Tropical Ecology **58**(2): 347–356, 2017
ISSN 0564-3295

www.tropecol.com

Composition and structure of woody vegetation in an urban environment in northern Zimbabwe

GAYLAD K. MUCHAYI, EDSON GANDIWA* & NEVER MUBOKO

School of Wildlife, Ecology and Conservation, Chinhoyi University of Technology, Private Bag 7724, Chinhoyi, Zimbabwe

Abstract: The objective of this study was to determine the effects of land use on the woody vegetation composition and structure between the area within the Chinhoyi University of Technology (CUT) campus and the adjacent (or surrounding) area, Chinhoyi, Zimbabwe. Woody vegetation was sampled in November 2014 using a total of 20 plots (10 in each stratum) delineated using a stratified sampling method. Woody vegetation species, height, basal circumference, density, evidence of tree cutting and fire damage were assessed inside all the plots. A total of 22 woody plant species (nine families) were recorded in the study area, i.e., within the CUT campus (18) and adjacent area (15) with a Jaccard Index of similarity of 43% between the two strata. Overall, 301 individuals were recorded in both strata, i.e., 57% trees, 22% shrubs and 21% seedlings. The protected area within the CUT campus had significantly ($P < 0.05$) higher tree density and tree basal area than the surrounding open vegetation whereas the surrounding open vegetation had significantly ($P < 0.05$) higher shrub and seedling densities than the protected area within the CUT campus. In contrast, no significant differences (all, $P > 0.05$) between the strata were recorded for tree height, shrub height, shrub basal area, species diversity and densities of tree cutting and fire damaged plants. Recorded structural differences were attributed to human influences and differing management systems across the land use systems. The findings highlight the importance of public greenery in urban landscapes (e.g., university campuses) for *ex situ* conservation of indigenous flora.

Key words: Biodiversity, Chinhoyi, invasive alien species, savanna, urban landscape.

Handling Editor: Mulualem Tigabu

Introduction

Conservation of biodiversity has been identified as one of the key aspects of sustainable land use practices both in rural and urban environments (Jabareen 2006; McKinney 2002). Land uses in urban areas are particularly diverse and intensive as they consist of a mosaic of small, fragmented land use types (Breuste 2002) such as public parks, university campuses and others, which house indigenous flora. The different purposes of urban land use types accommodate basic human needs for facilities in the residential, industrial and commercial, administration, education and other social institutions and recreation. These distinctions potentially contribute to different woody vegetation composition and structure across the urban landscape settings (Bourne & Conway 2014; Porter *et al.* 2001) and thus play an important role in conserving indigenous flora.

Human land use has been identified as a significant determinant of savanna vegetation composition and structure though considered secondary to climatic and edaphic factors. According

**Corresponding Author*; e-mail: egandiwa@gmail.com

to Sankaran *et al.* (2008), trends in most places in the savannas point to the fact that savanna vegetation composition and structure are maintained in their current form by human and biophysical drivers. Human activities affect vegetation composition and structure directly, as woodcutters and cultivators, and indirectly through their ability to manipulate fire and to influence herbivore numbers and distribution (Cilliers 1999; Frost *et al.* 1986; Gairola *et al.* 2015; Gandiwa 2014; Murthy *et al.* 2016; Nyelele *et al.* 2014). Land use can affect management practices and thus strongly influencing the vegetation composition and structure in savanna ecosystems (Higgins *et al.* 1999; Sultana *et al.* 2014; Wessels *et al.* 2011). It is generally predicted that human impact in non-protected areas has resulted in a decrease in biodiversity relative to protected areas (Shackleton 1993, 2000). Vegetation species diversity generally decreases with increasing land use intensity (Von Arx *et al.* 2002).

In this era of increasing urbanisation, especially in developing countries, urban landscapes, for example, public parks, university campuses and others, can house endangered indigenous flora, hence, such urban landscapes are important in the *ex situ* conservation of indigenous flora in public greenery (El-Juhany & Al-Harby 2013; Rajendran *et al.* 2014). For example, an earlier study at Gujarat University campus, Ahmedabad, India, highlighted a multi-stakeholder approach which includes the involvement of the university community, the local resident community and urban planners in various activities relating to environmental awareness and protection of biodiversity (Modi & Dudani 2013). Here, we aim to expand our knowledge on the role of university campuses' contribution to woody vegetation conservation in an African urban landscape setting. The objective of the present study was, thus, to determine the effects of land use on woody vegetation composition and structure between the area within a university campus and the adjacent (or surrounding) area using a case study of Chinhoyi University of Technology (hereafter CUT), Zimbabwe.

