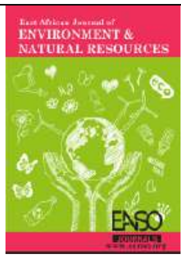


East African Journal of Environment and Natural Resources
eajenr.eanso.org
Volume 8, Issue 3, 2025
Print ISSN: 2707-4234 | Online ISSN: 2707-4242
Title DOI: https://doi.org/10.37284/2707-4242

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Impact of Selected Anthropogenic Disturbances on the Variability of Riparian Vegetation in the River Kathita Basin, Tharaka Nithi County, Kenya

Denis Kibaara Mugambi[1], Rithaa Jafford Njeru[1] & Agatha Nthenge[1]*

[1] Chuka University, P. O. Box 109-60400, Chuka, Kenya.
[*] Correspondence Email: kibaaradenis@gmail.com

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Date Published:

23 September 2025

Keywords:

Anthropogenic Disturbances, Sand Harvesting, Charcoal Burning, Livestock Drinking Bays, Riparian, Vegetation Variability.

ABSTRACT

The human-induced disturbances along the fragile riparian ecosystems have significant ecological disruptions, such as loss of biodiversity and ecological services rendered by the riparian vegetation. This study investigated the impact of these selected anthropogenic disturbances, specifically sand harvesting, charcoal burning, and livestock drinking bays, on the variability of the riparian vegetation in the River Kathita basin, Tharaka-Nithi County, Kenya. The study employed purposive sampling to target disturbed sites, whereas simple random sampling was used for vegetation sampling within the sites that were targeted. Three non-disturbed sites were used as control sites and were randomly sampled along a 15KM transect. Sites affected by sand harvesting, charcoal burning, and livestock grazing exhibited lower species diversity ($0 \geq H < 1.5$) while undisturbed sites maintained higher diversity ($1.1 > H \leq 2$). Although the Kruskal-Wallis test for tree diversity among the sites was not statistically significant ($p=0.07$), for tree species richness the test was ($p = 0.047$). Charcoal burning sites were characterised by large tree diameters at breast height (DBH) but lower tree heights. Sand harvesting and charcoal burning sites had high diversity of seedlings and saplings in abandoned sites, indicating the ability to recover and re-establishment of vegetation in the absence of disturbance and with protection. Livestock drinking bays showed a shift in vegetation composition from grasses and shrubs to dominance by forbs and herbaceous plants. There were strong correlations between sand harvesting, charcoal burning, livestock grazing, and tree diversity, which was significant for livestock grazing ($p=0.01$) and marginally insignificant for sand harvesting and charcoal burning ($p=0.06$). The study recommends that local and national stakeholders regulate sand harvesting, charcoal production in riparian areas, and develop strategies for managing livestock access to drinking bays. Future research should explore the combined effects of climate change, agriculture, and land-use policies on riparian habitat ecosystems.

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

APA CITATION

Mugambi, D. K., Njeru, R. J. & Nthenge, A. (2025). Impact of Selected Anthropogenic Disturbances on the Variability of Riparian Vegetation in the River Kathita Basin, Tharaka Nithi County, Kenya. *East African Journal of Environment and Natural Resources*, *8*(3), 90-109. https://doi.org/10.37284/eajenr.8.3.3691.

CHICAGO CITATION

Mugambi, Denis Kibaara, Rithaa Jafford Njeru and Agatha Nthenge. 2025. "Impact of Selected Anthropogenic Disturbances on the Variability of Riparian Vegetation in the River Kathita Basin, Tharaka Nithi County, Kenya". *East African Journal of Environment and Natural Resources* 8 (3), 90-109. https://doi.org/10.37284/eajenr.8.3.3691

HARVARD CITATION

Mugambi, D. K., Njeru, R. J. & Nthenge, A. (2025) "Impact of Selected Anthropogenic Disturbances on the Variability of Riparian Vegetation in the River Kathita Basin, Tharaka Nithi County, Kenya", *East African Journal of Environment and Natural Resources*, 8 (3), pp. 90-109. doi: 10.37284/eajenr.8.3.3691.

IEEE CITATION

D. K., Mugambi, R. J., Njeru & A., Nthenge "Impact of Selected Anthropogenic Disturbances on the Variability of Riparian Vegetation in the River Kathita Basin, Tharaka Nithi County, Kenya", *EAJENR*, vol. 8, no. 3, pp. 90-109, Sep. 2025.

