

Woody Vegetation Status across Rural and Urban Land Use Types on the Riparian Zone of Sakubva River in Mutare District, Eastern Zimbabwe

Clayton Mashapa^{1*}, Faith Chatikobo², Munashe Kurehwatira²,
Patience Mhuriro-Mashapa¹, Tapuwa Langton Wambe Nzara³

¹School of Wildlife and Environmental Sciences, Chinhoyi University of Technology, Chinhoyi, Zimbabwe

²Department of Agriculture and Natural Resources, Africa University, Mutare, Zimbabwe

³School of Entrepreneurship and Business Sciences, Chinhoyi University of Technology, Chinhoyi, Zimbabwe

Email: *clayiemashapa@yahoo.co.uk

How to cite this paper: Mashapa, C., Chatikobo, F., Kurehwatira, M., Mhuriro-Mashapa, P. and Nzara, T.L.W. (2026) Woody Vegetation Status across Rural and Urban Land Use Types on the Riparian Zone of Sakubva River in Mutare District, Eastern Zimbabwe. *Open Journal of Ecology*, **16**, 108-120.

<https://doi.org/10.4236/oje.2026.163007>

Received: March 24, 2024

Accepted: March 1, 2026

Published: March 4, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

The study assessed the woody vegetation attributes across the rural and urban land use types on the Sakubva riparian zone in Mutare District, eastern Zimbabwe. The study contributes to the formation of baseline information on Sakubva riparian zone with possible use of woody plants as indicator species for biomonitoring the ecological health of this riverine ecosystem. The study area of Sakubva River stretch was delineated into two study strata: (i) the upstream Mutare urban land use type, and (ii) the downstream Dora rural land use type. To describe the woody vegetation composition, abundance and structure of Sakubva riparian zone, the following variables were recorded: tree and shrub height, basal stem circumference, number of stems per plant, tree/shrub density, number of coppiced woody plants, woody species diversity, human induced damage on woody plants, fire damage on woody plants and plant status. Descriptive statistics were used to summarize data collected on woody vegetation attributes and significance differences across the two land use strata were analyzed using the Mann-Whitney *U* tests (one-tailed). Woody species diversity was determined using the Shannon-Weiner diversity index. A hierarchical cluster analysis (HCA) using the Wards method with a matrix of 30 sample plots and only the recorded woody species data was used to explore dominance of woody species across the study strata. The study recorded a woody species richness of 21 across the study area, which was dominated by the plant family *Fabaceae*, sub-family *Caesalpinoideae* of the prototype Miombo woodland. All the measured woody plant variables recorded no significant difference ($P > 0.05$) between the two defined study strata, except for the sapling

density ($P < 0.05$). The study hypothesized that Mutare urban environment has fewer human disturbances and a more intact riparian woodland as compared to rural land use in Dora community. However, it was concluded that woody vegetation composition and structure was generally less influenced by variations in land use type within the Sakubva riparian zone of eastern Zimbabwe. It was evident from this study that woody plants occurring in Mutare urban and rural Dora land use categories within the Sakubva riparian zone were to some extent damaged by humans as shown by evidence of past fires, wood harvesting and land clearance for gardening. We recommend continuous monitoring of riparian woodlands on varying land use categories across Mutare District, eastern Zimbabwe.

Keywords

Biomonitoring, Ecological Health, Land Use, Riparian, Woody Plants, Mutare District

1. Introduction

Riparian woodlands zones are connections between terrestrial and aquatic ecosystems and have biophysical and landscape characteristics [1]-[3]. As a component of riparian ecosystems, riparian woodlands play a key role in stabilizing riverbanks, combating soil erosion, trapping and removing nutrients, providing habitats for terrestrial organisms and maintaining ecosystem stability [1] [4]. The serial discontinuity concept of riverine ecosystems emphasizes the need to consider ecological health and biodiversity conservation of watershed catchment basins [5] [6]. Anthropogenic disturbances on unprotected areas of watershed ecosystems, have increased dramatically in recent decades, influencing riparian woodland dynamics at different spatial levels on wetlands across southern Africa [6]-[8]. Woodland alteration and logging in riparian zones threaten their integrity and sustainability [9] and it is reported that at least 65% of riverine habitats across the world are threatened by land use change [10].

Zimbabwe's freshwater resources are under threat from exploitation, poor management and ecological degradation [11]. Throughout Zimbabwean history, humans have settled on riverine landscapes because of their proximity to resources such as water and fertile soils, but also for aesthetic values [12] [13]. Human mediated land use conversion to agriculture and open grazing have led to loss in woodland cover, and biodiversity in southeastern Zimbabwe [14]. Disturbances on riparian zones such as excessive wood harvesting, land clearance for settlement, industrial, or agricultural activities would likely modify and influence state-and-transition dynamics in riverine woodland ecosystems [15]. Although mean annual precipitation may be the primary determinant of woody biomass [16] at landscape level, woody vegetation dynamics may primarily relate to disturbances [17]-[19].