Materials and Methods

Study area

The study was conducted at CUT main campus and its adjacent area within the town of Chinhoyi environs (17°21'S, 30°12'E) in Mashonaland West province, northern Zimbabwe (Fig. 1). Chinhoyi town has an average elevation of 1,158 m above sea level. The town has an average annual temperature of 25 °C, with October and November having a mean monthly maximum temperature of 30 °C and July having a mean monthly minimum of 19 °C (Bere *et al.* 2014). Average annual rainfall for Chinhoyi town is approximately 802 mm (Meteorological Services Department, unpublished data). The study area is characterised by miombo vegetation dominated by *Brachystegia* species, *Julbernardia globiflora* and *Vachellia* species, and with soils being predominantly sandy loam. The CUT main campus boundaries are clearly demarked by a wire fence. CUT was established by an Act of Parliament of Zimbabwe in December 2001. Previously, the CUT main campus was under Chinhoyi Technical Teachers' College that was founded in 1991. As of 2012, Chinhoyi town had a human population estimate of 79,000 (Zimbabwe National Statistics Agency 2013).

Sampling design

A stratified random sampling design was used with the study area divided into two, i.e., the area within the CUT main campus (protected area) and adjacent open area to the CUT campus (within 5 km zone of the university boundary). The CUT main campus was sub-divided into five areas, i.e., administration area, sports grounds, hostels, new engineering section and the CUT hotel area. In each sub-division, two plots were systematically placed. The location of the first plot in each sampling area was randomly determined using a grid-intercept method with numbers corresponding to the grids. Within the CUT campus, a distance of at least 30 m between the two plots was maintained. The plots in the adjacent area of the CUT campus were randomly placed within the 5 km sampling zone of the university boundary. Overall, a total of 20 plots measuring 20 × 30 m (0.06 ha) were sampled with each stratum having 10 plots (Fig. 1). Plot size was determined following Walkers' (1976) method taking into consideration at least 15 to 20 woody plants in a plot. The plots were marked using a 100 m measuring tape and metal pegs, and all sampled plots locations recorded using a hand held Garmin Geographic Positioning System (GPS) 60 receiver unit (Garmin Ltd., Olathe, Kansas, USA).

Data collection

Woody vegetation composition and structure were assessed in November 2014. Inside the plots,