MLA CITATION

Mugambi, Denis Kibaara, Rithaa Jafford Njeru & Agatha Nthenge. "Impact of Selected Anthropogenic Disturbances on the Variability of Riparian Vegetation in the River Kathita Basin, Tharaka Nithi County, Kenya". *East African Journal of Environment and Natural Resources*, Vol. 8, no. 3, Sep 2025, pp. 90-109, doi:10.37284/eajenr.8.3.3691

INTRODUCTION

Riparian ecosystems are among the Earth's most precious ecosystems, delivering a wide range of goods and services. Apart from the numerous benefits that the riparian ecosystems provide to humans, they are areas of high diversity and productivity. The human-induced disturbances like sand harvesting, charcoal burning, and overgrazing along the riparian areas most often have produced large-scale changes in the plant community structure and composition, and are the greatest risk to riparian ecosystem conservation and their biodiversity.

A study by Kondolf et al. (2007) in France found that the development of access roads and storage areas for sand mining has fragmented riparian forests. The findings coincided with those of Kori and Mathada (2012) in the riparian areas of Nzehele Valley, South Africa. In Kisumu County, Kenya, a study by Oyoo (2021) indicated that, indeed, sand harvesting affected the land cover and flora along riparian land through the clearing of vegetation as the topsoil is harvested as sand. In Tharaka Nithi, sand harvesting in the River Kathita basin to cater to the high demand in Tharaka-Nithi, Embu, and Meru counties has led to heightened vegetation clearance along the riparian zone to expose more sand, environmental degradation, and overall ecological compromise.

Charcoal and firewood serve as primary energy sources in both urban and rural areas across Africa and are used by over 80% percent of the population (FAO, 2010). In Tanzania, Malimbwi et. al. (2005) established that charcoal burning contributed to about 75% of deforestation in closed and open woodlands. A study by Kariuki (2002) in Kibwezi documented that charcoal making was the greatest contributor to vegetation cover loss. The study also found that tree harvesting in Kibwezi resulted in a change in tree species composition. In Tharaka-Nithi, economic difficulties in areas like the study area have led to increased illegal charcoal production along the River Kathita habitat. The Marimanti area is also famed for quality charcoal, increasing demand for charcoal production along the riparian zones.

Drinking bays utilised by a huge number of livestock to access watercourses result in livestock trampling on vegetation, overgrazing, which leads to degradation of the riparian vegetation, loss of biomass, and diversity. A study by Kyalo (2009) in the River Njoro Watershed, Kenya, revealed that uncontrolled open grazing along riparian zones led to significant land degradation and increased

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

pressure on natural resources. This finding aligns with research conducted in the River Nairobi basin (Majumdar & Avishek, 2023). River Kathita faces similar predicaments; however, a unique challenge it is facing is that it's one of the few permanent rivers in an arid and semi-arid land (ASAL) area where the main economic activity is livestock rearing. Other rivers in the area, such as the Thanatu, have had significant degradation of their riparian zones and subsequently dried up (Kirema, 2020). This raises serious concerns about the River Kathita riparian habitat, which faces similar trends of incursion and overgrazing on its riparian zones.

River Kathita is one of the two permanent rivers in the dry lands of Tharaka South constituency, and therefore, many communities along the river are highly dependent on it and its riparian habitat, thus establishing it as a key area for conservation efforts. Most economic, social, and cultural activities of the locals are closely tied to this riparian zone, making it highly susceptible to degradation. There is very little information about riparian areas in Kenya and significantly less in Tharaka-Nithi County. Moreover, there are limited studies on the state of riparian vegetation in the study area; hence, this study aims to bridge that gap in understanding how various disturbance-causing activities are altering riparian habitats in Marimanti, potentially jeopardising the provision of ecosystem services. The study findings will be useful in formulating sound decisions and policy briefs for efficient management and utilisation of riparian resources.

MATERIAL AND METHODS

The study area was between Marimanti (37°58'32.79" E, 0° 9'29.63" S) and Kibuka (38° 0'4.40" E, 0°15'55.32" S), along the riparian zone of the River Kathita basin, in Tharaka South Sub-County, Tharaka Nithi County, Kenya.