Most of the built-up area of Mutare City lies within the headwaters of Sakubva River basin and its tributaries which drains the main industrial and residential areas. This river also drains the rural Dora community to the west of the Mutare City in eastern Zimbabwe. As disturbance factors can alter the woody vegetation status, Sakubva riverine woodland is perceived by most water resource practitioners as threatened by anthropogenic activities [20] [21]. The urban and rural land use within Sakubva riparian zone may influence woody vegetation dynamics. This can lead to riparian woodland degradation and hence woody species extirpation in Sakubva riverine ecosystem. Effective land use and integrated water resource management is more feasible when accurate information is available regarding disturbance trends on identified indicator species for biomonitoring of the riverine ecosystem [22].

Despite its status and recognition as the largest perennial river, recharging the watershed basin of Mutare City, inadequate documentary evidence exists on Sakubva River and its riparian ecosystem [21]. The study aimed at assessing the vegetation attributes across the rural and urban land use types within Sakubva riparian zone. Specifically, the study objective was to determine the composition, abundance and structure of woody plants across two land use types within Sakubva riparian zone, eastern Zimbabwe. In this study, we hypothesized that Mutare urban study stratum has fewer human disturbances and a more intact Sakubva riparian woodland as compared to a rural land use study stratum in Dora community. The hypothesis was based on a combination of effects, the human-mediated changes on riparian woody vegetation across varying land use type at landscape level. We expected the urban environment to record fewer human disturbances and more intact riparian woodland as compared to a rural community in a developing country. The study findings will form baseline information on Sakubva riparian zone with possible use of woody plants as possible indicator species for biomonitoring the ecological health of this riverine ecosystem.

2. Materials and Methods

2.1. Study Area

Sakubva River is a perennial tributary of Odzi River which drains into Save River, the largest watershed catchment in eastern Zimbabwe (**Figure 1**). Sakubva River has its headwaters in Mutare City passing through industrial and human residential land use of the urban environment, then the river drains into a rural agricultural and communal settlement area of Dora community to the west of Mutare City. The river plays an important role in the economic and socio-ecology of Mutare urban and the rural communities it flows through. The larger part of the river is threatened with water pollution predominantly through sewage wastewater from the municipal sewage treatment works of Mutare City Council [21]. Dora rural community practices small scale agricultural activities dominated by vegetable gardening drawing irrigation water from Sakubva River [23]. The Dora rural people engage in enterprises such as extraction and sale of river sand, pit sand and

wood harvesting for construction works in Mutare City.

Mutare City is a fast-growing urban settlement in eastern Zimbabwe bordering Mozambique. Mutare District encompasses both Mutare City and Mutare rural which constitutes rural Dora community. Mutare District has a cool and wet climate with an annual rainfall range of 800 to 2,500 mm and a mean annual temperature range from a minimum of 9 to 12°C in cold and dry winter season to a maximum of 25 to 31°C during the hot and wet summer season [23]. Mutare District is characterized by scenic grassland areas interspersed with fynbos-like vegetation on the plateau summit, unique dwarf *Brachystegia spiciformis* woodland, moist montane forest and patches of medium to low altitude rainforest in the upper headwaters of Sakubva River watershed basin within the Mutare urban environment. Whereas, downstream in the rural Dora community, Sakubva River watershed is characterized by a semi-arid dry vegetation dominated by *Vachellia* shrubland [24].

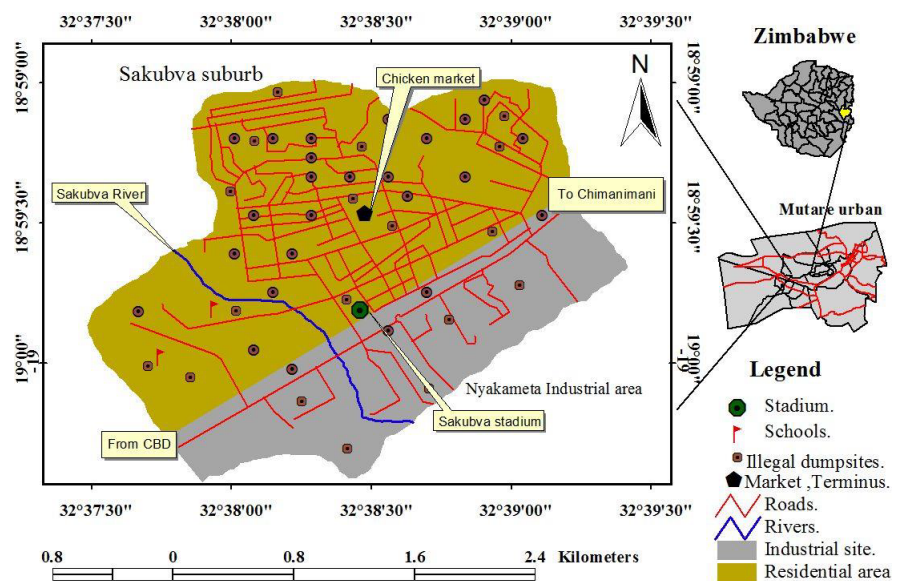


Figure 1. Showing study area Sakubva River which flows from Mutare urban through Dora rural community in Mutare District, eastern Zimbabwe (Source: [25]).