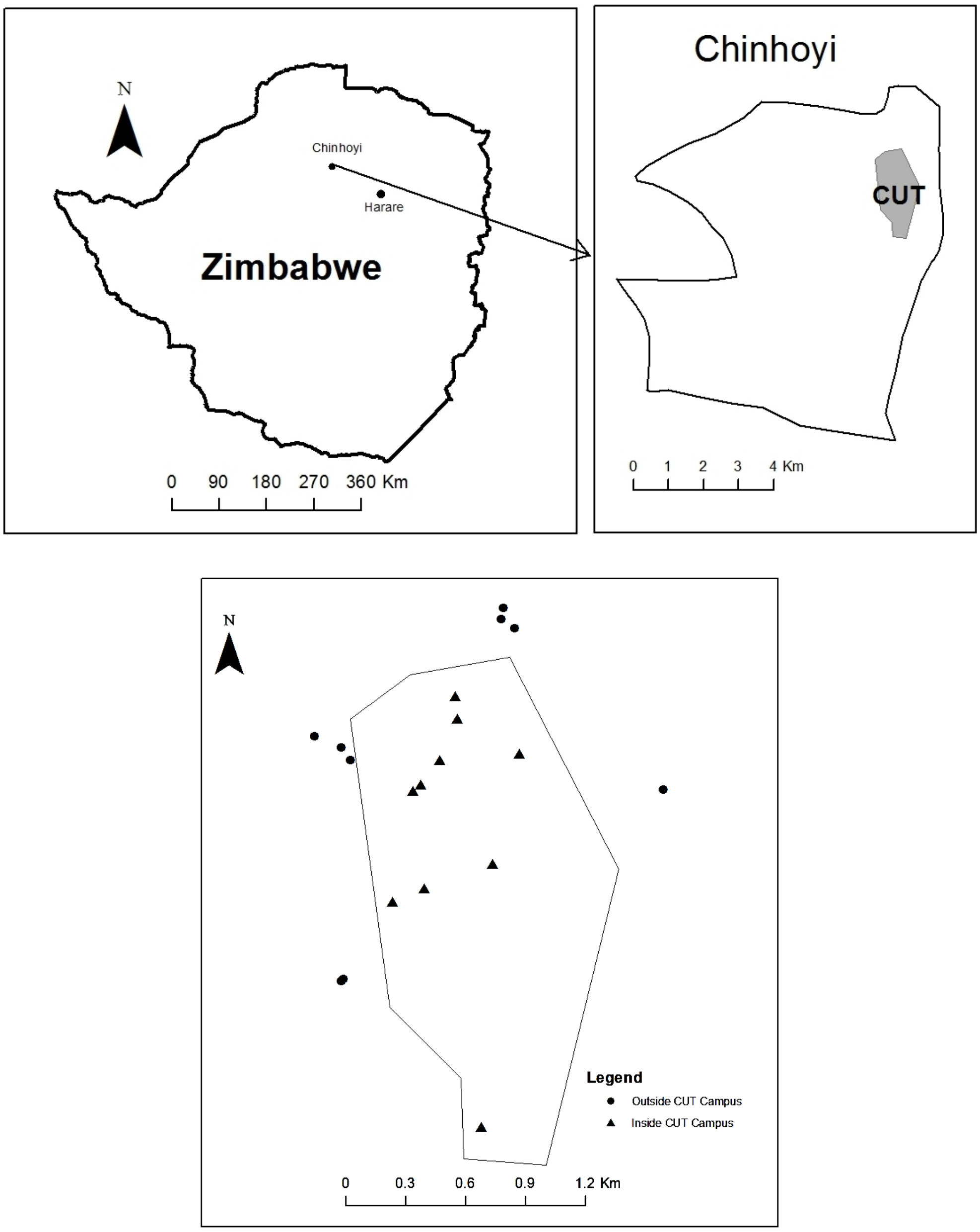

Fig. 1. Location of Chinhoyi University of Technology (CUT) and the spatial layout of plots within the CUT main campus and adjacent area in Chinhoyi, northern Zimbabwe.

woody vegetation was measured using non-destructive measures. The following vegetation attributes were recorded on data sheets in each plot: (i) species name through using a field guide (Coates-Pelgrave 1997); (ii) stage class-trees, i.e. woody plants ≥3 m in height; shrubs, i.e., woody plants 1.5 m to <3 m in height whereas those <1.5 m as seedlings (Gandiwa & Kativu 2009; Zida et al. 2008). Woody plant height was measured using a 6 m calibrated pole. (iii) Basal circumference was measured at 30 cm height above the ground (Mueller-Dombois & Ellenberg 1974). (iv) Evidence of tree cutting was assessed based on existing stumps and cut branches, and (v) evidence of fire damage through visual assessment of burnt marks on the woody plants' bark, stumps and charred plant remains inside the plots (Gandiwa & Kativu 2009).

Data analysis

The Shannon-Weiner diversity index (Shannon & Weaver 1949) was used to determine the diffe-

Table 1. List of woody plants recorded within the Chinhoyi University of Technology (CUT) main campus and adjacent area. Note: X represents the species recorded in each stratum.

Species	Family	Within CUT campus	Adjacent area to CUT campus
Azanza garckeana	Malvaceae		X
Bauhinia petersiana	Fabaceae	X	X
Bauhinia thonningii	Fabaceae	X	X
Brachystegia boehmii	Fabaceae	X	X
Brachystegia utilis	Fabaceae	X	
Burkea africana	Fabaceae	X	
Clerodendrum myricoides	Lamiaceae	X	X
Combretum adegonium	Combretaceae	X	
Combretum collinum	Combretaceae	X	
Dichrostachys cinerea	Fabaceae	X	
Diospyros lycioides	Ebenaceae	X	
Euclea natalensis	Ebenaceae		X
Ficus sycomorus	Moraceae	X	
Julbernardia globiflora	Fabaceae	X	X
Lantana camara	Verbenaceae	X	X
Melia azedarach	Meliaceae	X	
Peltophorum africanum	Fabaceae	X	
Senegalia burkei	Fabaceae	X	
Senegalia polyacantha	Fabaceae	X	X
Vachellia karroo	Fabaceae		X
Vachellia sieberiana	Fabaceae	X	X
Ziziphus mucronata	Rhamnaceae	X	X

rences in species composition in the study sites. The Jaccard index of community similarity (Ludwig & Reynolds 1988) was used to compare similarity of the two study strata based on common woody vegetation species. Mean plant heights were calculated for each plot by summing the individual plant heights and dividing them by the total number of plants in the plot. Basal area for each woody plant was calculated from the stem circumference data following Gandiwa and Kativu (2009). All individual plant basal areas were then summed to give the total basal area for each plot. Woody plant densities for each plot were converted into per hectare quantities. Data were tested for normality using the Shapiro-Wilk test, and since the data were not normal, the Mann-Whitney U-test was thus used for testing for differences across the two study strata using STATISTICA version 7 for Windows (StatSoft Inc., Tulsa, OK, USA). A principal component analysis (PCA) was performed to determine the association of sample plots from the two study strata based on the woody composition and structure data (ter Braak 1995).

Results

Vegetation composition and structure

A total of 301 individuals, comprised of 22 woody plant species (nine 9 families), were recorded in both strata with 57% of total woody plants being trees, 22% shrubs and 21% seedlings. The within the CUT campus stratum had 18 woody species whereas the adjacent area to the CUT campus stratum had 15 species (Table 1). The Jaccard index of similarity showed a 43% similarity between the two study strata with nine common species, namely, *Bauhinia petersiana, Bauhinia thonningii, Brachystegia boehmii, Clerodendrum myricoides, Julbernardia globiflora, Lantana camara, Senegalia polyacantha, Vachellia sieberiana* and *Ziziphus mucronata.*

The protected area within the CUT campus had significantly higher tree density (Mann-Whitney $U = 4.00$, $P < 0.05$, two-tailed) and tree basal area (Mann-Whitney $U = 18.00$, $P < 0.05$) than the surrounding open vegetation whereas the surrounding open vegetation had significantly

Table 2. Comparison of measured woody vegetation variables within Chinhoyi University of Technology (CUT) main campus and adjacent area. Note: Data are expressed as the median and range; *P*-values are from Mann-Whitney *U* test (two-tailed).

