International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 30 No. 1 December 2021, pp.291-299

Population Structure of Catha edulis (Vahl) Forssk. Ex Endl. And Its Impact on Woody Species Composition in Vumba, Zimbabwe

[1]Evelyn Ngarakana, [2]Clemence Zimudzi, [3]Shakkie Kativu and [4]Brita Stedje

[1,2,3]Department of Biological Sciences,
University of Zimbabwe,
Box MP167 Mt Pleasant, Harare, Zimbabwe,
[4]Natural History Museum,
University of Oslo,
P.O. Box 1172, Blindern, 0318 Oslo, Norway,

Abstract— Different variants of *C. edulis* have been introduced to Southern Africa by Somali and Ethiopian immigrants over the last few decades. Sites occupied by *C. edulis* in the Eastern Highlands of Zimbabwe tend to be species poor, with *C. edulis* dominating the flora. An investigation was carried out to establish the population structure of *C. edulis* within Vumba forest of Zimbabwe and its impact on native species. Results showed that, sites occupied by *C. edulis* were less diverse in terms of species composition with a total of 6 co-occurring species, while adjacent sites without *C. edulis* had a total of 15 species. Independent T test results showed that in both Shannon diversity index and Equitability test, the t Stat values of 60.56 and 63.82, respectively, were greater than the t Critical value of 2.78. Hence there is a significant difference in species diversity and evenness between *C. edulis* occupied sites and adjacent unoccupied sites. Diameter class distribution of *C. edulis* showed an inverse J-distribution across sites occupied by the species under different regimes of disturbance. Co-occurring species showed an irregular bell-shaped distribution with complete absence of individuals in classes 0-8 cm, 21-24 cm and 29-35 cm, suggesting that the species are in poor regeneration capacity. It was concluded that *C. edulis* has a high regeneration potential while populations of competing native species are in apparent unstable condition. The predominance of *C. edulis* in sections furthest away from disturbance suggests an encroachment of the species beyond disturbed sites.

Keywords—species; distribution; dominance; encroachment; composition; plant

I. Introduction

Catha edulis (Vahl) Forssk. ex Endl. is an evergreen woody plant species belonging to family Celastraceae [1]. The plant is known by different common names in several countries: 'chat' in Ethiopia, 'qat' in Yemen, 'mirra' in Kenya , Bushmen's tea or 'Khat' or 'Muzvaravashava' in Zimbabwe [2]. Its area of natural occurrence extends from Ethiopia and Eritrea, through Somalia to Kenya, Tanzania, Malawi southwards to Zimbabwe, South Africa and Madagascar. The centre of origin for *C. edulis* has for long been thought to be the south-western highlands of Ethiopia [3]. Recent studies however, point to Kenya as another possible area of origin [4].

Zimbabwe is recorded as one of *C. edulis'* natural areas of distribution and its spatial distribution in the country appears to be expanding [2]. Where it is fully established, few other species occur. Different variants of *C. edulis* appear to have been transported and planted in Southern Africa by Somali and Ethiopian immigrants over the past decades [5]. These new variants of *C. edulis* introduced into southern Africa appear to be spreading more aggressively than the native ones. These occupy forest margins in the Eastern Highlands of Zimbabwe. This is a major concern, as the highlands are part of the Eastern Afromontane biodiversity hotspot's ecosystem that provides fresh water and numerous other ecosystem services to the region [6].

An investigation of the population structure of *C. edulis* is urgent as it can be used to predict its future trends and also be used for making plans for management. Additionally, the impact of *C. edulis* on the species composition of the highlands needs to be assessed. Population structure here refers to age and size structure as partly explained by [7]. It indicates how size structure is expressed within a population and how it is likely to contribute to the continued success of the species. Through this, crucial life cycle stages of the species can be identified and targeted for the management of the species [8]. Species composition is a combination of species diversity and species evenness [9]. Greater species richness and productivity makes an ecosystem more resilient [9].

The specific objectives of the present study were to establish the population structure of *C. edulis* within Vumba forest of Zimbabwe and its impact on native species.

II. Materials and methods

II.1.Study area

The study was conducted in Vumba forest on the Eastern Highlands of Zimbabwe along the border with Mozambique [10] (Fig 1). The forest is approximately 246 km^2 and its highest altitude is 1911 metres above sea level [11]. Vumba receives an average annual precipitation of 1800mm, with the majority of it occurring from November to August [6].