The study used purposive and simple random sampling techniques along the 15 Km transect. Purposive sampling was employed while walking along the transect to target disturbed sites, whereas simple random sampling was used for vegetation sampling within the targeted sites. Three non-disturbed sites were used as control sites and were randomly sampled. Vegetation sampling was done on 16 sites, which included 4 sites for sand harvesting sites, 4 sites for charcoal burning sites, 5 sites for livestock drinking bays, and 3 as control sites. The choice of 16 sites balanced the need for detailed data with practical constraints such as time, resources, and accessibility. The number chosen allowed for manageable fieldwork while still providing enough data points to draw meaningful conclusions. This was supported by guidelines for practical considerations in field research and a guide to effective monitoring of aquatic and riparian resources (Kershner, 2004). Magnitude, indices, and other metrics were used as a method to infer a conclusion in order to address any limitations of the significance test due to the sample size used.

The three variables, sand harvesting, charcoal burning, and grazing bays, were chosen due to their observed impact on the River's habitat, and they were the most predominant disturbances on the riparian. Control sites were chosen from areas with minimal observed human activities along the riparian zone. The observational units were 20M by 20M quadrats for trees, 5m by 5m quadrats for shrubs, and 1m by 1m quadrants for grasses and herbaceous plants. Smaller quadrats were nested within the 20 by 20 M quadrant.

Species identification for trees, shrubs, grasses, and herbaceous plants in all the sampled sites was done by classification of the vegetation from family to the species level through the use of leaves, barks, fruits, and flowers, and using plant identification guide books such as Dharani, N. (2011) and Maundu, P., et al. (2005). To assess the vegetation structure within the laid quadrant, measurements on DBH using the measuring tape, measurements of tree height using calibrated poles, and estimated canopy and ground cover were recorded. Vegetation diversity was analysed through calculating species richness, Shannon-Weiner, and Simpson diversity

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

indexes. Statistical testing for significance differences in diversity indexes was done through the Kruskal-Wallis test. The test was preferred over the other non-parametric tests for its versatility with various datasets and its applicability to small and large sample sizes, providing reliable results even when the sample size is not large enough to meet the assumptions of parametric tests. The ground cover was estimated as the percentage area covered by vegetation within the quadrant, and the average was calculated to estimate the ground cover of each sampling site. Tree cover was estimated as the proportion of the ground area that is covered by the tree crowns when viewed from above and was expressed as a percentage. Spearman's correlation was used to test the relationship between anthropogenic activities and vegetation diversity. The test was preferred for its robustness with outliers, non-assumption of normality, and its ease of interpretation.

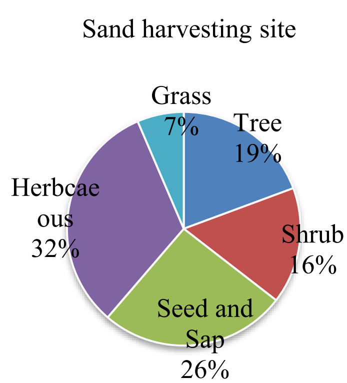
RESULTS AND DISCUSSIONS

Influence of Sand Harvesting on Riparian Vegetation Diversity Composition

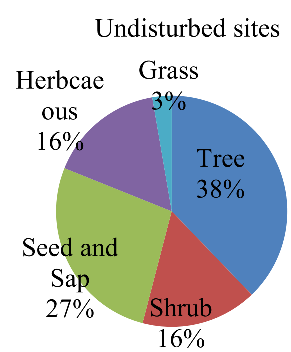
Floristic Composition

The highest composition in sand harvesting sites was herbaceous species with 32%, while in undisturbed sites, trees had the highest composition with 38% (Fig. 1a and b). A study by Zhao *et al.* (2015) showed that herbaceous species had a higher coverage compared to other vegetation types in mined sites, with herbaceous species covering 60% of the area, while other species covered 40%. Moreover, in reclaimed mines in China, Zhang *et al.* (2020) discovered that herbaceous species made up 60% of the plant diversity after six years of reclamation. This indicated that herbaceous plants in sand harvesting disturbed sites were more resilient to the disturbances as compared to other species.

Figure 1: (a) Sand Harvesting Sites



(B) Undisturbed Sites



Species Diversity Analysis

Tree species richness and vegetation diversity were highest for the undisturbed sites that were used as controls (Table 1). The finding coincides with Nasare *et al*. (2023), who observed that the Shannon-Weiner index was higher in the undisturbed site, compared to the sand mining sites in Dallung-Kukou catchment. The findings were also in agreement with a study by Garbin *et al*. (2018) that reported undisturbed sites had high vegetation diversity as compared to sand harvested areas.