	CUT campus		Adjacent area		
Variable	Median	Range	Median	Range	*P*-value
Tree height (m)	5.47	2.69	3.35	8.29	0.143
Tree density (ha^{-1})	145.83	244.44	29.17	116.67	0.0001
Tree basal area ($m^2\ ha^{-1}$)	3.43	10.53	0.31	12.83	0.015
Shrub height (m)	2.15	2.70	1.73	2.43	0.315
Shrub basal area ($m^2\ ha^{-1}$)	0.22	0.33	0.09	0.24	0.247
Shrub density (ha^{-1})	16.67	50.00	38.89	66.67	0.035
Seedling density (ha^{-1})	16.67	33.33	30.56	75.00	0.035
Shannon-Weiner diversity index (H')	0.66	1.67	1.12	1.47	0.315
Tree stump density (ha^{-1})	0.00	0.00	0.00	133.33	0.280
Fire damaged plants (ha^{-1})	0.00	83.33	25.00	100.00	0.247

higher shrub density (Mann-Whitney $U = 22.00$, $P < 0.05$) and seedling density (Mann-Whitney $U = 22.50$, $P < 0.05$; Table 2) than the protected area within the CUT campus. In contrast, no significant differences (all, $P > 0.05$) were recorded on tree height, shrub height, shrub basal area, seedling density, species diversity, densities of tree stumps and fire damaged plants between the two study strata.

Spatial pattern of vegetation composition and structure

Principal components 1 and 2 explained 57% of variation in the vegetation matrix from the 20 sample plots in both study strata (Fig. 2). Principal component 1 (eigenvalue = 3.72) defined a gradient from sites with taller trees, higher tree basal area and tree density to sites with higher seedling density. Principal component 2 (eigenvalue = 2.55) defined a gradient from sites with higher plant species diversity to sites with higher shrub densities. There were three groupings of sample plots, with the sample plots from within the CUT campus largely characterised by taller trees, higher tree densities and basal areas whereas those from the adjacent area to the CUT campus being largely characterised by higher species diversity and shrub densities. Tree cutting (stumps) and fire-damaged plants were more common in the adjacent area to the CUT campus. However, there were some minor similarities between sample plots in both strata as shown by sample plots that clustered outside the two main groups consisting, i.e., those drawn from within the CUT campus (represented by C): C3, C4, and those drawn from the adjacent area (represented by A): A17 and A18.

Discussion

The present study aimed at determining the effects of land use on woody vegetation composition and structure between the area within the CUT campus and the adjacent area in an urban landscape setting in Zimbabwe. Our results showed that the protected area within the university campus had significantly higher tree density and tree basal area than the surrounding open vegetation whereas the surrounding open vegetation had significantly higher shrub and seedling densities than the protected area within the university campus. In contrast, no significant differences were recorded in the woody vegetation composition between the two study strata. Thus, our results, as also supported by the principal component analyses, showed some differences and similarities between the two study strata.

The structural differences in woody vegetation between the two strata can be attributed to the influence of human disturbances (Fig. S1) since the study sites occurred in the same geographical setting. Woody communities characterised by harvesting and/or disturbances are usually associated with changes in community structure (Higgins *et al.* 1999; Mohandass *et al.* 2016; Wessels *et al.* 2011; Zisadza-Gandiwa *et al.* 2013). Our results corroborate with earlier studies in the savanna ecosystem which have reported a reduction in woody plant density and basal area associated with an increase in shrub and seedling

