

Chapter

Range Expansion of *Catha edulis*: Implications on Plant Communities in Upland Zimbabwe

Evelyn Ngarakana, Clemence Zimudzi, Shakkie Kativu and Brita Stedje

Abstract

Invasive plants have had significant impacts on vegetation communities of Zimbabwe. A study was undertaken to determine current and potential distribution of *C. edulis* in Zimbabwe using DIVA GIS and MAXENT, and to determine climatic conditions under which the species thrives, together with. The species population structure and its impact on native species. Results indicate that the species has its highest occurrence frequency in Manicaland Province, followed by Matebeleland South Province. Some 13% occurrence points were recorded at an altitude less than 600 m, 21% at an altitude ranging from 600–999 m, 43% at an altitude between 1000 and 1399 m and 23% at an altitude above 1400 m. *C. edulis* was recorded in areas of maximum temperature range of 34°C and a minimum of 20°C. The species also occurred in regions with a mean precipitation range as low as 60–300 mm and as high as 1000–1261 mm. Further, *C. edulis* distribution is predicted to expand in the Eastern Highlands (Manicaland), parts of Mazowe and Bindura (Mashonaland Central Province) and parts of Matobo (Matebeleland South Province). Diameter class distributions showed an inverse J-distribution in control sites and in all three sampled sections. An irregular bell-shaped distribution was recorded for co-occurring species on *C. edulis* occupied sites. It was concluded that *C. edulis*' regeneration potential is high and that of competing native species is unstable and has the potential to expand beyond the currently occupied sites.

Keywords: *Catha edulis*, predicted distribution, population structure, impacts, Zimbabwe

1. Introduction

Currently, global biodiversity is being threatened greatly by climate change and invasive species [1]. Several dozens of species and variants (including invasives) have been introduced into Zimbabwe [2], a majority of them within the Eastern Highlands where the climate supports the highest plant diversity. These include some suspected variants of *Catha edulis* (Vahl) Forssk. exEndl. *C. edulis* naturally occurs in the horn

of Africa down to southern Africa and Madagascar. Its centre of origin is believed to be Ethiopia and Kenya [3].

Observations on spatial distribution of *C. edulis* in Zimbabwe over the past few years indicate that it is spreading, and where this occurs, few other plant species thrive [4]. Immigrants from East Africa are suspected to have introduced different variants of *C. edulis* to Southern Africa [5]. Some such variants have become more aggressive and currently occupying forest margins in Manicaland, Zimbabwe (Eastern Highlands), an area which forms part of the eastern Africa biodiversity hotspot [6]. The Eastern Highlands ecosystem provides freshwater and other ecosystem services to a significant number of people in the region [6].

The climatic conditions under which *C. edulis* in Zimbabwe thrives and its current and potential sites of distribution in the country are not known. That, together with the population structure of the species, requires an urgent investigation as the results may be useful in predicting the species distribution trends and in wildlife management. An assessment of the impact of *C. edulis* on biodiversity of the Eastern Highlands biodiversity hotspot is also needed. Population structure, which partly reflects age and size structure, is indicative of the health and survival capacity of a species [7]. Important life stages of a species can be revealed and aid in wildlife management [8]. Species diversity and evenness make up species composition and the higher the species richness and productivity are the more resilient the ecosystem is [9].

The present study sought to map current and potential distribution of *C. edulis* in Zimbabwe using MAXENT and DIVA GIS, establish climatic conditions under which the species thrives, determine the population structure of *C. edulis* and assess its impact on indigenous species within Vumba Forest area of Zimbabwe. Maximum entropy (MAXENT), which relies only on presence data and background environmental information, was the preferred assessment method. The method also accommodates small sample size and allows for gaps in records [10].

2. Materials and methods

2.1 Study area

This study was conducted in Zimbabwe. About 4% of the country receives an annual rainfall of >1000 mm, and low mean annual temperatures which range from 15 to 18°C. Approximately 32% of the country has annual rainfall below 500 mm, with a high mean annual temperature of 21–25°C [11]. Some 16% of the country is under protection, and includes endemic and critically endangered plant and animal species [12].

Population structure studies were carried out in Vumba, Eastern Highlands of the country (**Figure 1**). Vumba is about 246 km² with its highest altitude being 1911 m [14]. The mean yearly precipitation is 1800 mm and majority occurs between November and August [6]. Soils are deep and well weathered [6]. Its vegetation comprises miombo woodland which favours high rainfall, evergreen Afromontane forests and montane grassland [14]. Most of the vegetation types have been exposed to severe disturbances which has paved way for the encroachment of such invasive species as *Cestrum aurantiacum* Lindl., *Lantana camara* L., *Vernonanthura polyanthus* (Spreng.) Vega & Dematteis and *Solanum mauritianum*