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Table 1: Tree's Diversity for Sand Harvesting Sites

Sites	Species Richness	Shannon-Weiner index	Simpson index
Site 1	0	0	0
Site 2	2	0.69	1
Site 3	4	1.34	0.73
Site 4	1	0	0
Control 1	7	1.83	0.92
Control 2	7	1.74	0.82
Control 3	4	1.1	0.64

Low tree species richness in sand harvesting sites was attributed to cutting trees to create paths for the sand trucks, creating space for the stockpiles, as well as exposing sand among other sand harvesting activities. The findings were similar to the observations of Ako et. al (2014), that sand and gravel mining in the Luku region led to deforestation and loss of species. Whereas Kruskal-Wallis indicated overall differences in tree species richness ($p=0.047$), pairwise comparison did not, which was attributed to the narrow significance difference from the Kruskal-Wallis test, or the magnitude of the differences was not strong enough. Species diversity indices, Shannon-Weiner and Simpson diversity, indicated no statistically significant differences among the sites ($p>0.05$). The statistical insignificance of the Shannon-Weiner and Simpson indices calls for further research to understand the drivers of biodiversity loss and the best practices for restoration and conservation. The restoration and conservation effort set by the authorities should be community-centred since the nature of the disturbances is community-driven by the economic gains of the sand harvesting business. Long-term monitoring to assess the effectiveness of conservation strategies and adapt them as needed should also be utilised, as well as full enforcement of NEMA sand harvesting regulations. Species richness and species diversity for shrubs were comparatively higher in the undisturbed sites (Table 2).

Table 2: Shrubs Diversity for Sand Harvesting Sites

	Species Richness	Shannon-Weiner index	Simpson’s index
Site 1	2	0.41	0.76
Site 2	1	0	1
Site 3	2	0.69	0.5
Site 4	1	0	1
Control 1	3	1.09	0.34
Control 2	3	1.1	0.33
Control 3	1	0	1

Species richness and diversity of the shrubs were low for both sand harvesting sites and the undisturbed sites, with marginal observable differences in favour of the undisturbed sites, but not statistically significant ($p=0.14$ and $p=0.17$). Low species richness and diversity for shrubs in all the sites could not be attributed to any anthropogenic factors observable, suggesting this may have been induced by ecological or environmental factors. The observed similarity in species richness and diversity concurred with Gabrin *et al*. (2018) findings that resting a vegetation in Brazil had similar species composition between the sand mined and undisturbed sites, which he attributed to the spatial proximity of the two sites.

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Sand harvesting sites had similar herbaceous vegetation composition as undisturbed sites, and marginal differences in terms of richness, Shannon-Weiner, and Simpson indices between the sand harvesting sites and undisturbed sites (Table 3). The marginal difference in all herbaceous diversity indices was not statistically significant (P>0.05)

Table 3: Herbaceous Diversity for Sand Harvesting Sites

	Species Richness	Shannon-Weiner index	Simpson index
Site 1	1	0	0
Site 2	0	0	0
Site 3	2	0.6365	0.667
Site 4	2	0.6931	0.6
Control 1	2	0.6616	0.5357
Control 2	2	0.673	0.6
Control 3	3	0.7072	0.5014

Some sand harvesting sites had similar species diversity as the undisturbed sites, indicating the ecological similarity of the study area, which corroborates the findings of Gabrin *et al*. (2018) in Brazil that spatial proximity of the sand harvesting sites and undisturbed sites was a reason for similarity in species composition of the sites. Lack of observable and statistical differences in diversity of shrubs and herbaceous species also indicates that the shrubs and herbaceous species are highly adaptable to disturbances, and this should inform rehabilitation species that can be used. Needless to say that also further research on long-term disturbance effects on the herbaceous and shrub diversity would be recommended.