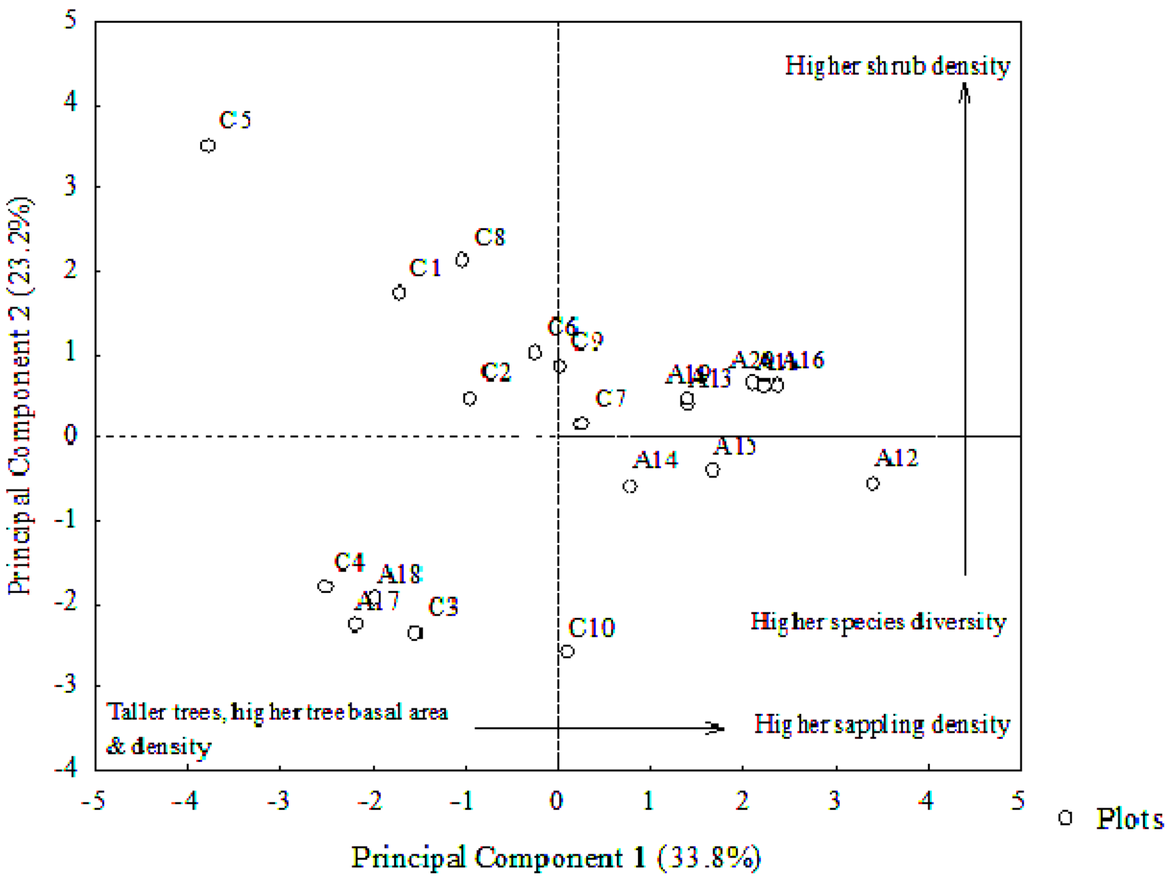

Fig. 2. Principal component analysis biplot showing association of 20 sample plots based on woody vegetation data drawn from within the Chinhoyi University of Technology (CUT) campus (represented by C) and adjacent area (represented by A) strata. Circles represent sample plots and arrows represent the gradients. The biplot shows two groups of major associations for sample plots drawn from within the CUT campus and those drawn from the adjacent area.

density in harvested (mostly non-protected) areas relative to unharvested (mostly protected) areas (Banda *et al.* 2006; McGregor 1994; Muboko *et al.* 2014). Some woody plant species are sensitive to intensive harvesting and decline in abundance while other species respond through coppice regrowth and this significantly influences the woodland structure (Syampungani *et al.* 2016; Wessels *et al.* 2011).

Despite the need for firewood, woodland degradation in urban environments is also caused by expansion of peri-urban farming, urbanisation and infrastructural development, and indirectly by overpopulation and poverty (Elmqvist *et al.* 2015; Maconachie 2012; Soga *et al.* 2014). Given that Chinhoyi town has a population of about 79,000 (Zimbabwe National Statistics Agency 2013) and also experience the challenges of energy provision, especially electricity, and increasing demand for food security, many local people utilise the open spaces for small-scale farming activities and also harvesting of woody plants for wood fuel. Increasing poverty and population density in urban areas especially in developing countries have been attributed to woodland losses as people engage in illegal wood harvesting and also small-scale farming (Chakravarty *et al.* 2012). Illegal wood harvesting can severely degrade woodlands (Putz *et al.* 2001). Several recent studies have reported the degradation of woodlands in urban areas in Zimbabwe as a result of illegal tree cutting primarily for wood fuel due to the electricity shortages, for example, in Bulawayo (Dube *et al.* 2014), Harare (Muboko *et al.* 2014) and Masvingo (Mapira & Munthali 2011).

Differences in land use system between the two study sites could have played an important role in the recorded differences in woody vegetation structure. The CUT campus is characterised by an active law enforcement system whereas the adjacent area to the CUT campus can to a larger extent be described as a 'semi-open access area' due to the limited law enforcement on land use and resource extraction. Small-scale farmers in peri-urban areas often lack title deeds (property rights) or legal entitlements to the land they use (Deacon 1999), and due to insecurity, land and associated natural resources tend to suffer challenges reminiscent of the 'tragedy of the commons' (Hardin 1968). Accordingly, Chomitz *et al.* (2007) suggests that poorly defined property rights are generally bad for people and woodlands, as this indirectly causes loss of biodiversity.