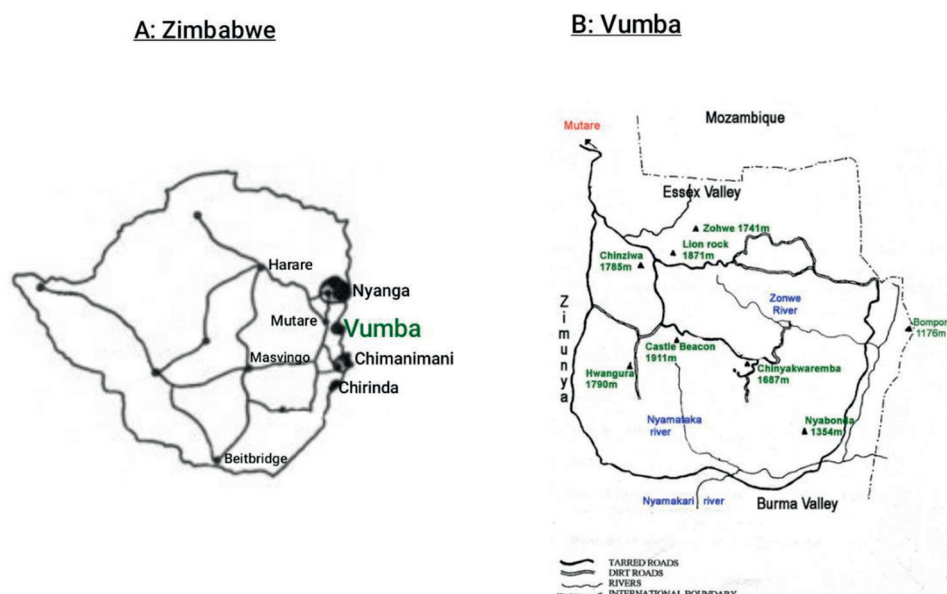


Figure 1.
 Study area map in Vumba (right), and its location within Zimbabwe (left) Ballings & Wursten [13].

Scop. [6]. Wattle and eucalypts are also planted for commercial purposes [6]. The following GPS coordinates are of the first, second and third study plots respectively: 19.064640°S, 32.720713°E; 19.078418°S, 32.750628°E; 19.071590°S, 32.744625°E.

2.2 Mapping of *C. edulis* populations

Sources for the species occurrence data were the Zimbabwean National Herbarium and Botanic Gardens, Global Biodiversity Information Facility (GBIF) (www.gbif.org) and Zimbabwe Flora (www.zimbabweflora.co.zw). In the course of field studies, new distribution records of *C. edulis* were recorded. The combined data were checked for duplication. The source for climate variables was WorldClim (www.worldclim.org). WorldClim has a total of 19 bioclimatic variables, 11 temperature and 8 precipitation matrices which represent different annual trends, seasonality and extreme environmental conditions [15]. Pearson correlation coefficients were examined in order to check all the variables for multicollinearity [16]. The first principal component analysis (PCA) analysed only one variable from each set of highly correlated variables ($r > 0.95$). The main bioclimatic variables were also determined by performing the Correlation analysis (CA) and PCA using the statistical program R version 3.1.3 [16]. Spatial resolution used was 30 arc seconds (about 1 km² per pixel). This allowed for maximum details [17]. DIVA-GIS [18] was used to map the distribution of *C. edulis* in the whole of Zimbabwe. It is a geographic information system that has been used in various mapping studies such as the mapping of spatial distribution of *Jatropha curcas* L. in Malaysia by Shabanimofrad *et al.* [19] and that of *Senecio vulgaris* L. in China by Cheng and Xu [15]. The software was used according to the manual guide by Scheldeman *et al.* [20].

2.3 Predicting *Catha edulis* potential sites of distribution

MAXENT model was used to predict the potential sites of distribution of *C. edulis*. One-time Split method was used to partition the occurrence records for use in validating the accuracy of the model's predictions [21]. 75% was randomly selected to make up the training data (calibration data) and the remaining 25% was the test data (evaluation data) [17]. Jackknife test was used to measure the importance of the climatic factors. MAXENT was run in default settings. Area Under Curve (AUC) was used to evaluate the predictive ability of the model generated by MAXENT [15]. Results were imported and visualised in DIVA-DIS. The software was used according to the manual guide by Scheldeman *et al.* [20] and explanations by Phillips *et al.* [22].

2.4 Population structure

The study was carried out in October and November 2020. Three *C. edulis* occupied sites representing at least 20% of the total area with the species were randomly selected. Three adjacent sites without *C. edulis* were also selected to be controls and were situated within 100 m from the occupied sites. *C. edulis* occupied sites where land had been cleared for the construction of electricity power line in the 1960s (pers. comm.) while the control sites had no obvious signs of disturbance.

Three lines of transect measuring 210 to 220 m were placed 60 m each from the disturbed point to the furthest point away from disturbance where *C. edulis* occurred. Following Walker [23] and Gandiwa & Kativu [24]'s set up, 20 x 10 m sampling plots were systematically placed 65 m apart each. Total plots in the sites occupied by *C. edulis* and the control sites were 27 each. Three sections were also demarcated in the sites occupied by *C. edulis* as sections (i) closest, (ii) mid-way, and (iii) furthest from disturbance.

Stem circumferences of each woody species in the study plots were measured at 1.3 m with a tape measure [25] and used to calculate diameter at breast height (circumference/ π). Each stem on multi-stemmed plants was measured and the values summed up to calculate the circumference of the plant [25]. All the woody species in the study plots were also identified *in situ* or at the National Herbarium in Harare.

Differences in species evenness and composition in the control sites and sites occupied by *C. edulis* were verified using the equitability test and Shannon-Weiner diversity index [26]. Separate analyses were done for each site and then averaged. Shapiro-Wilk test was used to test for normality in populations from both the sites occupied by *C. edulis* and the adjacent control sites in SPSS 2007. Significant differences in species richness and evenness in the sites invaded by *C. edulis* and the control sites were assessed using Independent T-test in Microsoft Excel 2007. Significant differences in means of the three sections studied also assessed using One Way ANOVA in Microsoft Excel 2007.