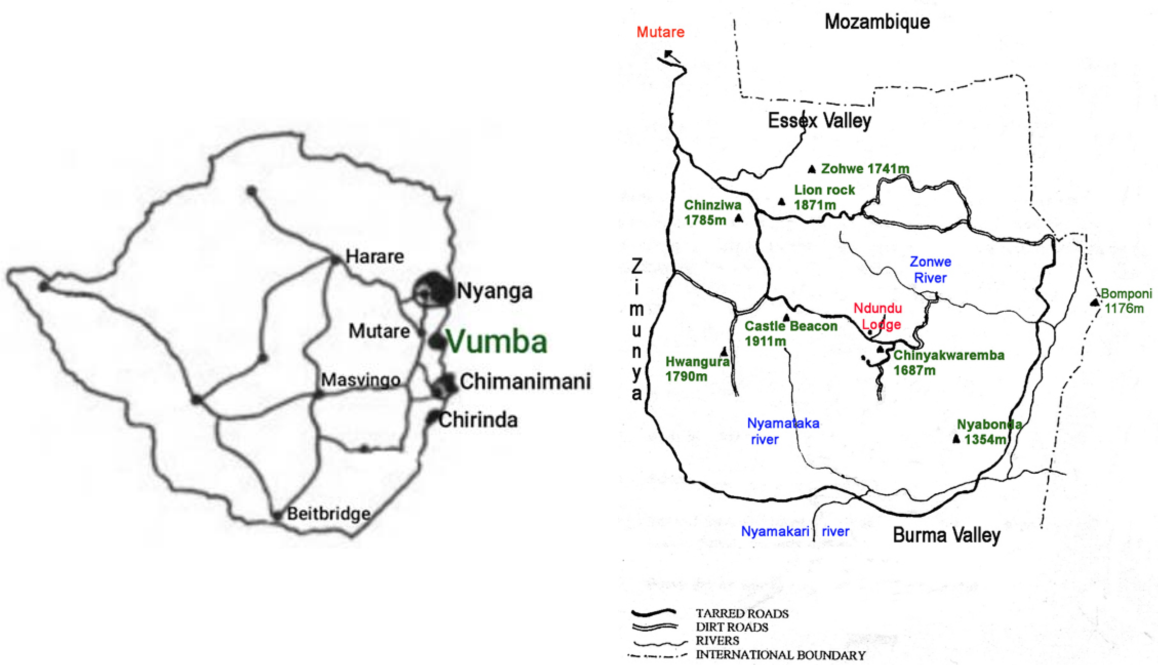

Fig. 1. Map of the study area Vumba (right), and its placement within Zimbabwe (left). Maps were adopted from [12].

During the cool season, the mean daily maximum temperature is 18°C and the mean daily minimum temperature is 7°C (www.vumba.climatemps.com). Mean daily maximum temperature for the warm season is 23°C and the mean daily minimum temperature is 12°C (www.vumba.climatemps.com). Soils are deep and well weathered [6]. Vegetation includes Afromontane evergreen forests, montane grassland, high rainfall miombo woodland and secondary scrub savanna [11]. Most of the forests have been disturbed to varying degrees due to development of roads and power-lines which have left the forests exposed to invasive species such as *Vernonanthura polyanthus* (Spreng.) Vega & Dematteis, *Lantana camara* L., *Solanum mauritiunam* Scop. and *Cestrum aurantiacum* Lindl. [6]. There are also commercial plantations of exotic species like the wattle and other eucalyptus trees [6]. The GPS coordinates of the invaded study plots 1, 2 and 3 are 19.064640° S, 32.720713° E; 19.078418° S, 32.750628° E;19.071590° S, 32.744625° E respectively.

II.2.Sampling design

Three sites occupied by *C. edulis* were randomly selected alongside three adjacent sites unoccupied by the species as controls. The occupied sites were close to areas disturbed by construction of electricity power lines in the 1960s or gaps created by dead trees. The three control sites were demarcated within 100m from the *C. edulis* occupied sites, and had no obvious signs of disturbance. The occupied sites represented approximately 20% of the area occupied by *C. edulis* within the study area.