Saplings and seedling species richness and diversity were observed to be higher in sand harvesting sites, with the exception of site 1 (Table 4); nevertheless, the observed difference in species diversity was not statistically significant (p>0.5)

Table 4: Saplings and Seedling Diversity for Sand Harvesting Sites

Sites	Species Richness	Shannon-Weiner index	Simpson's index
Site 1	0	0	0
Site 2	5	1.34	0.32
Site 3	5	1.43	0.27
Site 4	3	0.83	0.5
Control 1	1	0	1
Control 2	8	1.99	0.15
Control 3	2	0.64	0.56

Although the saplings and seedlings richness and diversity were not statistically significant, the richness and diversity were observably high on sand harvesting sites as compared to the undisturbed sites. This was attributed to the fact that the undisturbed sites were composed of mature vegetation and hence very few saplings, and that the clearance of trees on the sand harvesting sites opened the habitat and the immediate prolonged wet season (El Niño) before the study, allowing regrowth of the seedlings. These finding coincides with Muñoz Mazón (2022), who found that open

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

low-altitude areas supported more regrowth of seedling and their survival. This indicated resilience of the habitat and ability to recover in the absence of disturbance, and adaptive management strategies can be implemented based on ongoing observations to support ecosystem recovery and engage communities to implement sustainable practices. The canopy cover and ground cover were higher in the undisturbed sites (Table 5).

Table 5: Canopy and Ground Cover for Sand Harvesting Sites

Sites	Canopy cover %	Ground cover %
Site 1	0	32
Site 2	1	3
Site 3	10	3
Site 4	3	30
Control 1	70	60
Control 2	30	90
Control 3	40	67

Canopy cover and ground cover were statistically significant (p=0.03 and p=0.03, respectively), and the Dunn test for post hoc analysis indicated that the undisturbed sites (1, 2, and 3) were statistically significantly different from sand harvesting sites 1, 2, 3, and 4. The low canopy cover is explained by the low tree species in the sand harvesting sites as a result of cutting the trees to create truck roads, sand storage sites, and other activities leading to habitat degradation. Low ground cover in sand harvesting sites was due to unbridled clearing of the vegetation, which exposes the soil to agents of erosion, especially in a fragile ecosystem like the riparian habitat. This also explains the land use and land cover results, which showed that the area under the river has been increasing as one of the contributing factors. These findings were corroborated by Oyoo (2021), who noted that land covers are destroyed to expose the topsoil, which is harvested as sand in riparian land in the Kisumu region. Ashraf *et al*. (2011) observed that sand harvesting in Malaysia leads to the complete removal of vegetation. He attributed the destruction of vegetation to heavy equipment and sand piles near extraction sites. Same observations were made by Kori & Mathada (2012) in South Africa and Mohammed *et al*. (2022) in Nigeria.

Sand harvesting has a strong negative impact on tree diversity. 53% of the variability in tree diversity was attributed to the impact of sand harvesting activities. For shrub diversity, sand harvesting activities had a weak negative impact, and 20% of the variability in shrub diversity was attributed to the impact of sand harvesting activities. Sand harvesting activities had a moderate negative impact on herbaceous diversity, which accounted for 34% of the variability. However, the sand harvesting activities had a weak positive impact on sapling and seedling diversity, accounting for 0.49% of the variability (Table 6). The correlations were nevertheless not statistically significant, and further research would need to be conducted to ascertain that the variabilities were not by chance.

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Table 6: Spearman Correlation Analysis for Sand Harvesting Sites

Type	ρ	ρ2	p-value
Tree diversity	-0.73	0.53	0.06
Shrub diversity	-0.45	0.20	0.31
Herbaceous diversity	-0.58	0.34	0.17
Seedlings and Sapling diversity	0.07	0.05	0.89

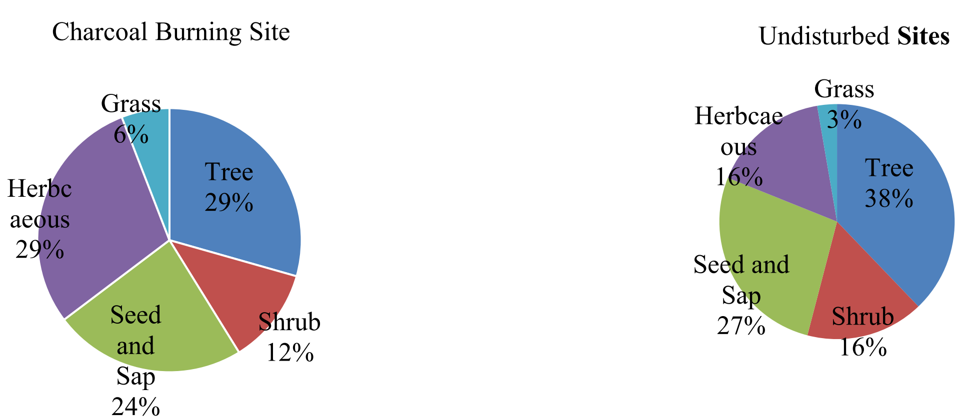
The strong negative correlation, although not statistically significant, suggests that tree diversity is likely impacted by disturbances. This could imply that disturbances such as sand harvesting significantly reduce tree diversity, potentially affecting ecosystem stability and services. The moderate negative correlations indicate that disturbances might also negatively affect shrub and herbaceous diversity, though the effects are less pronounced compared to trees. These plants might be more resilient or recover faster from disturbances. The very weak correlation suggests that seedlings and saplings are not significantly affected by disturbances. This could indicate a high potential for recovery and regeneration in disturbed sites, as young plants are still establishing themselves. Conduct long-term studies to observe changes over time. Future research should incorporate long-term monitoring and seasonal variations to help identify trends and long-term effects that might not be apparent in short-term studies.