The study area of Sakubva River and its riparian vegetation stretch, was delineated into two study strata defined as: (i) upper headwaters of Sakubva River, within the Mutare urban land use type, and (ii) the downstream lower Sakubva River, within the Dora rural land use type. Sample plots within a 100m radius from either side of the riverbanks of Sakubva River were selected from the Mutare District map. Sample plots within the defined study site of two different land use types were located by generating random points (GPS coordinates) in the selected Sakubva River watershed map. Guided by the Mutare District map, GPS handsets were used to track the position of sample plots along Sakubva River. A total of 30 sample plots across the entire Sakubva River watershed basin stretch were selected from the study sites. Based on the proportional longitudinal length of Sakubva

River within the two land use categories, 10 sample plots were located across the urban land use study stratum and 20 sample plots were in the rural land use study stratum. For this study, sampling plots measuring 30 m × 20 m were used. This plot size satisfies the consideration by earlier study method of including at least 15 - 20 trees in a sample plot [26].

2.2. Sampling Procedure, Measured Variables and Measurement Techniques

Woody trees were defined as rooted self-supporting woody plants ≥ 3 m height with a stem diameter ≥ 0.06 m, whereas shrubs were defined as rooted self-supporting woody plants < 3 m height with a stem diameter < 0.06 m [27]. To describe the woody species composition and structure along Sakubva River, the following variables were recorded: tree and shrub height, tree diameter at 1.3m height, basal stem circumference, number of stems per plant, number of coppiced woody plants, woody species diversity, human induced damage on woody plants, fire damage on woody plants, plant status (alive or dead), tree and shrub density. These variables were measured following the methods as outlined elsewhere [28]. All woody species within a sample plot were identified using a field guide [29]. Fire damage indicators were fire scars, scorch marks on branches, dead, burnt stems and charred plant remains [28]. Human induced damage were signs of wood harvesting like scars from wood harvesting tools, broken branches and stems. All woody plants were assessed to establish whether they were dead or alive.

Tree/shrub height: the height of woody plants was measured by placing a calibrated 8 m pole against a tree or shrub. For trees > 8 m, the pole was manually uplifted, or height visually estimated by observing it at a distance away from the tree. For multi-stemmed plants, only the height of the tallest stem was considered. **Tree diameter at breast height (dbh):** the circumference at 1.3 m above the ground level of each tree was measured using a 50 m tape measure. For shrubs, the **basal stem circumference** of each stem was measured just above the buttress swelling, to the nearest centimeter, using a tape measure. From the basal stem circumference, basal area was calculated using the formula:

$$\text{Basal area} = (C^2/4\pi)$$

where C is basal stem circumference.

Number of stems per plant: stems were physically counted for each sample plot. For each sample plot, the total number of stems was divided by number of woody plants in the sample plot, to give an average number of stems per plant. **Tree/Shrub Density:** density (e.g. tree/shrub stems per ha) for each plot was calculated using the formula:

$$\text{Density (stems/ha)} = \frac{\text{Number of woody stems}}{\text{Sample Plot area (m}^2\text{)}} \times 10,000 \text{ m}^2$$

Plant status and human induced damage on woody species: for dead plants, the cause of death was attributed to one of four factors *i.e.* (1) drought, (2) human

induced woody damage and (3) unknown. Any signs of woody damage such as fire scars, broken branches, stems and scarring, and uprooted trees or shrub were considered as human-induced damage. If dead, the plant's cause of death was recorded, and no other variable measurement was taken. Human induced wood damage was assessed based on the presence of damage signs on woody plants in accordance with another earlier study method [30]. For all the formulas applied in this study methods, they have no known application limit.

2.3. Data Analysis

Statistical tests were conducted using STATISTICA for Windows, version 6 [31]. Descriptive statistics were used to summarize data collected on woody vegetation attributes and woody vegetation variables were converted to per hectare [32]. To test whether the Sakubva riparian woody vegetation status was different between the two land use strata, we performed Mann-Whitney U tests (one-tailed) since our data was not normally distributed [33]. We considered there to be no significant difference when the value of the probability of significance (P) was greater than 0.05. Species diversity across the study strata was determined using the Shannon-Weiner diversity index [34]. The study explored dominance of woody species across the study strata by association and classification of sample plots based on woody vegetation composition through multivariate analysis. A hierarchical cluster analysis (HCA) using the Wards method with a matrix of 30 sample plots and only the recorded woody vegetation composition data was used to determine the similarities or dissimilarities of sample plots [35].