The study was conducted in October and November 2020. Three transect lines, 210m to 220m, were laid approximately 60m apart, running from the source of disturbance to the furthest point where *C. edulis* could still be observed. Sample plots measuring 20x10m were systematically laid at 65m intervals, similar to the setup of [13] and [14]. Twenty seven plots were laid in the *C. edulis* occupied sites and another 27 within the adjacent control sites. The plots in *C. edulis* occupied sites were further categorised into three sections, namely i) section near disturbance, ii) middle section from disturbance and iii) furthest section from disturbance.

II.3.Data collection

Within each plot, the identity of each woody species was established *in situ*, and the stem circumferences measured. Those which could not be identified in the field were collected and identified at the National Herbarium in Harare. Stem circumference at 1.3m was measured using a tape measure [15]. Circumferences for multi-stemmed plants were measured for each stem and the values summed up [15]. Diameter at breast height (dbh) was calculated using the following formula: circumference/pi.

II.4.Data analysis

Shannon-Weiner diversity index and equitability test were used to determine any differences in species composition and evenness within *C. edulis* occupied sites and adjacent control sites [16]. Data from the three *C. edulis* occupied sites and the adjacent sites were analysed separately and then averaged. Populations in both *C. edulis* occupied sites and the control sites were tested for normality using Shapiro-Wilk test in SPSS 2007. Independent T-test was used to check whether there was any significant difference in species diversity and evenness between *C. edulis* occupied sites and the adjacent control sites. One Way ANOVA was used to check for any significant difference in means of the 3 sections (i) section near disturbance,(ii) middle section from disturbance and (iii) furthest section from disturbance. Independent T-tests and One Way ANOVA were conducted in Microsoft Excel 2007.

III. Results

III.1. Woody species composition

Woody species recorded

A list of woody plant species recorded in the study sites is shown in Table 1. *Catha edulis* occupied sites had a total of six species namely, *Acacia abyssinica*, *C.edulis*, *Bersama abyssinica, Harungana madagascariensis, Trema orientalis* and *Heteropyxis dehniae,* while control sites had a total of 15 species belonging to 13 families. The results also show that three species, namely *A. abyssinica, B. abyssinica* and *H. dehniae* occurred in both *C. edulis* occupied sites and control sites.

TABLE I. Woody species recorded within C. edulis occupied and adjacent control sites. X Represents the species recorded in each site type.

Species	*Family*	*Sites occupied by Catha edulis*	*Sites not occupied by Catha edulis*
Acacia abyssinica Hochst. Ex Beth.	Fabaceae	X	X
Albizia gummifera (J.F. Gmel) C. A. Sm.	Fabaceae		X
Allophylus abyssinucus (Hochst.) Radlk.	Sapindaceae		X
Bersama abyssinica Fresen.	Melianthaceae	X	X
Bridelia mincrantha (Hochst.) Baill	Phyllanthaceae		X
Calodendrum capense (L.F.) Thunb	Rutaceae		X

Species	***Family***	***Sites occupied by Catha edulis***	***Sites not occupied by Catha edulis***
Catha edulis	Celastraceae	X	
Celtis africana Burm. f.	Ulmaceae		X
Ekerbegia capensis Sparrm.	Meliaceae		X
Faurea rubiflora Marner.	Proteaceae		X
Harungana madagascariensis Lam. Ex Poir	Clusiaceae	X	
Heteropyxis dehniae Suess	Heteropyxidaceae	X	X
Macaranga capensis (Baill.) Benth. Ex Sim.	Euphorbiaceae		X
Newtonia buchananii (Baker) G.C.C. Gilbert & Boutique	Fabaceae		X
Prunus Africana (Hook.f.) Kalkman.	Rosaceae		X
Rauvolfia caffra Sond.	Apocynaceae		X
Trema orientalis	Ulmaceae	X	
Trilepisium madagascariense DC.	Moraceae		X

Shapiro-Wilk test results for normality of plant population in C. edulis occupied sites and control sites.

The Shapiro-Wilk test values for the populations in *C. edulis* occupied sites and control sites were 0.22 and 0.21 respectively. Since the values are greater than the alpha value of 0.05, the populations are normally distributed therefore the parametric tests were used to check whether there was any significant difference in species diversity and evenness between *C. edulis* occupied sites and the adjacent control sites. They were also used to check for any significant difference in means of the 3 sections (i) section near disturbance, (ii) middle section from disturbance and (iii) furthest section from disturbance.

