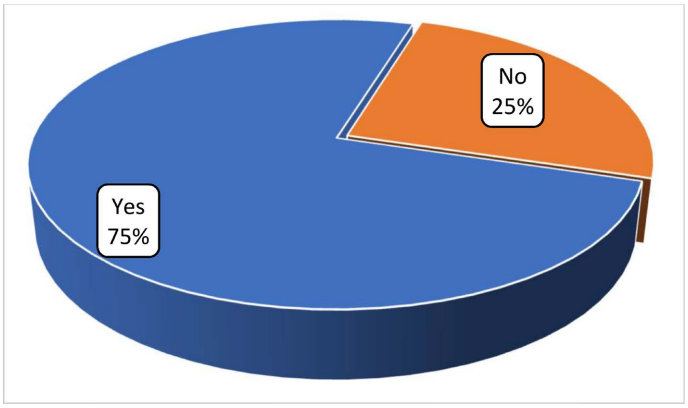

Figure 7. Respondents knowledge about the significant changes in climate mainly rainfall and temperature.

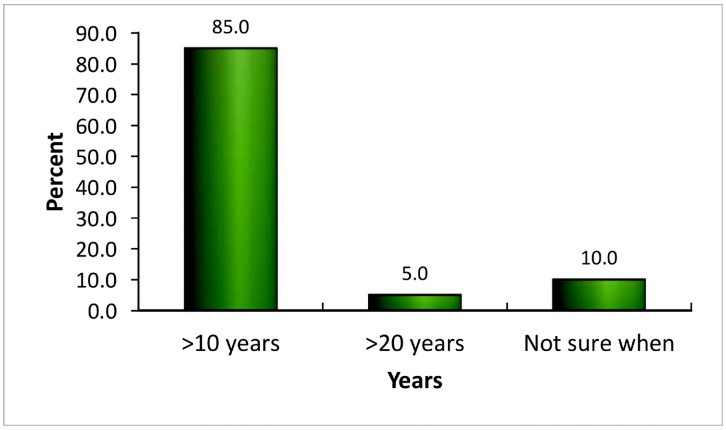

Figure 8. Years of significant changes in climate (rainfall and temperature).

reject the null hypothesis that invasive plant species have no significant impact on the environment in the Nyika National Park and allow us to adopt the alternative hypothesis since $p \leq 0.05$.

The results are in line with [17] which indicated that invasive alien plant species influence climate change. Climate change facilitates the spread and establishment of many alien invasive plant species and creates new opportunities for them to become invasive. Invasive alien plant species reduce the resilience of natural habitats, agricultural systems and urban areas to climate change [16]. Conversely, climate change reduces the resilience of habitats to biological invasions.

4. Conclusions

This study has proved the availability of invasive alien plant species on the biodiversity of the Nyika National Park and has shown to have the greatest representation on the plateau especially Chelinda. Invasive alien plant species in the park have damaged a number of natural ecosystems and caused considerable loss of biological diversity. They are particularly decreasing growth rate of native species. The invasive species reduce regeneration through competition for resources. Other impacts include harbouring pathogens which lead to loss of na-

tive species and disturbing the water flow.

Invasive alien plant species have proved to have negative impact on the livelihood of the surrounding communities of the Nyika National Park. Some of these invasive plant species are growing in the farms at a rampant rate. Research findings reveal that a total of 11 invasive plant species were observed within the Nyika National Park. The distribution of invasive plant species varied within Thanzima and Chelinda Camps. The most common four invasive plant species were *Pinus patula*, Bracken fern, Rubus and Black Wattle. Amongst the list of the top four dominant plant invasive species identified was *Pinus patula*.

The diversity of invasive alien plant species was more evident on the Nyika Plateau, dambo areas and cultivated areas around Nyika National Park.

Results have also shown that invasive alien plant species have negative significant impact on the social livelihoods of the people surrounding NNP. Findings of the study revealed that current common methods identified for getting rid of the invasive alien plant species were through manually removing and chemical control. These methods are on trial but no tangible results have been observed. The current methods used in eradication of invasive alien plant species are less like experiments in order to find the best method in eradicating the invasive alien plant species in the NNP.

5. Recommendations

Local communities surrounding the park should be involved in the management of invasive alien plant invasive species in their vicinity so as to improve the efficiency and sustainability of natural resources.

Furthermore, research into possible tree species that can provide the same benefits as the *Pinus patula* and *Rubus ellipticus* should be carried out to avail replacement trees that are not invasive so as to mitigate the resistance to invasive species eradication that might stem from those that benefit from its existence. Invasive species need to be mainstreamed into national policies and laws such as the forest act, National Forestry Policy as well as the Environmental Protection Act. There is need for continuous sensitization on the dangers and magnitude of the problem posed by invasive species on the socioeconomic livelihoods of stakeholders, the environment and biodiversity.