3. Results

3.1. Woody Vegetation Structure and Composition

A total of 543 woody plants, representing 21 woody species were recorded in the 30 sample plots. All the recorded woody plant variables indicated no significance difference ($P > 0.05$) between the two defined study strata, except for the sapling density ($P < 0.05$) (Table 1). About 68% of the recorded woody plants were living trees, 32% were dead stems, 43% showed evidence of human induced damage on the sampled woody plants.

Table 1. Summary of measured and recorded woody vegetation variables (Mean \pm Standard Deviation) along Sakubva River as it cut across the two land use study strata, eastern, Zimbabwe.

Variable	Grouping Strata-Land Use Type		U -value	P -value
	Sakubva River under rural environment ($n = 20$)	Sakubva River under urban environment ($n = 10$)		
Number of woody species	21.62 \pm 2.73	18 \pm 2.43	934	0.188
Tree height (m)	5.90 \pm 0.44	8.14 \pm 0.36	813	0.061
Shrub height (m)	0.31 \pm 0.23	0.44 \pm 0.20	895	0.069
Basal area (m ² /ha)	0.21 \pm 0.18	0.38 \pm 0.13	1 100	0.710

Continued

Human induced damaged plants (ha ⁻¹)	0.28 ± 0.47	0.47 ± 0.48	983	0.269
Woody species diversity (<i>H'</i>)	0.73 ± 0.42	0.91 ± 0.31	1 071	0.558
Sapling density (ha ⁻¹)	34.58 ± 1.00	13.41 ± 1.23	536	0.0001
Coppiced woody plants density (no. ha ⁻¹)	61.58 ± 1.80	54.58 ± 1.01	1 135	0.879
Tree density (ha ⁻¹)	49.65 ± 1.43	93 ± 2.63	1 150	0.893
Shrub density (ha ⁻¹)	72 ± 1.29	64.7 ± 1.14	1 165	0.910
Dead plants density (ha ⁻¹)	51.11 ± 01.63	32.78 ± 0.23	1 178	0.955

3.2. Woody Species Association in the Sakubva River Riparian Woodland, Eastern Zimbabwe

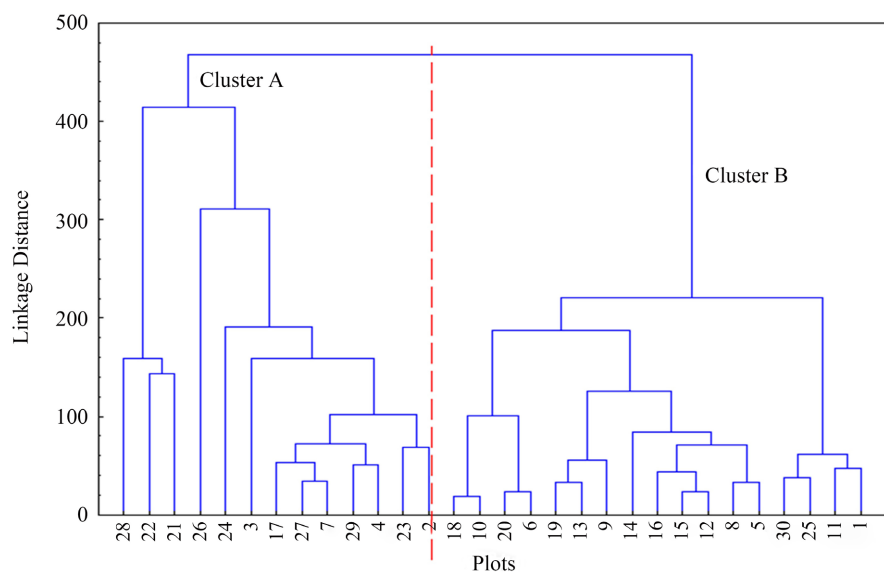


Figure 2. Hierarchical Cluster Analysis (HCA) dendrogram showing classification of sample plots into two (2) clusters based on woody species composition data from the 30 sample plots across Sakubva riparian zone, eastern Zimbabwe.

The HCA dendrogram showed two broad clusters from the 30 sampled plots within Sakubva riparian woodland, eastern Zimbabwe (Figure 2). Cluster A had a high dominance of sample plots drawn from the upper Sakubva River within the urban environment study stratum. There were only three plots from the rural land use study stratum in Cluster A. Plots in Cluster A were characterized by an association of the following species *Brachystegia spiciformis*, *Julbernardia globiflora*, *Ficus capensis* and *Eucalyptus spp.* Cluster B was dominated by sample plots from the lower Sakubva River within the rural environment study stratum and included the following common woody species *Vachellia karroo*, *Terminalia prunoides*, *Grewia bicolor*, *Prunus curatolifolia*, *Burkea africana*, *Combretum celastroides*, *Boscia angustifolia*, *Phylanthus kirkianu*, *Psidium guajava* and *Lantana camara*. The HCA dendrogram to a greater extent distinguished sample plots from the rural land use and urban land use groups based on woody species composition.