Shannon diversity index and results of the Equitability test.

The mean equitability value for *C. edulis* occupied sites was 0.11 which is close to 0, while that of control sites was 0.45 which is closer to 1. The Shannon diversity index for *C. edulis* occupied sites (0.73) was lower than that of the control sites (2.65). T test results also show that in both Shannon diversity index and Equitability test, t Stat values of 60.56 and 63.82, respectively, are greater than the t Critical value of 2.78. The P values of 4.45×10^{-7} and 3.6×10^{-7} for the Shannon diversity index and Equitability test, respectively, are also lower than the Alpha value of 0.05. Hence there is a significant difference in species diversity and evenness between *C. edulis* occupied sites and adjacent control sites.

III.2. Diameter class distribution of C. edulis stems in sections near disturbance, mid-way from disturbance and furthest from disturbance

Diameter class distribution of the average number of *C. edulis* stems recorded in plots near disturbance, mid-way from disturbance and furthest from disturbance in *C. edulis* occupied sites is illustrated in Fig 2. The diameter class distribution of the species shows an inverse J distribution in all three sections.

Average number of *C. edulis* stems per site expressed as percentage in the three diameter classes recorded in plots near disturbance, in mid-way from disturbance and furthest from disturbance in *C. edulis* occupied sites are shown in Table 2. A mean of 502 stems were measured in the diameter class 0-8cm. The highest percentage (46.4%) was recorded in plots furthest from disturbance, while the lowest percentage (20.1%) was recorded in plots within the disturbance. A mean of 125 stems were measured in the diameter class 8cm<16cm, with the highest percentage (57.6%) being recorded in plots within the disturbance, and the lowest

(18.4%) within plots furthest away from disturbance. A mean of 18 stems were measured in the 16cm<24cm diameter class, but no recordings were made within plots furthest away from disturbance. 83.3% of these were recorded within disturbed plots.

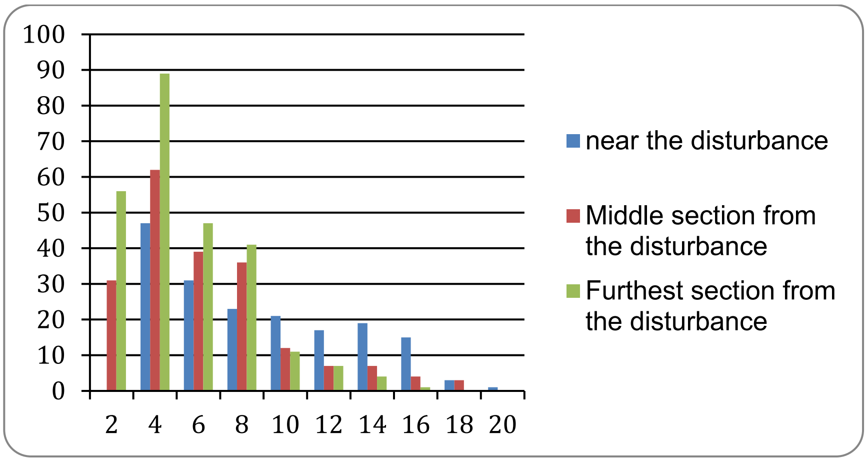

Fig. 2. Diameter class distribution of the mean number of *C. edulis* stems recorded in plots near disturbance, mid-way from disturbance and furthest from disturbance in *C. edulis* occupied sites.

TABLE II. AVERAGE NUMBER OF *C. EDULIS* STEMS PER SITE EXPRESSED AS PERCENTAGE IN THE THREE DIAMETER CLASSES RECORDED WITHIN THE DISTURBED PLOTS, MID-WAY FROM DISTURBANCE AND FURTHEST AWAY FROM DISTURBANCE IN *C. EDULIS* OCCUPIED SITES.

Diameter class (cm)	***Section within the disturbance***	***Section mid-way from disturbance***	***Section furthest away from disturbance***
0≥8	(233) 46.40%	(168) 33.50%	(101) 20.10%
8≤16	(23) 18.40%	(30) 24%	(72) 57.60%
16≤24	(0) 0%	(3) 16.70%	(15) 83.30%

One way ANOVA and independent T- test summary results for the mean of C. edulis stems in the three diameter classes recorded within disturbed plots (ND), mid-way from disturbance(MD) and furthest away from disturbance (FD) in C. edulis.

