Assessment of alien invasive plant species along a distance gradient from dip tanks in a Highveld Area

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Abstract

Long term dip tank use for livestock health management results in piosphere formation which presents a conducive environment for the proliferation of alien invasive plants. These invasive plants can alter soil edaphic properties, out-compete indigenous species, and change ecosystem functions, ultimately leading to rangeland degradation. Therefore, assessments of alien plants around dip tanks provide basis for studying their impact on rangelands. The objective of this study was to establish an inventory of alien plants around dip tanks. The assessments were conducted at three dip tanks in Marondera, Zimbabwe. A 1000 m transect was laid at the edge of each dip tank, and measurements on both woody and herbaceous species were taken at 50, 100, 200, 400 and 800 m along the transect. Results indicated that the common alien species were *Lantana camara*, *Oxalis latifolia*, *Tagetes minuta, Cassia rotindifolia*, *Richardia scabra, Bidens pilosa* and *Datura stramonium*. At all dip tanks there were significant differences ($P<0.05$) in L. camara density as well as richness of herbaceous species other than alien invasives. Significant differences ($P<0.05$) were also observed for *C. rotindufolia*, *R. scabra*, and *D. stramonium*. The results indicated the proliferation of invasive plants along a distance gradient from dip tanks. Therefore, early management of invasive species is recommended in order to curb serious long-term adverse impacts.

Keywords: piosphere, cattle production, animal health, rangeland productivity, native vegetation

Introduction

Sustainability of livestock production systems in rural areas largely depends on animal nutrition and health. For cattle, dip tanks are the primary resource for health management. Dip tanks are normally constructed on rangelands that are in close proximity to homesteads. Other facilities that usually form part of the dip tanks include cattle holding facilities for routine health management practices such as dosing and weighing. Thus, dip tanks serve as sites where the national government provides veterinary extension services (Musoke et al., 2015). However, due to high cattle concentrations at dipping sessions, sections of rangelands within the vicinity of dip tanks are characterised by overgrazing and high deposition of dung and urine, creating environmental perturbation that leads to piosphere formation (Beyene & Mlambo, 2012). This favours proliferation of alien plant species. Consequently, due to high invasiveness, the alien plants can spread to the rest of the rangeland adversely affecting rangeland productivity and hence animal nutrition (O'Connor and van Wilgen 2020). Assessment of alien invasive plants around dip tanks can therefore provide valuable information for rangeland management.

Disturbed areas have been shown to have high invasability. For instance, soil disturbance facilitates the spread of these species by modifying resource and substrate availability and providing opportunity for establishment in the absence of competitors (Burke & Grime 1996; Davidson et al, 2011). Increased foraging activity and cattle hoof action around dip tanks causes overgrazing, and exacerbates soil erosion and compaction (Kgosikoma et al, 2013). Generally, invasive plants can change soil edaphic properties, out-compete indigenous species, and change ecosystem functions, ultimately leading to rangeland degradation. High deposition of dung and urine around dip tanks also increases pockets of fertility, creating conducive conditions for alien plants. Traits of invasive species such as high plant growth and photosynthetic capacity, lower regrowth-related traits, such as carbohydrate storage, and an increased plant qualitative defense aid in the process of invasion (Kleunen et al, 2010; Moravcová et al, 2010). Deeper comprehension of the effects of alien plant species due to piosphere formation around dip tanks can provide important information for more effective rangeland management and restoration.

Although many previous scholars have studied alien invasive plants, few have focused on the impact of these species in relation to dip tanks. Generally, where the piospherical effect of resource centres has been investigated, focus has mainly been on water sources, nutrient licks etc (Andrew, 1988; Jaweed, 2018; Shahriary, 2021). Therefore, the objective of this study was to assess alien invasive plant species along a distance gradient from dip tanks with particular reference to plant species richness, frequency, density and abundance. This would inform effective methods of improving rangeland productivity.