The most dominant woody species in upper Sakubva River, within the urban land use stratum were *Brachystegia spiciformis* and *Julbernardia globiflora*. In lower Sakubva River, the rural land use stratum, the dominant species included the *Vachellia karroo*, *B. spiciformis* and *J. globiflora*. Common woody species on all sample plots included: *B. spiciformis* and *J. globiflora*.

4. Discussion

The woody plant community across Sakubva riparian zone showed domination by *B. spiciformis* and *J. globiflora*. The dominant woody plant family is *Fabaceae* sub-family *Caesalpinoideae* of the prototype Miombo woodland [36], specifically resembling the Miombo woodlands of southern Africa savanna [37]. The woody species richness (21) across the riparian woodland of Sakubva River, concur relatively well with the Miombo forests occurring elsewhere within the same region of eastern Zimbabwe. For instance, earlier study recorded 17 woody species across the protected Mapembe Nature Reserve near Mutare City [30]. However, the woody species richness for Sakubva riparian zone is relatively low as compared to other study findings on woody vegetation composition in southeastern Zimbabwe. In an earlier study, there was a record of 59 and 43 woody species in Save-Runde River confluence and Manjinji Pan Important Bird Areas, respectively, in southeastern Zimbabwe [38]. Another earlier study in Save Valley recorded 192 woody species in Mutema-Musikavanhu communal land in southeastern Zimbabwe [19]. Relatively low woody species richness in Sakubva riparian zone may be attributed to excessive anthropogenic activities like selective cutting down of woody plants targeting specific species. There was evidence of excessive tree extraction along Sakubva River as represented by relatively high density of coppiced woody plants and high number of dead plant density. This could be driven by excessive harvesting of fuel wood across the study area. Zimbabwe faced economic challenges from the 2000 s to the 2020 s and this may persist, causing increased electricity power cuts, leading both rural and urban people to heavily rely on wood fuel as a source of energy [18]. Excessive wood extraction is known to affect microsites for plant establishment and the resultant woody plant diversity and plant density [39], this could be a contributing factor to relatively low woody species diversity and high dead wood density across Sakubva riparian zone.

There were no significant differences among most of the assessed woody plant variables across the study strata except for sapling density. This indicated that land use type and its influence on Sakubva riparian woodland between the urban and rural land use are not yet fully pronounced. Land use in this case involves the modification of natural environment of Sakubva riparian woodland into built environment such as stream bank gardening, grazing pastures and human settlements in Dora rural land use, whereas infrastructure and industrial development causing riparian woodland cover changes in Mutare urban. Significant differences in sapling density between the Sakubva riparian zone under rural and urban land use strata is likely attributed to the usual high impact of human induced disturb-

ances on woodlands in rural communities as common in Zimbabwe [19] [30]. The most observed trend is that human disturbed woody vegetation is characterized by high sapling density [19]. This confirms the theory of invasibility which states that whenever there are unutilized resources in an ecosystem following disturbance, that ecosystem becomes susceptible to invasion by saplings as these disturbed habitat and species-poor communities contain more unoccupied niches [40]. For woody species of slow growth rate like the indigenous woody plants of Miombo woodlands, recruitment is interpreted as viable when woody vegetation has a larger proportion of saplings than larger trees, and recruitment is considered poor when there are larger proportions of trees than saplings [41]-[43]. Based on this indicator, the present study results of high proportion of tree density as compared to saplings could suggest less vibrant recruitment of woody plants within the riparian woodland of Sakubva River, eastern Zimbabwe.

The woody vegetation structural and compositional similarities along Sakubva River suggested uniform woodland disturbances which can have a long-term effect in influencing woodland degradation, although there are other factors such as topography, edaphic and climate variations which we did not investigate. It was evident from this study that woody plants occurring in Mutare urban and rural Dora land use categories were to some extent damaged by humans with evidence of past fires and wood harvesting. For instance, affected woody plants showed burn marks, scars, black surfaces and charred plant remains. Moreover, the uniform presence of coppiced woody plants across the study strata indicated a woody plant re-sprouting capacity of various woody species, which is a plant adaptive mechanism to growth disturbance which seems common across Sakubva riparian woodland. This is clear evidence that some level of disturbance on woody plants is inflicted across the riparian woodland of Sakubva River, eastern Zimbabwe. There is need for continuous monitoring of woody vegetation on the varying land use categories across the riverine ecosystems in Mutare District, eastern Zimbabwe.