One Way Anova test shows that the P values ($6.8x10^{-7}$, $1.2x10^{-6}$, and $6.6x10^{-5}$) for the three diameters classes of the 3 sections are smaller than the alpha value (0.05). This indicates that there is a significant difference in at least two of the mean numbers of *C. edulis* stems in the sections. T- test results indicate significant differences among all the 3 paired sections: (1) within disturbance and furthest away from the disturbance (2); mid-way from disturbance and near the disturbance (3) mid-way from disturbance and furthest away from disturbance since the P values ($3.7x10^{-5}$, $1.7x10^{-4}$, $1.4x10^{-3}$, 0.031, $2.31x10^{-4}$, $8.36x10^{-5}$, 0.035, 0.01, 0.005) are less than alpha value (0.05).

III.3. Diameter class distribution of woody species stems (excluding C. edulis) recorded in C. edulis occupied sites and in control sites and C. edulis stems in C. edulis occupied sites

Diameter class distributions of (1) average number of stems (excluding *C. edulis*) recorded in *C. edulis* occupied sites, (2) average number of stems recorded in control sites and (3) average number of *C. edulis* stems recorded in *C. edulis* occupied sites are illustrated in Fig 3. The diameter class distributions shown for stems recorded in the control sites and *C. edulis* stems recorded in *C. edulis* occupied sites indicate an inverse J distribution, while that for stems recorded in *C. edulis* occupied sites (excluding *C. edulis*) indicates an irregular bell-shaped distribution with complete absence of individuals in classes 0-8cm, 21-24cm and 29-35cm.

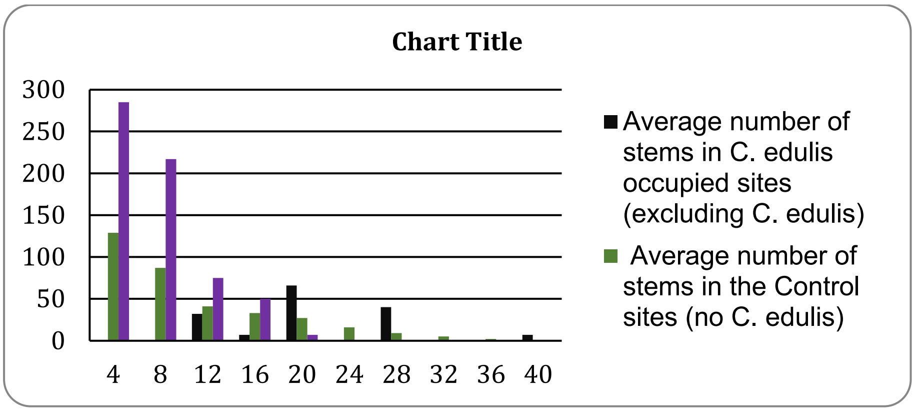

Fig. 3. Diameter class distribution of (i) average number of native stems (excluding *C. edulis*) recorded in *C. edulis* occupied sites, (ii) average number of native stems recorded in control sites (not occupied by *C. edulis*), and (iii) average number of *C. edulis* stems recorded in *C. edulis* occupied sites.

IV. Discussion

Results of Shannon diversity index and equitability test showed significant differences in species diversity and evenness between *C. edulis* occupied plots and adjacent control plots; with the *C. edulis* occupied sites having significantly low species diversity and evenness. Similar trends were observed by [17] and [18]. *C. edulis* produces high numbers of seeds. This provides it with competitive advantage in occupying new habitats [19]; [20]; [21].

Sections furthest away from disturbance had a significantly higher number of *C. edulis* individuals which were also significantly younger compared to those nearer the disturbed sites. *C. edulis* individuals near disturbed sites got established first hence were older. When conditions are conducive, *C. edulis* being a tall species, the relatively small seeds [3], disperse further away from the parent plants [22]. This reduces infra-specific competition and extends the species distribution [23]. Tall trees provide seeds with a higher starting point and open space to allow the seeds to be blown farther away with minimum disturbance from other plants. *C. edulis* seedlings and shrubs are hence, more densely stocked compared to adult plants [24]. The seedlings as a consequence constitute a higher population compared to the predominantly adult plants.