Materials and methods

Study area

The study was conducted in Marondera District of Mashonaland East Province in Zimbabwe. Marondera experiences mean temperature of about 180C and annual rainfall in the range of 600 to 1200 mm. Soils in Marondera are generally sandy loamy. The study was carried out at three dip-tanks namely Chimbwanda, Manyaira and Madamombe. These three dip tanks serve approximately the same number of animals, and are in Natural Region IIb of the Zimbabwe agro-ecological zones. Livestock and crop production are both common livelihood sources in Marondera.

Data Collection

The data was collected between December and April. For plant species assessments, a 1000 m transect was laid from the edge of each dip tank at least 50 m from road and rivers to avoid possible road and river effects. Three 0.5 m x 0.5 m quadrants were systematically laid at each of the following distances from the dip tanks: 50, 100, 200, 400 and 800 m. Frequencies and richness of herbaceous alien invasive plants, as well as density of woody invasives were recorded at each of these distances. Field guides were used for identification of the plant species.

Data analysis

IBM SPSS (2012) was used for analysis of variance (ANOVA) of the variables. Significance was declared at $P < 0.05$. Species richness was determined as the total number of plant species encountered in plots. Woody species densities were calculated for each distance variable using the formula:

Density (plants/ha) = Number of plants × (10 000 m2) / (Plot area (m2))

Frequency (F) was calculated as the number of times a plant occurred.

Results

Eighteen invasive herbaceous species were observed at Madamombe dip tank, while 15 alien herbaceous species were recorded at both Manyaira and Chimbwanda dip tanks. Common alien herbaceous species observed at all dip tanks included *Oxalis latifolia, Tagetes minuta, Cassia rotindifolia, Richardia scabra, Bidens pilosa* and *Datura stramonium*. There were also 23 different woody species at all dip tanks, with some being common at all three dip tanks. Specifically, there were 16 at Madamombe, 3 at Manyaira and 12 at Chimbwanda. Lantana camara was the only alien woody species observed at all the three dip tanks.

Table 1. Alien invasive species observed at Madamombe, Manyaira and Chimbwanda dip tanks

Species	Family	Common English name
Lantana camara	Verbenaceae	Cherry pie
Oxalis latifolia	Oxalidaceae	Garden pink-sorrel
Tagetes minuta	Asteraceae	Marigold
Cassia rotindifolia	Fabaceae	Round leaf cassia
Richardia scabra	Rubiaceae	Florida pusley
Bidens pilosa	Asteraceae	Black jack
Datura stramonium	Solanaceae	Thorn apple

The species frequencies of *C. rotindufolia, R. scabra, D. stramonium* and *L. camara* were statistically significant P<0.05) along the distance gradient. Higher frequencies were recorded at distances near the dip tanks than at 800 m from the dip tanks. The species frequencies of *O. latifolia, T. minuta,* and *B. pilosa* were statistically insignificant (P>0.05) along the distance gradient (Table 2).

Table 2. Mean frequencies of alien invasive species along the distance gradient from dip tanks

Species	Distance from dip tanks (m)	P

	50	100	200	400	800	
Oxalis latifolia	9.94^{a}	10.00^{a}	10.78^{b}	10.50^{b}	10.38^{a}	0.05
Tagetes minuta	14.83^{a}	16.56^{b}	16.83^{b}	13.28^{c}	14.44^{a}	0.05
Cassia rotindufolia	11.22^{a}	12.61^{b}	9.61^{c}	13.22^{d}	10.38^{e}	0.02
Richardia scabra	17.28^{a}	13.83^{b}	12.83^{c}	10.50^{d}	11.94^{e}	0.02
Bidens pilosa	9.94^{a}	10.00^{a}	16.78^{b}	10.50^{c}	10.38^{c}	0.05
Datura stramonium	9.94^{a}	16.11^{b}	10.78^{c}	10.50^{c}	11.69^{d}	0.02

Means with different superscripts within the rows differ significantly (P < 0.05)

For the rest of the non-invasive herbaceous species, results also showed that along the transects at each all dip tank, there were significant differences (P<0.005) (Table 3). Results for richness also showed that the parameter was generally lower at 50 m than at 800 m.