Influence of Charcoal Burning on Riparian Vegetation Composition and Structure

Floristic Composition

In charcoal burning sites, herbaceous and tree species formed the highest composition with 29% (Figure 2a and b). These findings collaborates a study by Stephan *et al*., (2010) that noted post-fire recovery often leads to a higher percentage of herbaceous species compared to other vegetation type and a study by Masunga *et al*., (2013) in the Kalahari Sand System which found that fire and grazing significantly affected herbaceous plant species composition, with herbaceous species showing higher cover and biomass compared to other vegetation types.

Figure 2: (a) Charcoal Burning Sites **(b) Undisturbed Sites**



Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Species Diversity Analysis

Tree Species richness and diversity were high in control sites and moderate in abandoned charcoal sites (sites 2 and 3) (Table 7). However, the observed overall differences among the sites were not statistically significant (p>0.05)

Table 7: Tree Diversity for the Charcoal Burning Sites

	Species Richness	Shannon-Weiner index	Simpson index
Site 1	1	0	0
Site 2	6	0.64	0.28
Site 3	5	1.47	0.82
Site 4	1	0	0
Control 1	7	1.83	0.92
Control 2	7	1.74	0.89
Control 3	4	1.1	0.64

The low observable species richness, Shannon-Weiner, and Simpson index in charcoal burning sites was attributed to the logging of trees for charcoal production. These observations were in agreement with submissions of Kouami *et al*. (2009) that reported species richness and Shannon-Weiner index were higher in unexploited sites than in charcoal production sites in the zones of Sudanian and Guinean savanna Forests in Togo and with Kalema & Witkowski (2012) that reported low species richness and diversity in savanna woodlands of Nakasongola District Uganda was attributed to unsustainable harvesting of wood plant species for charcoal as well as study by Arnold and Persson (2003) in South Africa that found selective cutting cause depletion of preferred tree species. The overall significant differences in the Species richness, Shannon-Weiner, and Simpson index were in agreement with a study by Kiruki *et al*. (2017) in semi-arid areas in Kenya, which reported that low charcoal production does not have clear effects on the woodland diversity, structure, and density.

The abandoned charcoal-burning sites showed vegetation recovery, having high species richness and moderate Shannon-Weiner and Simpson indices, mostly from young trees. A concurrent finding by a study conducted in the Guánica Commonwealth Forest in Puerto Rico found that abandoned charcoal pits had a higher diversity of native tree species compared to active sites. The abandoned sites showed significant recovery with native species dominating the regrowth (Colón and Lugo 2006). Similarly, a study by Schmidt *et al*. (2016) in Hesse, Germany, found that abandoned charcoal kiln sites supported a more diverse range of young tree species, compared to active sites. Low tree diversity in active charcoal-burning sites was attributed to cutting down trees and burning them to produce charcoal, directly reducing tree diversity by removing trees and disrupting the habitat. This indicates that continued intense and frequent charcoal production will have detrimental implications for the riparian tree diversity and cover, with the possible outcome of desertification of the River Kathita habitat. The abandoned charcoal sites had moderate to high tree diversity, indicating a natural process of re-establishment of trees and succession after disturbance that allows for the re-establishment of tree species, indicating that in the absence of disturbances, these sites can gradually develop a tree community that is similar to undisturbed sites when there are favourable conditions for growth.