Three of the six species found in *C. edulis* occupied sites, *T. orientalis, H. madagascariensis* and *C. edulis* are all recorded as pioneer species [25].Establishment and growth of the other two species, however, appears to be suppressed by *C. edulis. T. orientalis* [26] and *H. madagascariensis* [27] are small to medium sized trees, usually growing up to 10 m and 10 m – 15 m in height, respectively. *C. edulis* on the other hand, can grow up to 25 m [28]. The dense formation of *C. edulis* individuals allows the species to form closed canopies. This allows the species to shade seedlings of competing species, thus depriving them of light [24]. A number of species have the tendency of using this strategy as suggested by [18] on *Impatiens glandulifera* which shades off seedlings of other species as it is the tallest annual in areas it invades. This then retards germination and establishment of species beneath its canopy, and in turn, reduces species diversity and evenness [18].

The inverse J-distribution of *C. edulis* suggests that the species has a good regeneration potential [29]. Woody plant species display this type of distribution when number of individuals within the species or population is higher in lower diameter classes and gradually decreases towards the higher classes. In such a pattern, there are many seedlings that can be recruited into successive growth stages, thus enhancing sustainability of the species [30]. Native plant species within sites occupied by *C. edulis* display an irregular bell-shaped distribution. When species display an irregular population distribution pattern, it implies that their regeneration capacity is not keeping pace with mortality above a fixed diameter limit [30]. This suggests that such species are in poor regeneration capacity [29] and potentially threatened. Control sites also indicated healthy regeneration capacity of the native species.

Population stem diameter distribution structure is based on the assumption that populations with many small stems are self-replacing when compared to those with larger stems. On the other hand, populations with relatively few, small stems are in decline [31]. This assumption has been questioned in studies that reported declining populations with size structures that display the classic reverse J shape [32], while increasing or stable populations also showed size structures which did not adjust to the negative exponential curve [33]. This was explained through differences in growth rates among size classes. This method has been used however in several studies by [34], [29], [30] and [35]. While it is not recommended as the sole basis for management decisions, it does give an insight on species population status [31].

V. Conclusion

The study established that *Catha edulis* has a high regeneration potential while populations of competing native species are in apparent unstable condition. The predominance of *C. edulis* also in sections furthest away from disturbance suggests an encroachment of the species beyond disturbed sites. This is most worrisome for the continued stability of populations of native species. Further studies are proposed to elucidate mechanisms that enhance the aggressive growth pattern and suppression of competing species by *C. edulis* in the study area.

References

[1] L. S. Kandari, H. R. Yadav, A. K. Thakur, & T. Kandaro. Chat (*Catha edulis*): a socio economic crop in Harar Region, Eastern Ethiopia. *SpringerPlus*, vol 3(579), pp 1–9, 2014. https://doi.org/10.1186/2193-1801-3-579.

[2] B. Wursten, P. Ballings, M. C. Palgrave, & M. Hyde. Catha edulis (Vahl) Forssk. ex Endl. 2016 Retrieved July 6, 2017. http://www.zimbabweflora.co.zw/speciesdata/species.php?species_id=137020, unpublished.

[3] H.A.M. van der Vossen. *Catha edulis* (Vahl) Forssk. ex Endl. [Internet] Record from PROTA4U. Oyen, L.P.A. & Lemmens, R.H.M.J. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. 2002. Accessed 3 September 2018. https://uses.plantnet-project.org/en/Catha_edulis_(PROTA), unpublished.

[4] L. R. Tembrock, C.D. Broeckling, A. L. Heuberger, M. P. Simmons, F. R. Stermitzd & J. M. Uvarova. Employing Two-stage Derivatisation and GC–MS to Assay for Cathine and Related StimulantAlkaloids across the Celastraceae. *Phytochemical Analysis*, volume 28, pp 257–266, 2017. doi: 10.1002/pca.2671

[5] I. Surve. Chewing the khat is illegal, says Sanab. *Independent Online (IOL)*, 2000. Retrieved from https://www.iol.co.za/news/south-africa/chewing-the-khat-is-illegal-says-sanab-35917, unpublished.