Both study sites (strata) showed some evidence of fire impact on woody plants as evidenced by the recorded fire damaged plants although there were no significant differences between the two study strata. CUT management uses fire as a management tool to control grass and undergrowth whereas in the adjacent area to the CUT campus, fires are mainly for clearing areas for agricultural activities by those utilising these areas for crop production. Savanna trees are susceptible to fire when they are young but as they grow larger some species become resistant to fire, a mechanism called "size escape" (Bond & Midgley 2001; Wakeling *et al.* 2011). However, if properly manipulated, fire can be useful for woodland management (Brockett *et al.* 2001; Gandiwa 2011).

Non-significant variation in species diversity was recorded in this study despite some changes in the woodland structure between the study sites. This may suggest that at small-scale woody vegetation diversity is more similar due to the closeness of the study sites. Tobler's First Law of Geography states that everything is related to everything else but near things are more related than distant things (Tobler 2004). It is also likely that there exist a non-selective harvesting of tree species in the study area hence the lack of significant difference in woody vegetation diversity since pressure on limited woody resources can also lead to indiscriminate cutting of even undesirable species (Mapira & Munthali 2011). Moreover, local people engaged in agricultural activities seem not to completely remove woody plants from the land but allow some plants to grow, hence promoting the existence of woody species. However, of particular note, is the presence of an invasive alien species, *Lantana camara*, recorded in this study which may have detrimental effect on the ecosystem in the long-term.

Conclusion

This study represents the first record of the current composition and structure of woody vegetation at CUT main campus and the adjacent area. The study highlights the importance of urban landscapes, such as university campuses, in conserving indigenous flora, particularly woody vegetation structure, given that the protected area within the university campus was characterised by less degraded woody vegetation structure compared to the surrounding areas. We thus recommend for the review and effective enforcement of existing policy and regulatory instruments to ensure the protection of indigenous flora in areas adjacent to the CUT campus. Moreover, it is essential to develop indigenous flora management plans and monitoring programmes for urban landscapes, e.g., university campuses and public greenery, so as to promote the conservation of especially endangered indigenous flora. Future studies should examine the intensity of woody vegetation extraction and human land-use practices in urban environments and how these relates to the intermediate disturbance hypothesis (Connell 1978) and invasive alien species dynamics in the study area and other similar settings.

Acknowledgements

We thank the Chinhoyi University of Technology management for supporting this study; Abel Chemura for assistance with the study area map; Ronald Chipere, Given Matseketsa, Pearl Nyazika, Sithabile Bafana, Gregory Chiyangwa and Tapiwa Zimunya for their assistance in field data collection. Comments and suggestions from Professor Mulualem Tigabu and an anonymous reviewer helped improve the quality of the manuscript.

References

Banda, T., M. W. Schwartz & T. Caro. 2006. Woody vegetation structure and composition along a protection gradient in a miombo ecosystem of western Tanzania. *Forest Ecology and Management* **230:** 179–185.

Bere, T., T. Mangadze & T. Mwedzi. 2014. The application and testing of diatom-based indices of stream water quality in Chinhoyi Town, Zimbabwe. *Water SA* **40:** 503–512.

Bond, W. J. & J. J. Midgley. 2001. Ecology of sprouting in woody plants: the persistence niche. *Trends in Ecology & Evolution* **16:** 45–51.

Bourne, K. S. & T. M. Conway. 2014. The influence of land use type and municipal context on urban tree species diversity. *Urban Ecosystems* **17:** 329–348.

Breuste, J. 2002. Urban ecology. pp. 405–414. *In:* O. Bastian & U. Steinhardt (eds.) *Development and Perspectives of Landscape Ecology*. Kluwer Academic Publishers, Dordrecht.

Brockett, B. H., H. C. Biggs & B. W. Van Wilgen. 2001. A patch mosaic burning system for conservation areas in southern African savannas. *International Journal of Wildland Fire* **10:** 169–183.

Chakravarty, S., S. K. Ghosh, C. P. Suresh, A. N. Dey & G. Shukla. 2012. *Deforestation, Causes, Effects and Control Strategies, Global Perspectives on Sustainable Forest Management.* InTech, Available from: http://www.intechopen.com/books/globalpers pectiveson-sustainable-forest-management / defores tation-causes-effects-andcontrol-strategies.

Chomitz, K. M., P. Buys, G. D. Luca, T. S. Thomas & S. Wertz-Kanounnikoff. 2007. *At Loggerheads? Agricultural Expansion, Poverty Reduction and Environment in the Tropical Forests*. World Bank Policy Research Report. World Bank, Washington DC.

Cilliers, S. S. 1999. Vegetation of analysis of open spaces in Potchefstroom, North West Province, South Africa. pp. 549–562. *In:* J. Timberlake & S. Kativu (eds.) *African Plants: Biodiversity, Taxonomy and Uses*. Royal Botanic Gardens, Kew.