3. Results

Current spatial distribution and location altitude of *C. edulis* in Zimbabwe is as illustrated in **Figure 2**. Manicaland Province recorded the highest number of *C. edulis* presence points, followed by Matebeleland South Province. Of the 161 *C. edulis* presence points recorded, 13% occur at an altitude less than 600 m represented by yellow

triangles. 21% occur at an altitude ranging from 600 to 999 m and represented by orange squares. The highest presence points recorded (43%) occur at an altitude between 1000 and 1399 m, and this is followed by 23% which occur at an altitude above 1400 m.

Spatial distribution of *C. edulis* in Zimbabwe and maximum temperature of warmest month at each site are illustrated in **Figure 3**. Sampled *C. edulis* occupies sites with four temperature ranges were recorded out of five. The occupied sites include those with a maximum temperature range of 31–34°C represented by white, 28–31°C represented by yellow, 24–28°C represented by neon/light green and those with the maximum temperature range of 20–24°C represented by forest/dark green.

Spatial distribution and sites' average precipitation of warmest month of *C. edulis* are as illustrated in **Figure 4**. The sampled *C. edulis* is shown to be occupying sites with all five different precipitation ranges. The occupied sites include those with a mean precipitation range of 60 to 300 mm represented by white, 300 to 500 mm represented by yellow, 500 to 800 mm represented by neon-green, 800 to 1000 mm represented by pine-green and those with a mean precipitation range of 1000 to 1261 mm represented by tea-green.

Potential sites of distribution of *C. edulis* in Zimbabwe are illustrated in **Figure 5**. Further *C. edulis* distribution is predicted in the Eastern Highlands (Manicaland Province), parts of Mazowe and Bindura (Mashonaland Central Province) and parts of Matobo (Matebelaland South Province) with a probability of 0.5 to 1 represented by red.

Table 1 shows the percentage contributions of the 19 bioclimatic variables that were used in modelling the potential sites of spread of *C. edulis* in Zimbabwe. Results show that precipitation of driest month (BIO14), mean temperature of warmest quarter (BIO10) and maximum temperature of warmest month (BIO5) had the highest contribution in the modelling of *C. edulis* distribution in Zimbabwe shown in **Figure 4**. Their total contribution was 74.1%.

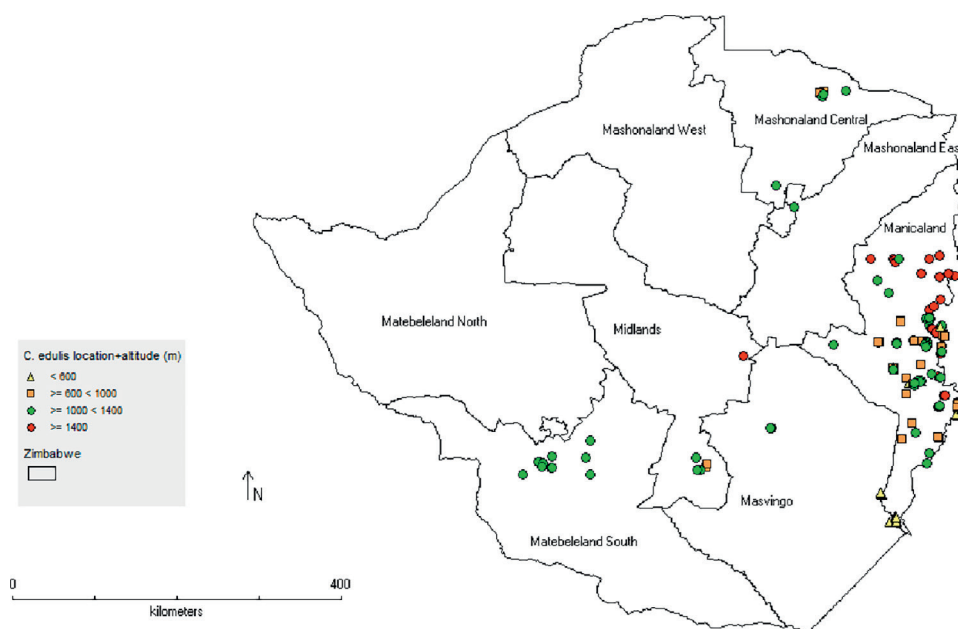


Figure 2.
 Distribution and altitudinal location of *C. edulis* in Zimbabwe.