5. Conclusion

The study aimed at assessing the woody vegetation attributes across the rural and urban land use types across Sakubva riparian zone in Mutare District, eastern Zimbabwe. The study recorded no significant differences in woody vegetation composition and structure across the Sakubva riparian zone under the urban and rural land use in Mutare District, eastern Zimbabwe. It was concluded that woody plant composition and structure is generally uniform across land use type as Sakubva River cuts across the urban and rural environment of Mutare District, eastern Zimbabwe. However, it was evident from this study that woody plants occurring in Mutare urban and rural Dora land use categories on Sakubva riparian zone were to some extent damaged by humans with evidence of past fires and wood harvesting. The study can inform baseline information on Sakubva riparian zone with possible use of woody plants as indicator species for biomonitoring the ecological health of this riverine ecosystem.

Recommendations

Development of a local riparian habitat monitoring framework with tools that assess variables related to biodiversity, water quality, river-bank vegetation structure and river channel modifications to monitor local riverine ecosystem health and to inform decisions for maintaining riparian biodiversity and ensuring the provision of riverine ecosystem services through sustainable management.

As watershed catchment regulators and large-scale water resource system owners, Zimbabwe state actors like the Zimbabwe National Water Authority, Environmental Management Agency, Mutare Rural District Council and Mutare City Council must put in place more enabling measures (e.g. strengthened law enforcement to combat streambank cultivation, wildfires and excessive riparian wood harvesting) needed to ensure that Sakubva riparian ecosystem is sustainably managed and preserved.

Given that gardening expansion is the main driver of Sakubva riparian woodland degradation, then much transformational change is needed in the way in which food is produced. Rural Dora communities must move away from inappropriate streambank cultivation that drive large-scale conversion of riparian woodland to agricultural production and the loss of riparian-related biodiversity. Adopting sustainable production practices like agroforestry, agrosilviculture to restore the productivity of degraded riparian land zone.

Investors and Mutare urban land use development projects should adopt business models that are environmentally and socially responsible to preserve Sakubva riparian zone. These actions may require investments toward restoration ecology for Sakubva riparian zone.

Further studies to investigate the possible interactive effects of industrial or mining induced river pollution and other environmental determinants like water quality in influencing the ecological health status of the wider Sakubva-Odzi-Save watershed catchment basin.

Acknowledgements

We are indebted to the following Zimbabwe Government Offices; Mutare District Administration Office, Manicaland Provincial Office of the Environmental Management Agency, Department of Water Resources in Manicaland Province, Mutare City Council, Mutare Rural District Council and the traditional leader Chief Zimunya for allowing us to undertake this research study. Special thanks to various people from different government departments of Mutare District Zimbabwe, who participated in this study.

Conflicts of Interest

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

References

- [1] Bedison, J.E., Scatena, F.N. and Mead, J.V. (2013) Influences on the Spatial Pattern

- of Soil Carbon and Nitrogen in Forested and Non-Forested Riparian Zones in the Atlantic Coastal Plain of the Delaware River Basin. *Forest Ecology and Management*, **302**, 200-209. <https://doi.org/10.1016/j.foreco.2013.03.012>
- [2] Sutfin, N.A., Wohl, E.E. and Dwire, K.A. (2016) Banking Carbon: A Review of Organic Carbon Storage and Physical Factors Influencing Retention in Floodplains and Riparian Ecosystems. *Earth Surface Processes and Landforms*, **41**, 38-60. <https://doi.org/10.1002/esp.3857>
- [3] Mligo, C. (2017) Diversity and Distribution Pattern of Riparian Plant Species in the Wami River System, Tanzania. *Journal of Plant Ecology*, **10**, 259-270. <https://doi.org/10.1093/jpe/rtw021>
- [4] Dosskey, M.G., Vidon, P., Gurwick, N.P., Allan, C.J., Duval, T.P. and Lowrance, R. (2010) The Role of Riparian Vegetation in Protecting and Improving Chemical Water Quality in Streams. *JAWRA Journal of the American Water Resources Association*, **46**, 261-277. <https://doi.org/10.1111/j.1752-1688.2010.00419.x>
- [5] Stanford, J.A. and Ward, J.V. (2001) Revisiting the Serial Discontinuity Concept. *Regulated Rivers. Research & Management*, **17**, 303-310. <https://doi.org/10.1002/rrr.659>
- [6] Zheng, J., Arif, M., He, X., Liu, X. and Li, C. (2023) Distinguishing the Mechanisms Driving Multifaceted Plant Diversity in Subtropical Reservoir Riparian Zones. *Frontiers in Plant Science*, **14**, Article ID: 1138368. <https://doi.org/10.3389/fpls.2023.1138368>
- [7] Mligo, C. and Mligo, C. (2011) Anthropogenic Disturbance on the Vegetation in Makurunge Woodland, Bagamoyo District, Tanzania. *Tanzania Journal of Science*, **37**, 94-108. <https://doi.org/10.65085/2507-7961.1890>
- [8] Nivedi, S. and Mohan, N.S. (2024) Disturbances on Riparian Vegetation: A Comprehensive Review. *International Journal of Research and Review*, **11**, 200-208. <https://doi.org/10.52403/ijrr.20240422>
- [9] Celentano, D., Rousseau, G.X., Engel, V.L., Façanha, C.L., de Oliveira, E.M. and de Moura, E.G. (2014) Perceptions of Environmental Change and Use of Traditional Knowledge to Plan Riparian Forest Restoration with Relocated Communities in Alcântara, Eastern Amazon. *Journal of Ethnobiology and Ethnomedicine*, **10**, 1746-4269. <https://doi.org/10.1186/1746-4269-10-11>
- [10] Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., et al. (2010) Global Threats to Human Water Security and River Biodiversity. *Nature*, **467**, 555-561. <https://doi.org/10.1038/nature09440>
- [11] Mashapa, C. (2018) Human Livelihoods and Sustainable Conservation: Herbivory and Anthropogenic Impacts on Woody Vegetation in Save Valley, Southeastern Lowveld of Zimbabwe. Ph.D. Thesis, Chinhoyi University of Technology.
- [12] Moyo, N.A.G. (1998) Water Resources. In: Chenje, M., Sola, L. and Paleczny, D., Eds., *The State of Zimbabwe's Environment*, Government of the Republic of Zimbabwe, Ministry of Mines, Environment and Tourism, 213-268.
- [13] Matayaya, G., Wuta, M. and Nyamadzawo, G. (2017) Effects of Different Disturbance Regimes on Grass and Herbaceous Plant Diversity and Biomass in Zimbabwean Dambo Systems. *International Journal of Biodiversity Science, Ecosystem Services & Management*, **13**, 181-190. <https://doi.org/10.1080/21513732.2017.1299222>
- [14] Mashapa, C., Gandiwa, E., Muboko, N. and Muhriro-Mashapa, P. (2020) Land Use and Land Cover Changes in a Human-Wildlife Mediated Landscape of Save Valley Conservancy, South-Eastern Lowveld of Zimbabwe. *The Journal of Animal and Plant Sciences*, **31**, 583-595. <https://doi.org/10.36899/japs.2021.2.0246>