Coates-Pelgrave, K. 1997. *Trees of Southern Africa*. Struik Publishers, Cape Town.

Connell, J. H. 1978. Diversity in tropical rain forests and coral reefs. *Science* **199:** 1302–1310.

Deacon, R. T. 1999. Deforestation and ownership: evidence from historical accounts and contemporary data. *Land Economics* **75:** 341–359.

Dube, P., C. Musara & J. Chitamba. 2014. Extinction threat to tree species from firewood use in the wake of electric power cuts: a case study of Bulawayo, Zimbabwe. *Resources and Environment* **4:** 260–267.

El-Juhany, L. I. & A. A. Al-Harby. 2013. Status and diversity of ornamental plants in King Saud University Campus at Riyadh, Saudi Arabia. *American Eurasian Journal Agricultural and Environmental Science* **13:** 471–478.

Elmqvist, T., H. Setälä, S. Handel, S. van der Ploeg, J. Aronson, J. Blignaut, E. Gómez-Baggethun, D. Nowak, J. Kronenberg & R. de Groot. 2015. Benefits of restoring ecosystem services in urban areas. *Current Opinion in Environmental Sustainability* **14:** 101–108.

Frost, P., E. Medina, J. C. Menaut, O. Solbrig, M. Swift & B. Walker. 1986. Responses of savannas to stress and disturbance. International Union of Biological Sciences. *Biology International,* (IUBS) Special Issue No. 10**:** 1–82.

Gairola, S., R. S. Rawal & N. P. Todaria. 2015. Effect of anthropogenic disturbance on vegetation characteristics of sub-alpine forests in and around Valley of Flowers National Park, a world heritage site of India. *Tropical Ecology* **56:** 357–365.

Gandiwa, E. & S. Kativu. 2009. Influence of fire frequency on *Colophospermum mopane* and *Combretum apiculatum* woodland structure and composition in northern Gonarezhou National Park, Zimbabwe. *Koedoe* **51:** Art. #685, 13 pages.

Gandiwa, E. 2011. Effects of repeated burning on woody vegetation structure and composition in a semi-arid southern African savanna. *International Journal of Environmental Sciences* **2:** 458–471.

Gandiwa, E. 2014. Vegetation factors influencing density and distribution of wild large herbivores in a southern African savannah. *African Journal of Ecology* **52:** 274-283.

Hardin, G. 1968. The tragedy of the commons. *Science* **162:** 1243–1248.

Higgins, S. I., C. M. Shackleton & E. R. Robinson. 1999. Changes in woody community structure and composition under constrasting landuse systems in a semi-arid savanna, South Africa. *Journal of Biogeography* **26:** 619–627.

Jabareen, Y. R. 2006. Sustainable urban forms their typologies, models, and concepts. *Journal of Planning Education and Research* **26:** 38–52.

Ludwig, J. A. & J. F. Reynolds. 1988. *Statistical Ecology. A Primer on Methods and Computing*. John Wiley & Sons, New York.

Maconachie, R. 2012. *Urban Growth and Land Degradation in Developing Cities: Change and Challenges in Kano Nigeria*. Ashgate Publishing, Ltd.

Mapira, J. & A. Munthali. 2011. Household energy demand: wood fuel consumption and peri-urban deforestation in the city of Masvingo (Zimbabwe). *Journal of Sustainable Development in Africa* **13:** 264–279.

McGregor, J. A. 1994. Woodland pattern and structure in a peasant farming area of Zimbabwe: ecological determinants and present and past use. *Forest Ecology and Management* **63:** 97–133.

McKinney, M. L. 2002. Urbanization, biodiversity, and conservation. *BioScience* **52:** 883–890.

Modi, N. R. & S. N. Dudani. 2013. Biodiversity conservation through urban green spaces: A case study of Gujarat University in Ahmedabad, India.

International Journal of Conservation Science **4:** 189–196.

Mohandass, D., A. C. Hughes, B. Mackay, P. Davidar & T. Chhabra. 2016. Floristic species composition and structure of a mid-elevation tropical montane evergreen forests (sholas) of the western ghats, southern India. *Tropical Ecology* **57:** 533–543.

Muboko, N., T. Chigumira, C. Mashapa, E. Gandiwa, G. Chibememe & V. K. Muposhi. 2014. Impacts of wood poaching on vegetation structure and composition in Mukuvisi Woodland, Zimbabwe. *Journal of Environmental Protection* **5:** 156–163.

Mueller-Dombois, D. & H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. John Wiley & Sons, New York.

Murthy, I. K., S. Bhat, V. Sathyanarayan, S. Patgar, M. Beerappa, P. R. Bhat, D. M. Bhat, N. H. Ravindranath & M. A. Khalid. 2016. Vegetation structure and composition of tropical evergreen and deciduous forests in Uttara Kannada District, Western Ghats under different disturbance regimes. *Tropical Ecology* **57:** 77–88.