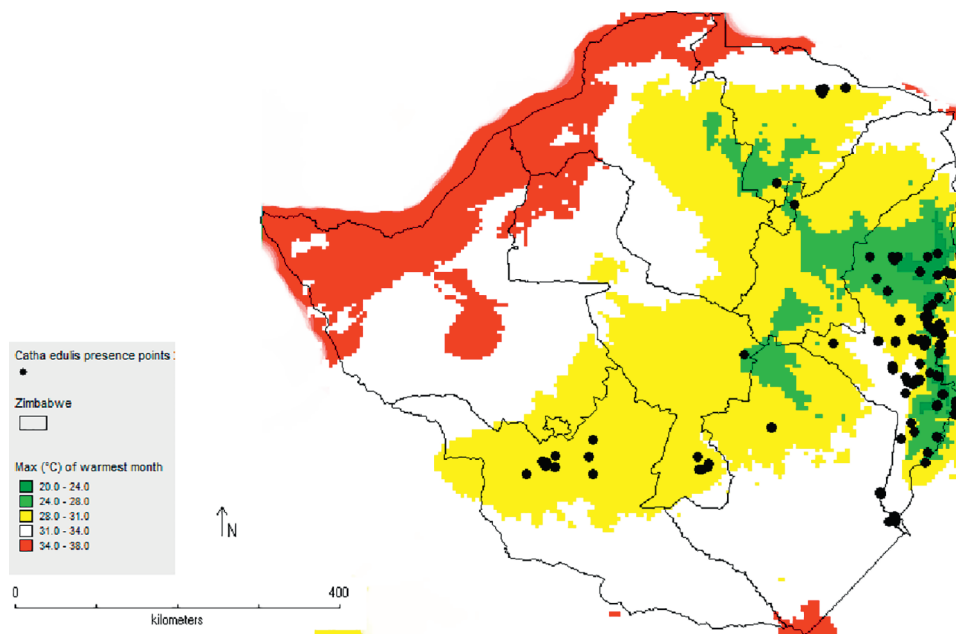


Figure 3.
Distribution of *C. edulis* with location maximum temperatures of warmest month in Zimbabwe.

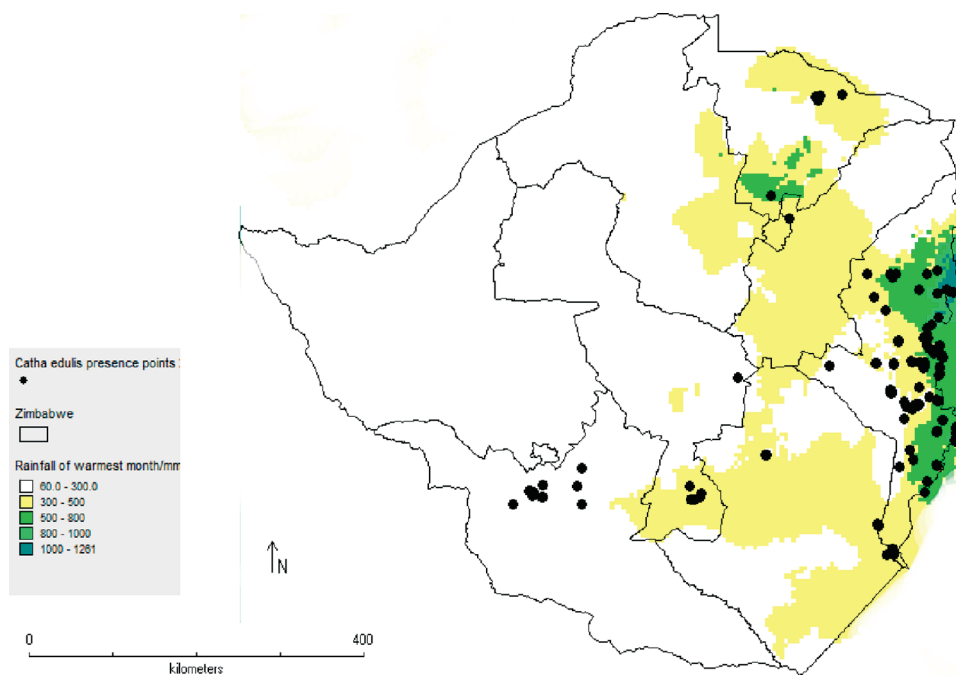


Figure 4.
Distribution of *C. edulis* with mean precipitation of warmest month in Zimbabwe.

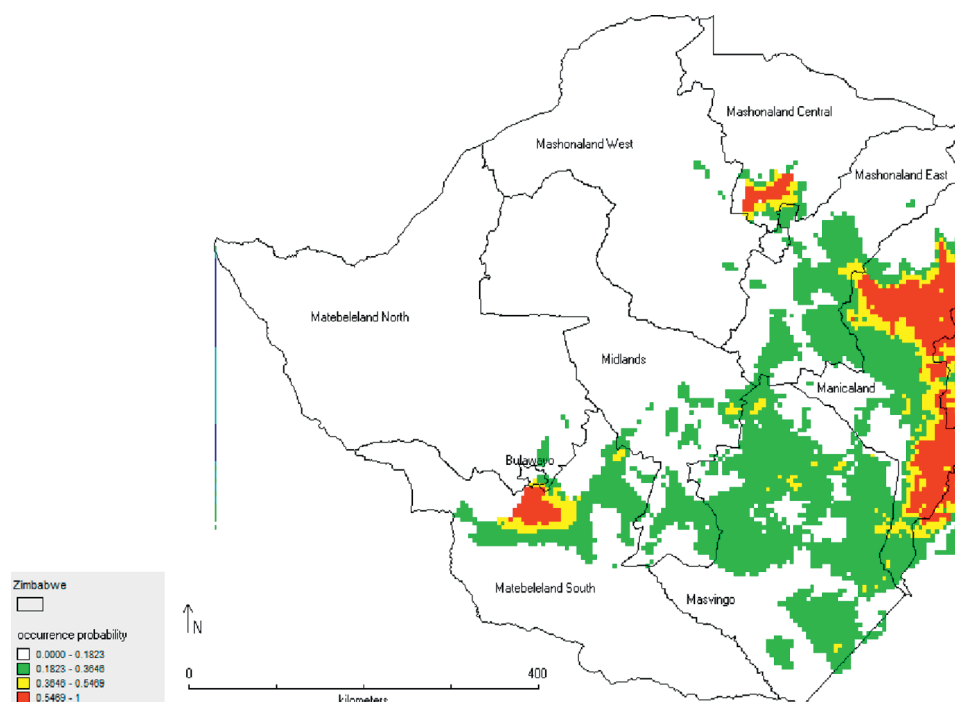


Figure 5.
 Potential sites of distribution of *C. edulis* in Zimbabwe.