There is need for establishment and coordination of technical support from affected agencies for purposes of planning for both short- and long-term management programmes. During this phase; appropriate, regulatory and management action plans to be taken against invasive plant species can be made.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Westphal, M.I., Browne, M., MacKinnon, K. and Noble, I. (2008) The Link between

International Trade and the Global Distribution of Invasive Alien Species. *Biological Invasions*, **10**, 391-398. https://doi.org/10.1007/s10530-007-9138-5

[2] García-Díaz, P., Cassey, P., Norbury, G., Lambin, X., Montti, L., Pizarro, J.C., et al. (2021) Management Policies for Invasive Alien Species: Addressing the Impacts Rather than the Species. *BioScience*, **71**, 174-185. https://doi.org/10.1093/biosci/biaa139

[3] Poland, T.M., Patel-Weynand, T., Finch, D.M., Miniat, C.F., Hayes, D.C. and Lopez, V.M. (2021) Invasive Species in Forests and Rangelands of the United States: A Comprehensive Science Synthesis for the United States Forest Sector. Springer, Cham. https://doi.org/10.1007/978-3-030-45367-1

[4] González-Montelongo, C. and Pérez-Vargas, I. (2021) Is an Invasive Alien Tree Able to Sustain a Similar Lichen Diversity as the Native Forest? The Case of the Sweet Chestnut (*Castanea sativa* Mill.) and the Laurel Forest in Macaronesia. *Forest Ecology and Management*, **488**, Article ID: 119009. https://doi.org/10.1016/j.foreco.2021.119009

[5] Bukombe, J.K., Nkwabi, A.K., Mangewa, L.J., Sweke, E.A., Kavana, P.Y., Liseki, S.D., and Kija, H.H. (2021) Alien Invasive Species in Tanzania. In: Pullaiah, T. and Ielmini, M.R., Eds., *Invasive Alien Species: Observations and Issues from Around the World*, John Wiley & Sons Ltd., Hoboken, 263-290. https://doi.org/10.1002/9781119607045.ch9

[6] Szumańska, I., Lubińska-Mielińska, S., Kamiński, D., Rutkowski, L., Nienartowicz, A. and Piernik, A. (2021) Invasive Plant Species Distribution Is Structured by Soil and Habitat Type in the City Landscape. *Plants*, **10**, Article No. 773. https://doi.org/10.3390/plants10040773

[7] Sudimier-Rieux, K. (2015) The Role of Ecosystem in Climate Change Adaptation and Disaster Risk Reduction. European and Mediterranean Major Hazards Agreement.

[8] Ahimbisiwe, B.P. (2018) A Social Economic Assessment of Plant Invasive Species on Forestry Production: The Case of *Senna spectabillis* in Budongo Forest Reserve. Uganda University of Pretoria, Pretoria.

[9] Strydom, V. (2015) Research at Grassroots for Social Sciences and Human Service Professions.

[10] Allan, B. (2012) Elementary Statistics. McGraw Hill, New York.

[11] Food and Agriculture Organization of the United Nations (2017) Progress towards Sustainable Forest Management in Malawi. Food and Agriculture Program, Malawi.

[12] Powell, K.I., Chase, J.M. and Knight, T.M. (2013) Invasive Plants Have Scale-Dependent Effects on Diversity by Altering Species-Area Relationships. *Science*, **339**, 316-318. https://doi.org/10.1126/science.1226817

[13] McLeod, M.L., Bullington, L., Cleveland, C.C., Rousk, J. and Lekberg, Y. (2021) Invasive Plant-Derived Dissolved Organic Matter Alters Microbial Communities and Carbon Cycling in Soils. *Soil Biology and Biochemistry*, **156**, Article ID: 108191. https://doi.org/10.1016/j.soilbio.2021.108191

[14] Invasive Species Specialist Group (2018) Global Invasive Species Database. IUCN the World Conservation Union Species, Survival Commission.

[15] Lazzaro, L., Essl, F., Lugliè, A., Padedda, B.M., Pyšek, P. and Brundu, G. (2018) Invasive Alien Plant Impacts on Human Health and Well-Being. In: Mazza, G. and Tricarico, E., Eds., *Invasive Species and Human Health*, CABI, Wallingford, 16-33. https://doi.org/10.1079/9781786390981.0016

[16] Shackleton, R.T., Shackleton, C.M. and Kull, C.A. (2019) The Role of Invasive Alien Species in Shaping Local Livelihoods and Human Well-Being: A Review. *Journal of Environmental Management*, **229**, 145-157. https://doi.org/10.1016/j.jenvman.2018.05.007

[17] Avalos, G., Chacón-Madrigal, E. and Artavia-Rodríguez, L.G. (2021) Invasive Plants of Costa Rica Current Status and Research Opportunities. In: Pullaiah, T. and Ielmini, M.R., Eds., *Invasive Alien Species*: *Observations and Issues from Around the World*, Chapter 4, John Wiley & Sons Ltd., Hoboken, 57-76. https://doi.org/10.1002/9781119607045.ch37