Nyelele, C., A. Murwira, M. D. Shekede & P. H. Mugabe. 2014. Woodland fragmentation explains tree species diversity in an agricultural landscape of Southern Africa. *Tropical Ecology* **55:** 365–374.

Porter, E. E., B. R. Forschner & R. B. Blair. 2001. Woody vegetation and canopy fragmentation along a forest-to-urban gradient. *Urban Ecosystems* **5:** 131–151.

Putz, F. E., G. M. Blate, K. H. Redford, R. Fimbel & J. Robinson. 2001. Tropical forest management and conservation of biodiversity: an overview. *Conservation Biology* **15:** 7–20.

Rajendran, A., V. Aravindhan & A. Sarvalingam. 2014. Biodiversity of the Bharathiar university campus, India: A floristic approach. *International Journal of Biodiversity and Conservation* **6:** 308–319.

Sankaran, M., J. Ratnam & N. Hanan. 2008. Woody cover in African savannas: the role of resources, fire and herbivory. *Global Ecology and Biogeography* **17:** 236–245.

Shackleton, C. M. 1993. Fuelwood harvesting and sustainable utilisation in a communal grazing land and protected area of the eastern Transvaal lowveld. *Biological Conservation* **63:** 247–254.

Shackleton, C. M. 2000. Comparison of plant diversity in protected and communal lands in the Bushbuckridge lowveld savanna, South Africa. *Biological Conservation* **94:** 273–285.

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

Soga, M., Y. Yamaura, S. Koike & K. J. Gaston. 2014. Woodland remnants as an urban wildlife refuge: a cross-taxonomic assessment. *Biodiversity and Conservation* **23:** 649–659.

Sultana, A., M. S. Hussain & D. K. Rathore. 2014. Diversity of tree vegetation of Rajasthan, India. *Tropical Ecology* **55:** 403–410.

Syampungani, S., M. Tigabu, N. Matakala, F. Handavu & P. C. Oden. 2016. Coppicing ability of dry miombo woodland species harvested for traditional charcoal production in Zambia: a win–win strategy for sustaining rural livelihoods and recovering a woodland ecosystem. *Journal of Forestry Research*, DOI 10.1007/s11676-11016-10307–11671.

ter Braak, C. J. F. 1995. Ordination. pp. 91–173. *In:* R. G. H. Jongman, C. J. F. Ter Braak & O. F. R. Van Tongeren (eds.) *Data Analysis in Community and Landscape Ecology*. Cambridge University Press, Cambridge.

Tobler, W. 2004. On the first law of geography: A reply. *Annals of the Association of American Geographers* **94:** 304–310.

Von Arx, G., A. Bosshard & D. Hansjörg. 2002. Land-use intensity and border structures as determinants of vegetation diversity in an agricultural area. *Bulletin of the Geobotanical Institute Eidgenössische Technische Hochschule (ETH)* **68:** 3–15.

Wakeling, J. L., A. C. Staver & W. J. Bond. 2011. Simply the best: the transition of savanna saplings to trees. *Oikos* **120:** 1448–1451.

Walker, B. H. 1976. An approach to the monitoring of changes in the composition and utilization of woodland and savanna vegetation. *South African Journal of Wildlife Research* **6:** 1–32.

Wessels, K., R. Mathieu, B. Erasmus, G. Asner, I. Smit, J. Van Aardt, R. Main, J. Fisher, W. Marais & T. Kennedy-Bowdoin. 2011. Impact of communal land use and conservation on woody vegetation structure in the Lowveld savannas of South Africa. *Forest Ecology and Management* **261:** 19–29.

Zimbabwe National Statistics Agency. 2013. *Zimbabwe Population Census 2012*. Population Census Office, Zimbabwe National Statistics Agency, Harare.

Zida, D., M. Tigabu, L. Sawadogo, D. Tiveau & P.C. Odén. 2008. Long-term effects of prescribed early fire, grazing and selective tree cutting on seedling populations in the Sudanian savanna of Burkina Faso. *African Journal of Ecology* **47:** 97–108.

Zisadza-Gandiwa, P., C. T. Mabika, O. L. Kupika, E. Gandiwa & C. Murungweni. 2013. Vegetation structure and composition across different land uses in a semiarid savanna of southern Zimbabwe. *International Journal of Biodiversity* vol. 2013, doi:10.1155/2013/692564

(Received on 10.09.2015 and accepted after revisions, on 26.09.2016)

Supporting Information

Additional Supporting information may be found in the online version of this article.

Fig. S1. Woody vegetation in the adjacent area to the Chinhoyi University of Technology (CUT) campus stratum showing crop farming and brick molding activities (a-c) and woody vegetation in an area recently burnt by a prescribed fire (d), November 2014. Photo credits: G. Muchayi.