Figure 6 shows relative importance of the variables with respect to training gain after jackknife test had been done. BIO14 generated the highest gain when used as the only bioclimatic variable of the model and its omission also resulted in the strongest decrease of gain among all the variables. This is consistent with the relevance of bioclim variables test (**Table 1**).

Figure 7 shows the predictive ability of the model in **Figure 5** generated by Maxent using Area Under Curve (AUC) of the Receiver Operating Characteristic (ROC) curve. Random prediction (black line) is a reference line. Both training data (red line) and test data (blue line) shows that the model had a high predictive ability with a high AUC value of 0.95.

Table 2 lists the woody plant species observed in the study plots. Sites invaded by *C. edulis* had 6 species while sites unoccupied by *C. edulis* had 15 species. *Trema orientalis* and *Harungana madagascariensis* were only found in the sites occupied by *C. edulis* while *Bersama abyssinica*, *Heteropyxis dehniae* and *Acacia abyssinica* were recorded in both invaded and control sites.

Sites occupied by *C. edulis* and the adjacent control sites had greater Shapiro–Wilk test values (0.22 and 0.21, respectively) than the alpha value (0.05). The populations are therefore normally distributed. Parametric tests were used to check for differences in species richness and evenness among the populations in the study sites. Means of the sections close to, mid-way and furthest from disturbance were also subjected to parametric tests to check for differences among study sections.

Variable	Name of variable	Percent contribution	Permutation importance
BIO14	Precipitation of driest month	53.7	27.3
BIO10	Mean temperature of warmest quarter	12.6	2.9
BIO5	Maximum temperature of warmest month	7.8	8.4
BIO19	Precipitation of coldest month	6.7	0
BIO16	Precipitation of wettest month	3.1	10.6
BIO7	Temperature annual range	2.6	0
BIO9	Mean temperature of driest quarter	2.3	12.8
BIO4	Temperature seasonality	2.1	3.7
BIO15	Precipitation seasonality	1.4	11.3
BIO18	Precipitation of warmest month	1.3	7.6
BIO3	Isothermality	1.3	4.9
BIO17	Precipitation of driest month	1.2	2.1
BIO13	Precipitation of wettest month	1.2	2.9
BIO8	Mean temperature of wettest month	1.1	0
BIO12	Annual precipitation	1	3.3
BIO6	Mean temperature of coldest month	0.6	0.1
BIO2	Mean diurnal range	0.1	2.2
BIO11	Mean temperature of coldest quarter	0	0
BIO1	Annual mean temperature	0	0

Table 1.
Relevance of each bioclimatic variable for the model.

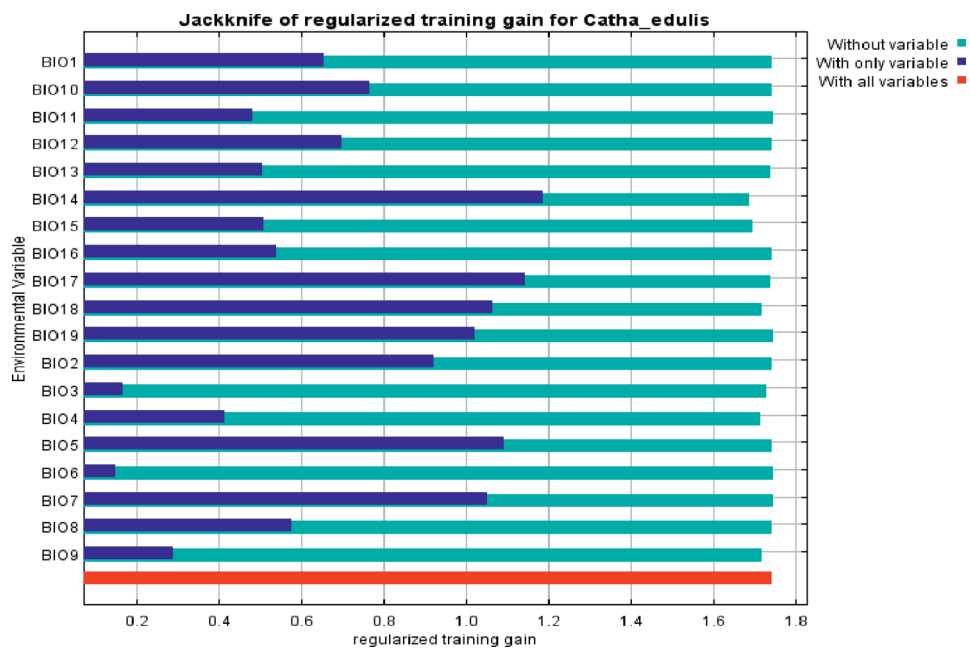


Figure 6.
Results of jackknife evaluation of the relative importance of the variables with respect to training gain.