Table 3. Herbaceous species richness along the distance gradient of the study areas

Herbaceous species richness	Distance from dip tanks (m)					P
	50	100	200	400	800	
Madamombe	6^{a}	8^{b}	8^{b}	5^{c}	8^{b}	0.02
Manyaira	8^{a}	7^{b}	8^{a}	5^{c}	7^{b}	0.04
Chimbwanda	5^{a}	4^{b}	8^{c}	6^{c}	6^{c}	0.02

Density

The density of *L. camara* differed significantly (P<0.05) along the distance gradient from the dip-tanks (Figure 1).

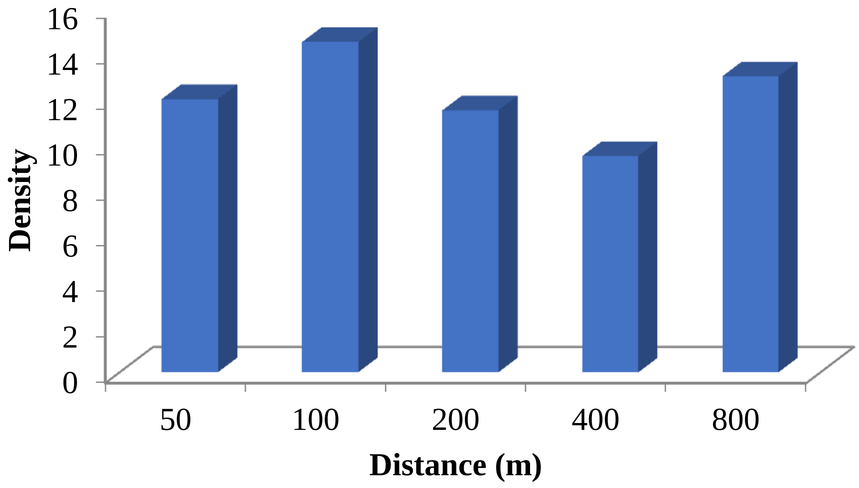

Figure 1. Density of *Lantana camara*

Discussion

Our findings indicated that the common alien species were *Lantana camara*, *Oxalis latifolia, Tagetes minuta, Cassia rotindifolia, Richardia scabra, Bidens pilosa* and *Datura stramonium*. All these species have adapted to the local environment Reference. For instance, *B. pilosa*, whose seeds may remain viable for 5 - 6 years has high reproductive potential and fast-growing rates, and a single plant may produce up to 6000 seeds per year which can easily be dispersed attached to animals, birds, human clothes or by wind and water (Rojas-Sandoval, 2020). In fact, where *B. pilosa* is abundant, it forms dense stands that outcompete and eliminate crops and native vegetation, and its leaf and root contain allelopathic substances that suppress the germination and establishment of seedlings of native plant species (Rojas-Sandoval, 2020). Likewise, *L. camara* can reproduce in different ways such as through suckers, seed dispersal by birds and other animals, when its branches develop root after coming into contact with soil, or when stem fragments or pieces of the rootstock (crown) give rise to new plants after being moved by machinery or dumped in garden waste (BioNET-EAFRINET, n.d). Once well established, it becomes difficult to eradicate most invasive species. Therefore, the best form of management of these species is to prevent their introduction.