[6] J. Timberlake, P. Ballings, J. Vidal Jr, B. Wursten, M. Hyde, A. Mapaura, S. Childes, M. Coates Palgrave & V. R. Clark. Mountains of the Mist: A first plant checklist for theBvumba Mountains, Manica Highlands(Zimbabwe-Mozambique). *Phyto Keys,* volume 145, pp. 93–129, 2020, https://doi.org/10.3897/phytokeys.145.49257

[7] K. Tarsi, & T. Tuff. Introduction to Population Dermography. *Nature Education Knowledge*, volume 3 (11), p. 3. 2012. <%0Awww.nature.com/scitable/knowledge/library/introduction-to-populationdemographics-%0A83032908>.

[8] J. F. Meekins & B. C. Mccarthy. Effect of Population Density on the Demography of an Invasive Plant (*Alliaria petiolata*, Brassicaceae) Population in a southeastern Ohio Forest. *The American Midland Naturalist*, volume 147 (2), pp. 256–278. 2006. doi: 10.1674/0003-0031(2002)147[0256:EOPDOT]2.0.CO;2

[9] M. K. Dyderski & A. M. Jagodzi´nski. Impact of Invasive Tree Species on Natural Regeneration Species Composition, Diversity and Density. *Forests,* volume 11, pp. 456-476, 2020. doi:10.3390/f11040456

[10] V. R. Clark. The Eastern Highlands Research Initiative: Final report back on meetings held in Zimbabwe. Unpublished report of theManica Highlands Initiative, Botany Department, Rhodes University, Grahamstown, 2013.

[11] V. R. Clark, J. R. Timberlake, M. A. Hyde, A. Mapaura, M. Coates Palgrave, B. T. Wursten, P. Ballings, J. E. Burrows, H. P. Linder, G. K. McGregor, C. Chapano, D. C. H. Plowes, S. L. Childes, S. Dondeyne, T. Müller, N.P. Barker. A first comprehensive account of floristic diversity and endemism on the Nyanga Massif, Manica Highlands (Zimbabwe-Mozambique). *Kirkia*, volume 19, pp. 1–53. 2017. doi:10.3897/phytokeys.145.49257

[12] P. Ballings & B. Wursten. Vumba – Facts. 2001. https://vumba-nature.com/wp/vumba-nature/vumba-facts/. Retrieved date: 22 January 2021, unpublished.

[13] B.H. Walker. An approach to the monitoring of changes in the composition and utilisation of woodland and savanna vegetation. *South African Journal of Wildlife Resources,* volume 6(1), pp. 1–32, 1976.

[14] E. Gandiwa & S. Kativu. Influence of fire frequency on *Colophospermummopane* and *Combretumapiculatum* woodland structure and composition in Northen Gonarezhou National Park, Zimbabwe. *Koedoe*, volume 51(1), Art.#685, 13 pages, 2009. doi:10.4102/koedoe.v51i1.685.

[15] G. K. Muchayi, E. Gandiwa & N. Muboko. Composition and structure of woody vegetation in an urban environment in northern Zimbabwe. *Tropical Ecology* volume 58(2) pp. 347–356, 2017.

[16] C. E. Shannon & W. Weaver. The Mathematical Theory of Communication. University of Illinois Press, Urbana, 1949.

[17] M. Hejda, P. Pysek & V. Jarosík. Impact of invasive plants on the species richness,diversity and composition of invaded communities. *Journal of Ecology,* volume 97, pp. 393–403, 2009. https://doi.org/10.1111/j.1365-2745.2009.01480.x

[18] P. E. Hulme & E. T. Bremner. Assessing the impact ofImpatiens glanduliferaon riparianhabitats: partitioning diversity components following species removal. *Journal of AppliedEcology*, 43, pp. 43–50, 2006. https://doi.org/10.1111/j.1365-2664.2005.01102.x

[19] R. E. Landenberger, N. L. Kota & J. B. McGraw. Seed dispersal of the non-native invasive tree *Ailanthus altissima* into contrasting environments. *Plant Ecology*, volume 192(1), pp. 55-70, 2007. DOI 10.1007/s11258-006-9226-0

[20] J. Wan, C. Wang & F. Yu. Wind effects on habitat distributions of wind-dispersed invasive plants across different biomes on a global scale: Assessment using six species. *Ecological Informatics*, volume 42, pp. 38-45, 2017. doi: 10.1016/j.ecoinf.2017.09.002.