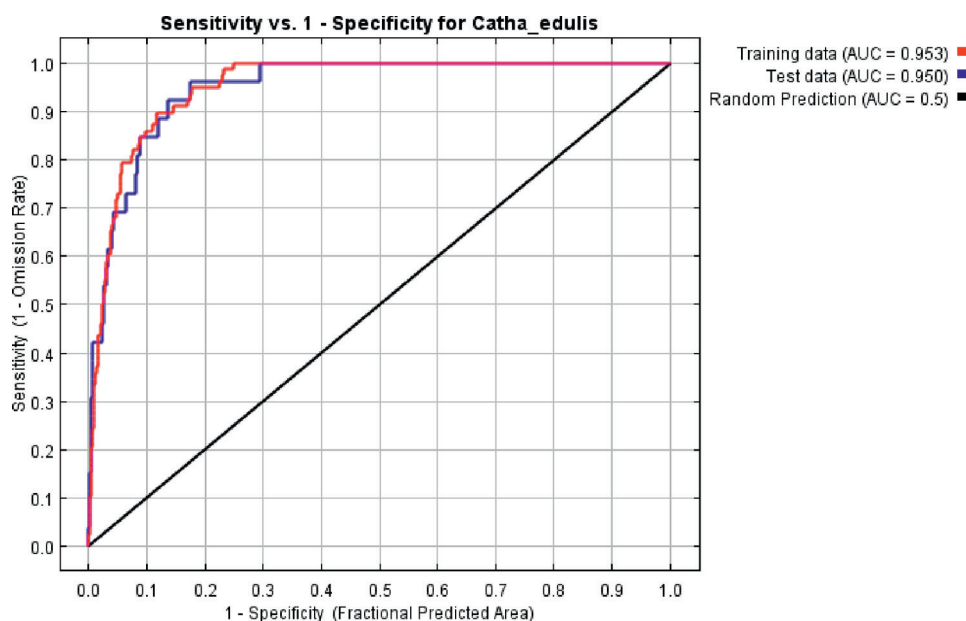


Figure 7.
 Evaluation of the predictive ability of the model generated by Maxent using AUC of the ROC curve.

Sites occupied by *C. edulis* had mean equitability value of 0.11 while the adjacent control sites had a value of 0.45. The latter is closer to 1 while the former is closer to 0. Control sites also had a higher Shannon diversity index of 2.65 compared to that of the sites occupied by the *C. edulis* (0.73). T Stat values in both Equitability test and Shannon diversity index (63.82 and 60.56, respectively) are higher than 2.78 which is the t Critical value. Equitability test and Shannon diversity index's P values of 3.6×10^{-7} and 4.45×10^{-7} are less than 0.05 which is the Alpha value. Therefore, the differences in species evenness and diversity in sites occupied by *C. edulis* and the unoccupied sites is significant.

Results of diameter class distribution of *C. edulis* stems in the section close to, middle section and furthest from disturbance respectively are shown in **Figure 8** and all three sections display an inverse J-distribution.

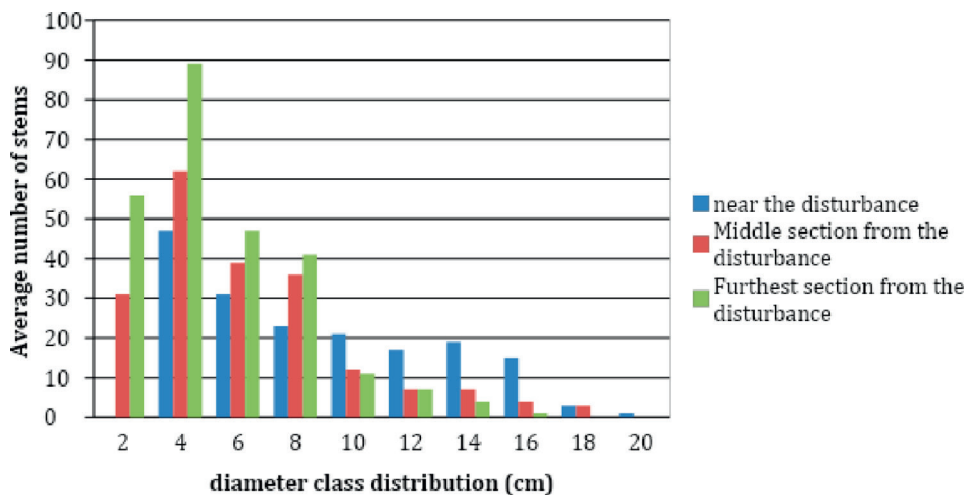
Percentages of mean number of *C. edulis* stems recorded in the section close to, mid-way and furthest from disturbance in the three diameter classes are summarised in **Table 3**. 0-8 cm diameter class had an average of 502 stems. Section closest to the disturbance had the lowest percentage (20.1%) while the one furthest from the disturbance had the highest percentage (46.4%). The second diameter class (8<16 cm) had an average of 125 stems and 18.4% of these stems were recorded in the section furthest from disturbance while 57.6% were in the section closest to the disturbance. 16<24 cm diameter class had zero recordings in the section furthest from disturbance while 83.3% of the 18 stems recorded in this diameter class were from the section closest to the disturbance.