- [15] Campbell, B.M., Cunliffe, R.N. and Gambiza, J. (1995) Vegetation Structure and Small-Scale Pattern in Miombo Woodland, Marondera, Zimbabwe. *Bothalia*, **25**, 121-126. <https://doi.org/10.4102/abc.v25i1.721>
- [16] Sankaran, M., Hanan, N.P., Scholes, R.J., Ratnam, J., Augustine, D.J., Cade, B.S., *et al.* (2005) Determinants of Woody Cover in African Savannas. *Nature*, **438**, 846-849. <https://doi.org/10.1038/nature04070>
- [17] Mackenzie, C.A., Chapman, C.A. and Sengupta, R. (2011) Spatial Patterns of Illegal Resource Extraction in Kibale National Park, Uganda. *Environmental Conservation*, **39**, 38-50. <https://doi.org/10.1017/s0376892911000282>
- [18] Muboko, N., Chigumira, T., Mashapa, C., Gandiwa, E., Chibememe, G. and Muposhi, V.K. (2014) Impacts of Wood Poaching on Vegetation Structure and Composition in Mukuvisi Woodland, Zimbabwe. *Journal of Environmental Protection*, **5**, 156-163. <https://doi.org/10.4236/jep.2014.52019>
- [19] Mashapa, C., Gandiwa, E. and Muboko, N. (2019) Socio-Economic and Ecological Outcomes of Woodland Management in Mutema-Musikavanhu Communal Areas in Save Valley, Southeastern Lowveld Zimbabwe. *The Journal of Animal and Plant Sciences*, **29**, 1075-1087.
- [20] Distefano, E. (2005) Human-Wildlife Conflict Worldwide: A Collection of Case Studies, Analysis of Management Strategies and Good Practices. SARD Initiative Report, FAO.
- [21] Basvi, A., Shambira, L and Mapira, J. (2018) Challenges of River Pollution in the Dora Community, Mutare (Zimbabwe). *International Journal of Current Innovations in Advanced Research*, **1**, 42-56.
- [22] Hobbs, R.J., Arico, S., Aronson, J., Baron, J.S., Bridgewater, P., Cramer, V.A., *et al.* (2006) Novel Ecosystems: Theoretical and Management Aspects of the New Ecological World Order. *Global Ecology and Biogeography*, **15**, 1-7. <https://doi.org/10.1111/j.1466-822x.2006.00212.x>
- [23] Mashapa, C., Matenda, T., Mudyazvivi, E., Mhuriro-Mashapa, P., Mufunda, W., Dube, L., *et al.* (2014) Assessment of Market Potential for Horticultural Produce for Smallholder Farmers around Mutare City, Eastern Zimbabwe. *Greener Journal of Social Sciences*, **4**, 85-93. <https://doi.org/10.15580/gjss.2014.3.012414062>
- [24] Mashapa, C., Gandiwa, E., Mhuriro-Mashapa, P. and Zisadza-Gandiwa, P. (2014) Increasing Demand on Natural Forest Products in Urban and Peri-Urban Areas of Mutare, Eastern Zimbabwe: Implications for Sustainable Natural Resources Management. *Nature and Faune*, **28**, 42-48.
- [25] Chirema, E.T. (2017) Challenges and Opportunities Associated with Community Participation in Solid Waste Management in Sakubva, Mutare. BSc Thesis, Midlands State University.
- [26] 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 Resources*, **6**, 1-32.
- [27] Ben-Shahar, R. (1998) Changes in Structure of Savanna Woodlands in Northern Botswana Following the Impacts of Elephants and Fire. *Plant Ecology*, **136**, 189-189. <https://doi.org/10.1023/a:1009708021735>
- [28] Gandiwa, E. and Kativu, S. (2009) Influence of Fire Frequency on *Colophospermum mopane* and *Combretum apiculatum* Woodland Structure and Composition in Northern Gonarezhou National Park, Zimbabwe. *Koedoe*, **51**, a685. <https://doi.org/10.4102/koedoe.v51i1.685>