Diameter at breast height and the tree height among the sites were not statistically significant (p>0.05). Nonetheless, general observations showed the basal diameter for the active charcoal burning sites (1 and 3) was bigger than for the abandoned sites (2 and 3), though their height was similar. The basal diameter in charcoal burning sites ranged from a mean of 18-

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

105 as compared to 7-64 in undisturbed sites (Table 8).

Table 8: Basal Diameter and Height for Charcoal Burning Sites

	DBH	Height
Site 1	105	5
Site 2	18.3	5.06
Site 3	24.82	4.59
Site 4	80	20
Control 1	64.4	8.39
Control 2	12.8	3.875
Control 3	7.75	6.25

Trees in charcoal-burning sites had an observable large basal diameter and short height, which indicated disturbances that hindered optimal growing conditions. A study by Sapkota *et al*. (2019) in Nepal attributed anthropogenic disturbances to the shift in average DBH of trees to medium and large-sized trees, suggesting a reduction in the forest population structure. Similarly, Aabeyir *et al*. (2020) in Ghana observed that in charcoal-disturbed sites, the trees had a large basal area and short height because the larger trees are harvested for charcoal, and the remaining trees, which are often suppressed or younger, do not grow as tall. The observed large DBH and short height indicated a change in the tree attributes and structure due to charcoal burning disturbance. This was in agreement with a study by Sapkota *et al*. (2019) in Nepal that attributed anthropogenic disturbances to the shift in average DBH of trees to medium and large-sized trees in the disturbed sites, indicating declining forest population structure and resulting in mid-sized and mature trees. Trees that had larger basal diameter were in active charcoal burning sites which indicated that they were preferred for selective logging for the purposes of charcoal production which was in agreement with a study in Ghana that found that trees used for charcoal often had larger DBH but were shorter in height compared to those in undisturbed areas (Aabeyir *et al*., 2020) due to selective harvesting practices that target larger diameter trees.

There was a marginal observable difference in shrub diversity (Table 9) that was statistically insignificant ($p>0.05$) in charcoal burning sites, as compared to undisturbed sites, which was attributed to the ability of shrub species to adapt and recover after disturbances. Concurring findings by Jones *et al*., (2023) in the USA observed that shrub density and diversity did not differ in fire sites versus undisturbed sites and indicated that native shrub cover can recover in the long term, making the shrub communities in burned sites similar to those in undisturbed sites. Similarly, a study by Smith et al. (2019) found that shrub cover in burned sites can recover to levels similar to undisturbed sites over time, depending on factors like precipitation and fire frequency.

Table 9: Shrub Diversity for Charcoal Burning Sites

	Species Richness	Shannon-Weiner index	Simpson index
Site 1	1	0	0
Site 2	2	0.69	1
Site 3	0	0	0
Site 4	2	0.67	0.03
Control 1	3	1.09	0.73
Control 2	3	1.1	1
Control 3	1	0	0

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Sapling and seedling species richness and diversity were high in abandoned charcoal sites and control site 2 (Table 10).

Table 10: Seedling and Saplings Diversity

	Species Richness	Shannon-Weiner index	Simpson index
Site 1	0	0	0
Site 2	4	1.22	0.75
Site 3	5	1.61	1
Site 4	1	0	0
Control 1	1	0	0
Control 2	8	1.99	0.92
Control 3	2	0.64	0.67

In charcoal-burning sites, abandoned charcoal-burning sites had high species richness, indicating the ability to recover in the absence of the disturbances. The observed ability of abandoned charcoal-burning sites to recover concurred with a study by Ndegwa *et al*. (2016) in Mutoma, which reported that there were comparably high sapling species richness and density in disturbed woodlands in charcoal-burning areas, displaying the potential of the woodland vegetation to recover. Similar observations were made by Vieira *et al*. (2006) that recently cut and cleared dry forests of Central America, where regeneration rapidly restored the number of species on a given site. Identical observations have been made by Aguilar *et al*. (2012) in Mexico and in Kenya (Okello *et al*., 2001), with variations in recovery period. Additionally, these findings of the vegetation resilience and the ability of abandoned sites to recover suggest that ecosystems can bounce back if given time and protection. The seedlings and saplings were observed to be mostly from *Acacia* species, which were native species. The observable differences in seedling and sapling diversity among the sites were, however, not statistically significant (p>0.05). Hence, the study recommends further long-term research to track the observed changes in seedling and sapling diversity.