Results of the One Way Anova show that at least means of *C. edulis* stems in the three diameter classes and the three sections had a significant difference as the 0.05 alpha value was greater than 6.8×10^{-7} , 1.2×10^{-6} , and 6.6×10^{-5} p values. T-test results showed that the means of *C. edulis* stems in all the three sections were significantly different as 0.05 alpha value was greater than 3.7×10^{-5} , 1.7×10^{-4} , 1.4×10^{-3} , 0.031, 2.31×10^{-4} , 8.36×10^{-5} , 0.035, 0.01, 0.005 P values.

Family	Species	<i>C. edulis</i> invaded sites	Control sites
Apocynaceae	<i>Rauwolfia caffra</i> Sond.		x
Celastraceae	<i>Catha edulis</i> Forssk. ex Endl	x	
Clusiaceae	<i>Harungana madagascariensis</i> Lam. ex Poir.	x	
Euphorbiaceae	<i>Macaranga capensis</i> (Baill.) Benth. ex Sim.		x
Fabaceae	<i>Acacia abyssinica</i> Hochst. Ex Beth.	x	x
Fabaceae	<i>Albizia gummifera</i> (J.F. Gmel.) C.A. Sm.		x
Fabaceae	<i>Newtonia buchananii</i> (Baker) G.C.C. Gilbert & Boutique.		
Heteropyxidaceae	<i>Heteropyxis dehniae</i> Suess.	x	x
Meliaceae	<i>Ekebergia capensis</i> Sparrm.		x
Melanthaceae	<i>Bersama abyssinica</i> Fresen.	x	x
Moraceae	<i>Trilepisium madagascariense</i> DC.		x
Phyllanthaceae	<i>Bridelia micrantha</i> (Hochst.) Baill.		x
Proteaceae	<i>Faurea rubiflora</i> Marner.		x
Rosaceae	<i>Prunus africana</i> (Hook.f.) Kalkman.		x
Rutaceae	<i>Calodendrum capense</i> (L.F.) Thunb.		x
Sapindaceae	<i>Allophylus abyssinicus</i> (Hochst.) Radlk.		x
Ulmaceae	<i>Celtis africana</i> Burm. f.		x
Ulmaceae	<i>Trema orientalis</i> (L.) Blume.	x	

Table 2.

Woody species recorded in sites *C. edulis* invaded and non-invaded sites. **X** shows that the species is present in the site.

**Figure 8.**

Diameter class distribution of the mean number of *C. edulis* stems observed in sections close to, mid-way and furthest from *C. edulis* invaded sites.

Diameter class (cm)	near the disturbance	Middle section from the disturbance	Furthest section from the disturbance
$0 \geq 8$	(233) 46.40%	(168) 33.50%	(101) 20.10%
$8 \leq 16$	(23) 18.40%	(30) 24%	(72) 57.60%
$16 \leq 24$	(0) 0%	(3) 16.70%	(15) 83.30%

Table 3.
 Percentages of *C. edulis* stems recorded in the three diameter classes in study sections.

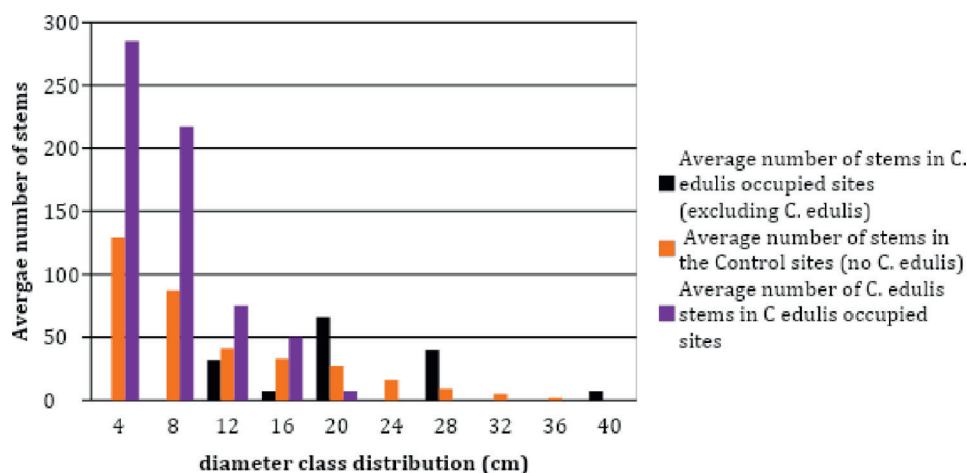


Figure 9.
 Diameter class distribution of the (1) mean number of native stems co-occurring with *C. edulis*, (2) mean number of native stems invaded sites (3) mean number of *C. edulis* stems in sites invaded sites.

Results of diameter class distribution are shown in **Figure 9**. An inverse J distribution is indicated for both native plant stems in uninvaded sites and also for *C. edulis* stems in sites it exclusively occupies. An irregular bell shaped distribution is indicated for native stems co-occurring with *C. edulis* with zero stems being recorded in classes 0–8, 21–24 and 29–35 cm.

4. Discussion

Altitude, temperature and precipitation were the primary parameters used in constructing the maps because of their crucial role in determining plant distribution, growth and persistence [27]. Altitude influences such microclimatic conditions as temperature and precipitation [28]. *C. edulis* was found to be predominantly occurring in the Eastern Highlands of Zimbabwe, a region characterised by relatively high altitude, high rainfall and low temperatures. This observation is consistent with what was reported in Yemen and Ethiopia by Al-hebshi & Skaug [29], Zahran et al. [30] and Kandari et al. [31]. *C. edulis*, being an evergreen tree [31], is well adapted to these conditions. Broad-leaved subtropical evergreen trees have low water use efficiency. Hence, they thrive in high rainfall conditions. They use the stored, readily available underground water for evaporative cooling during the dry season to avoid excessive light and heat stress which enables them to retain their leaves throughout the dry season [32].