Results also indicated significant differences in *C. rotindufolia, R. scabra, D. stramonium* and *L. camara* along the distance gradient. This observation was not surprising as alien species are generally common in disturbed habitats (Mudzengi et al. 2014). Thus, in our study where there was more concentrated grazing near the dip tanks than further away, hence more trampling by cattle, high frequency of alien invasive species in close vicinity to the dip tanks was expected. As observed, this led to piosphere formation. Areas near dip tanks are also fertile due to concentrated dung deposition by cattle, creating favourable conditions for proliferation of alien species. As an example, *D. stramonium* has been observed to grow along roadsides and at dung-rich livestock enclosures (Preissel & Preissel, 2002; Veblen, 2012). Comparisons of herbaceous species along the distance gradient have also indicated an increasing trend of richness as we move away from the dip tanks. This could be attributed to the corresponding decreasing trend of some of the alien invasive species. Thus, further away from the dip tanks where alien species are less frequent than near the dip tanks, these invasives have less impact on other herbaceous species, hence the latter then start to increase in richness as observed in this study. *Datura stramonium* is a poisonous weed that competes aggressively with crops in the field and pasture. The plant has also been shown to affect the basic and complex geometric characteristics of maize seeds such as dimension, aspect ratio, equivalent diameter, sphericity, surface area and volume (Karimmojeni, 2021). *Lantana camara* has been reported to out-compete native species, leading to a reduction in biodiversity (Kohli, 2006). Although no significant differences were observed for *O. latifolia* in the present study, its extracts have been reported to reduce the percentage of seed germination of snapdragon (*Anthirrhinum majus* L.), an ornamental plant by up to 43.7 units (Pego & Fialho, 2018). Thus, although alien invasive species might be more at the dip tanks, in the long term they can proliferate to the rest of the rangeland negatively affecting structure and composition of other plants.

Some of the alien plant species did not show significant differences along the transects, and consequently did not have significant effect on other native vegetation. However, they can be of no economic value to livestock production. For instance, the flowers of *B. pilosa* are phytotoxic and poisonous, just like *O. latifolia*. All parts of *D. stramonium* contain dangerous levels of poison that may be fatal if ingested by humans and other animals, including livestock (Rojas-Sandoval, 2020). Some alien species are hosts and vectors of harmful parasites that have detrimental impacts on agriculture and the environment. *Bidens pilosa* is a host and vector of root knot nematodes (*Meloidogyne incognita*), tomato spotted wilt virus and fungal pests such as *Cercospora* spp. and *Uromyces* spp. (ISSG, 2018; PROTA, 2018). However, some of them may also be of economic value (Bairwa et al, 2010; Salehi et al, 2018). For instance, wild marigold has a growing demand for its essential oils in the flavour and fragrance. *Bidens pilosa* has antioxidant and antimicrobial activities which may be useful in the treatment of diarrhoea in humans, where for instance, untreated surface water is used (Shandukani et al, 2018).

Although this study was done at a local scale, it demonstrated the need for proper management of rangelands, particularly around resource centres such as dip tanks. Appropriate methods can also be employed to control these species. Such methods can be manual, mechanical, chemical or depending on type of species, labour requirements, terrain, cost, and level of invasibility. For instance, while *B. pilosa* can be controlled by persistent mowing, hoeing and hand pulling in order to prevent seed production, manual or mechanical control methods are not effective on *O. latifolia* (Pope, 1968; CABI, 2021). Chemically, it can be controlled by the use of herbicides such as glyphosate-trimesium, oxyfluorfen and atrazine. However, some chemicals are not environmentally friendly, and hand-pulling may be more effective. This can be applied, for example, in control of isolated plants of *D. stramonium* before they set seed, while larger infestations can be controlled by tillage when weeds are in the seedling stage (Henderson, 2002). Likewise, it is also easier to control *L. camara* early in its manifestation compared to established stands. For some species, integrated management may be necessary. For instance, a reduced herbicide rate with hand-weeding was shown to act as a safer and sustainable approach for control of *T. minuta* whereby a reduced dose of imazethapyr integrated with hand weeding was reported to be a more sustainable approach (Walia et al, 2021).

Conclusion

Long-term dip tank use resulted in piosphere formation characterised by high frequencies of alien invasive species at distances closer to the dip tanks than further away. However, herbaceous species richness showed an opposite trend. Alien species could have had negative impact on herbaceous species through competition for resources, release of allelopathic chemicals or high reproductive performance. This could potentially lead to reductions in rangeland productivity. Disturbance due to concentrated grazing and trampling by cattle, as well as dung-deposits at the dip tanks also created environments that were conducive for proliferation of alien invasive species. Early management of invasive species is therefore important in order to curb serious long-term adverse impacts that may reduce rangeland productivity.

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