[21] C. Egawa. Wind dispersal of alien plant species into remnant natural vegetation from adjacent agricultural fields.*Global Ecology and Conservation,* volume 11, pp. 33-41, 2017. https://doi.org/10.1016/j.gecco.2017.04.008

[22] F. Thomson, A. Moles, T.D. Auld & R.T. Kingsford. Seed dispersal distance is more strongly correlated with plant height than with seed mass. *Journal of Ecology,* volume 99 (6), pp. 1299 – 1307, 2011. https://doi.org/10.1111/j.1365-2745.2011.01867.x

[23] X. Yang, W. Zhang & Q. He. Effects of intraspecific competition on growth, architecture and biomass allocation of Quercus Liaotungensis. *Journal of Plant Interactions*, volume 14(1), pp. 284–294, 2019. https://doi.org/10.1080/17429145.2019.1629656

[24] G. Dessie & P. Kinlund. 'Khat expansion and forest decline in Wondo Genet, Ethiopia', *GeografiskaAnnaler: Series B, Human Geography,* volume 90 (2), pp. 187–203, 2008. https://doi.org/10.1111/j.1468-0467.2008.00286.x

[25] M.A. Hyde, B.T. Wursten, P. Ballings & M. Coates Palgrave. *Flora of Zimbabwe: Home page,* unpublised, 2020a. https://www.zimbabweflora.co.zw/index.php, retrieved 24 December 2020

[26] M.A. Hyde, B.T. Wursten, P. Ballings & M. Coates Palgrave. *Flora of Zimbabwe: Species information: Tremaorientalis,* unpublished 2020b https://www.zimbabweflora.co.zw/speciesdata/species.php?species_id=120090, retrieved 22 December 2020.

[27] M.A. Hyde, B.T. Wursten, P. Ballings & M. Coates Palgrave. *Flora of Zimbabwe: Species information: Harunganamadagascariensis,* unpublished,2020c. https://www.zimbabweflora.co.zw/speciesdata/species.php?species_id=140420, retrieved 22 December 2020.

[28] M.A. Hyde, B.T. Wursten, P. Ballings & M. Coates Palgrave. *Flora of Zimbabwe: Species information: Catha eduli*, unpublished, 2018. https://www.zimbabweflora.co.zw/speciesdata/species.php?species_id=137020, retrieved 2 December 2018.

[29] T. Mekonen, B. Ayele & Y. Ashagrie. Woody Plant Species Diversity, Structure and Regeneration Status of Woynwuha Natural Forest, North West Ethiopia. *Asian Journal of Ethnopharmacology and Medicinal Foods*, volume 01 (01), pp. 07-19, 2015.

[30] D. Nabasumba, G. Eilu, J. Bahati & G. Katwesigye. Utilisation and conservation status of indigenous woody plant species in a sedentary pastoral production system in south-western Uganda. *Uganda Journal of Agricultural Sciences*, volume 17 (2), pp. 125 – 137, 2016. doi:10.4314/ujas.v17i2.1

[31] C.B. Virillo, F.R. Martins, J.Y. Tamashiro & F.A.M. dos Santos. Is size structure a good measure of future trends of plant populations? An empirical approach using five woody species from the Cerrado (Brazilian savanna).*Acta Botanica Brasilica*, volume 25 (3), pp. 593-600, 2011. http://dx.doi.org/10.1590/S0102-33062011000300012.

[32] E.A. Johnson, K. Miyanishi & H. Kleb. The hazards of interpretation of static age structures as shown by stand reconstruction in a *Pinuscontorta – Piceaengelmanii* forest. *The Journal of Ecology,* volume 82, pp. 923-931, 1994.

[33] R. Condit, R. Sukumar, S.P. Hubbell & R.B. Foster. Predicting population trends from size distributions: a direct test in a tropical tree community.*The American Naturalist,* volume 152, pp. 496-509, 1998.

[34] A.F. Souza. Ecological interpretation of multiple population size structures in trees: The case of Araucaria angustifolia in South America. *Austral Ecology*, volume 32, pp. 524–533, 2007. doi:10.1111/j.1442-9993.2007.01724.x

[35] G. Mucheye & G. Yemata. Species composition, structure and regeneration status of woody plant species in a dry Afromontane forest, Northwestern Ethiopia. *Cogent Food & Agriculture* volume 6:1, 1823607, 2020. https://doi.org/10.1080/23311932.2020.1823607.