The results, however, show that *C. edulis* also occurs in other parts of Zimbabwe which are at low altitude and characterised by low rainfall and high temperatures. Similar results were summarised by Zahran et al. [30] where different variants of *C. edulis* were distinguished by the Yemenis farmers based on different altitude and climatic conditions under which they thrive. Most plants in dry areas have shallow roots which allow quick uptake of moisture and nutrients near the soil surface [33].

Dessie & Kinlund [34] also reported that *C. edulis* was expanding into relatively higher temperature, lower rainfall and lower altitudinal zones, resulting in the decline of forests in Wondo Genet, Ethiopia. The present study observed similar range expansion trends for *C. edulis* occupied sites in the Eastern Highlands of Zimbabwe. Dessie & Kinlund [34] attributed range expansion of *C. edulis* to various factors, including the species ecological adaptability and its genetic variation [35].

Plants with broader climatic and altitudinal needs are reported to be highly adaptive, with potential to become invasive [36]. Most non-invasive species biological activities and growth occur within specific narrow temperature ranges. Such species require specific amounts of precipitation for physiological processes [37]. However, species with dominance and invasive tendencies tend to tolerate a wide range of climatic and edaphic conditions [36]. In a study to assess invasion risk of plants by Higgins & Richardson [38], a physiologically based species distribution model was used, and it concluded that species that tolerate a wider range of environmental conditions tend to be invasive. Findings of the present study showed that *C. edulis* in Zimbabwe thrives under broad climatic conditions, and has the potential to expand its range of distribution in the Eastern Highlands of the country.

Sites occupied by *C. edulis* had significantly different species evenness and diversity from those not occupied by the *C. edulis*. Other studies involving plant species with invasive properties also showed similar trends [39, 40]. *C. edulis* has a competitive advantage as it produces seeds in large quantities, allowing it to occupy new extended habitats [41, 42].

Plots further away from the point of disturbance had notably younger and higher numbers of *C. edulis* stems in comparison to those closest to the disturbance. *C. edulis* individuals nearest the disturbance were the first ones to occupy the site hence are the oldest. In conducive conditions, the combination of *C. edulis* being tall plus producing relatively smaller seeds [43], allows it to disperse its seeds furthest away from the parent plant [44]. This reduces intra specific competition and enhances increased range distribution for the species [45]. Seeds from tall trees are dispersed from a higher point which is significantly open thereby reduces chances of other plants disturbing them. Shrubs and seedlings of *C. edulis* are therefore more densely populated than the adults [34] in a similar sized area, thus, comprising a higher population density in comparison with a site occupied predominantly by adults.

Fifty percent of the species found in sites disturbed areas are pioneer species [46]. The height, densely packed establishment of *C. edulis* and its closed canopy formation tend to suppress the growth of co-occurring pioneer species. Their seedlings are deprived of light due to the shade formed by *C. edulis*' closed canopy growth form [34]. This strategy has been observed in other species for example, *Impatiens glandulifera* [40]. This species reduces evenness and diversity in habitats it invades by forming a closed canopy over seeds of co-occurring species, thereby depriving them of light which disturbs germination and also cause stunted growth [40].

The observed inverse J-distribution for *C. edulis* implies that the species is in a healthy regenerating state [47]. This distribution pattern is usually displayed when the lower diameter classes have a higher number of individuals which steadily reduce

towards the higher diameter classes. Such a distribution ensures sustainability of the population as there will be numerous seeds that can be recruited into the following growth stages [48]. An irregular-bell shaped distribution like the one shown by the co-occurring native species in sites occupied by *C. edulis* suggests that the rate of regeneration is lower than the mortality rate at certain diameter classes [48] therefore the population will be in poor regeneration potential [47]. Hence, their populations are under threat. Native species in sites not occupied by *C. edulis* showed a healthy regeneration potential.

The main driving assumption in population diameter class distribution structures is that a population with more stems in the lower diameter classes compared to the higher ones is constantly regenerating, while that with fewer stems in the lower classes compared to the higher classes is in decline [49]. However, this assumption is not true for all species populations as some have displayed the reverse J-shape distribution but well known to be declining [7]. Some species which do not display the reverse J-shape distribution are actually known to be increasing or their populations are in stable states [50]. These observations have been credited to the different growth rates sometimes found among different size classes. The population diameter distribution method and interpretation, however, has been used successfully in many studies by Souza [47, 48, 51]. While it is not recommended as a sole assessment method, it is a useful basis for management decisions in the absence of complementary demographic approaches [49].

5. Conclusion

Catha edulis has stable populations with high potential for regeneration in the Eastern Highlands of Zimbabwe, while co-occurring indigenous species are in a decline or unstable state. The persistence of *C. edulis* in sites furthest away from points of disturbance suggests that disturbance is not the only determinant factor for the invasion taking place, which is a worrisome observation for the continued existence of the indigenous species in the area. Future studies must focus on elucidating mechanisms that support and encourage the dominance of *C. edulis* and potentially suppressing co-occurring native species in areas occupied by *C. edulis*.

Acknowledgements

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