- [29] Coates-Palgrave, K. (1997) *Trees of Southern Africa*. Struik Publishers.
- [30] Muboko, N., Mushonga, M.R., Chibuwe, N., Mashapa, C and Gandiwa, E. (2013) Woody Vegetation Structure and Composition in Mapembe Nature Reserve, Eastern Zimbabwe. *Journal of Applied Science and Environmental Management*, **17**, 475-481.
- [31] StatSoft Inc. (2001) *Statistica for Windows*, Version 6, 2300. StatSoft.
- [32] Gandiwa, E., Zisadza-Gandiwa, P., Goza, D., Mashapa, C. and Muboko, N. (2014) Diversity and Structure of Woody Vegetation across Areas with Different Soils in Gonarezhou National Park, Zimbabwe. *Southern Forests: a Journal of Forest Science*, **76**, 111-116. <https://doi.org/10.2989/20702620.2014.921007>
- [33] Sokal, R.R and Rohlf, F.J. (1995) *Biometry: The Principles and Practice of Statistics in Biological Research*. 3rd Edition, Freeman.
- [34] Ludwig, A.J. and Reynolds, J.F. (1988) *Statistical Ecology. A Primer on Methods and Computing*. John Wiley and Sons.
- [35] Green, P.E., Carmone, F.J. and Smith, S.M. (1989) *Multidimensional Scaling: Concepts and Applications*. Allyn and Bacon.
- [36] Timberlake, J. and Chidumayo, E. (2001) *Miombo Ecoregion Vision Report*. Report for WWF-SARPO. Occasional Publications in Biodiversity No. 20. Biodiversity Foundation for Africa, Bulawayo, 79 p.
- [37] Grundy, I.M. (1995) Wood Biomass Estimation in Dry Miombo Woodland in Zimbabwe. *Forest Ecology and Management*, **72**, 109-117. [https://doi.org/10.1016/0378-1127\(94\)03467-b](https://doi.org/10.1016/0378-1127(94)03467-b)
- [38] Gandiwa, P., Chinoitezvi, E. and Gandiwa, E. (2013) Structure and Composition of Woody Vegetation in Two Important Bird Areas in Southern Zimbabwe. *Journal of Animal and Plant Sciences*, **23**, 813-820.
- [39] Hobbs, R.J. and Huenneke, L.F. (1992) Disturbance, Diversity, and Invasion: Implications for Conservation. *Conservation Biology*, **6**, 324-337. <https://doi.org/10.1046/j.1523-1739.1992.06030324.x>
- [40] Davis, M.A., Grime, J.P. and Thompson, K. (2000) Fluctuating Resources in Plant Communities: A General Theory of Invasibility. *Journal of Ecology*, **88**, 528-534. <https://doi.org/10.1046/j.1365-2745.2000.00473.x>
- [41] Condit, R., Sukumar, R., Hubbell, S.P. and Foster, R.B. (1998) Predicting Population Trends from Size Distributions: A Direct Test in a Tropical Tree Community. *The American Naturalist*, **152**, 495-509. <https://doi.org/10.1086/286186>
- [42] Lykke, A.M. (1998) Assessment of Species Composition Change in Savanna Vegetation by Means of Woody Plants' Size Class Distributions and Local Information. *Biodiversity & Conservation*, **7**, 1261-1275. <https://doi.org/10.1023/a:1008877819286>
- [43] Wright, S.J., Muller-Landau, H.C., Condit, R. and Hubbell, S.P. (2003) Gap-Dependent Recruitment, Realized Vital Rates, and Size Distributions of Tropical Trees. *Ecology*, **84**, 3174-3185. <https://doi.org/10.1890/02-0038>