Herbaceous species richness is higher compared to grasses in charcoal burning sites and the undisturbed sites (Table 11). The charcoal-burning sites had similar herbaceous and grass species as the undisturbed sites. There was no statistical significance difference among the sites (p>0.05) for both the herbaceous and grass species.

Table 11: Herbaceous and Grass Diversity for Charcoal Burning Sites

Herbaceous				Grasses			
	Species Richness	Shannon-Weiner index	Simpson index		Species Richness	Shannon-Weiner index	Simpson index
Site 1	2	0.56	0.43	Site 1	2	0.07	0.03
Site 2	2	0.64	0.67	Site 2	0	0	0
Site 3	8	1.53	0.71	Site 3	0	0	0
Site 4	0	0	0	Site 4	1	0	0
Control 1	2	0.66	0.53	Control 1	0	0	0
Control 2	2	0.67	0.6	Control 2	1	0	0
Control 3	3	0.71	0.50	Control 3	0	0	0

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

While herbaceous species showed resilience across multiple sites, the study also observed that the role of fire is shaping the vegetation community. The density of the herbaceous species in charcoal burning sites was higher compared to the sand harvesting sites, and additionally, the grass species. The observed pattern concurred with a study by Spicer *et al*. (2022), which explored patterns of herbaceous diversity in forest ecosystems and highlighted the role of disturbances in shaping plant communities. It noted that disturbances, including fire, can create conditions that promote herbaceous diversity. The findings were also in agreement with a study by Vachova *et al*. (2021) in the Czech Republic that investigated plant diversity in different forest types and found that disturbances lead to increased herbaceous diversity

Charcoal burning activities had a strong negative impact on tree diversity, accounting for 53% of the variability; however, it was not statistically significant. Charcoal burning activities had a weak negative impact on shrub diversity. A 20% of the total variability in shrub diversity was attributed to the impact of sand harvesting activities. Charcoal burning activities had a moderate, negative impact on herbaceous diversity, which accounted for 18.49% of the total variability of herbaceous diversity in the sites. Charcoal burning activities had a weak negative impact on sapling and seedling diversity, accounting for 2.25% variability of sapling and seedling diversity in the sites (Table 12).

Table 12: Charcoal Burning Correlation for Vegetation Diversity

Vegetation type	ρ	ρ2	p-value
Tree diversity	-0.73	0.53	0.06
Shrub diversity	-0.45	0.2	0.31
Herbaceous diversity	-0.43	0.19	0.31
Seedlings and Sapling diversity	-0.15	0.02	0.75

The strong negative correlation indicates that tree diversity, seedlings and saplings diversity was impacted by livestock overgrazing and trampling in the drinking bays. Charcoal burning disturbances greatly affect the diversity of trees in the riparian habitat. The moderate negative correlations for the shrub and herbaceous diversity indicate that disturbances also negatively affect shrub and herbaceous diversity, although not as profound as the tree diversity, indicating that they might be more resilient or quicker to recover from the disturbances than the trees. This should inform decision makers on the enforcement measures and regulations on charcoal production. The very weak correlation suggests that seedlings and saplings are not significantly affected by disturbances, or the sites have high potential for recovery. Further research to investigate these relationships of longer term and comparison with the riparian habitats with similar disturbances in the area is recommended.

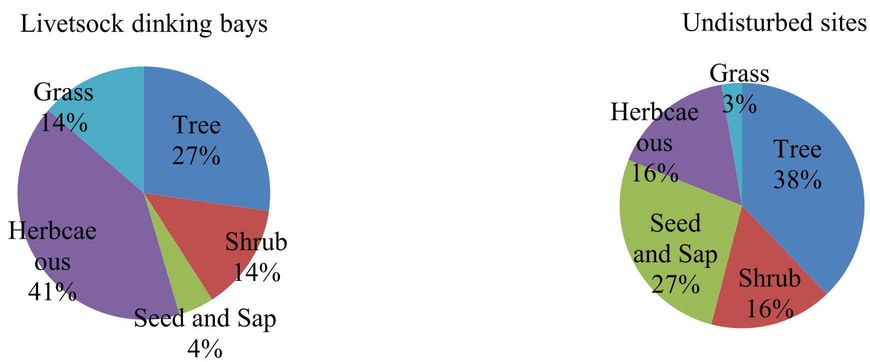
Influence of Livestock Drinking Bays on Riparian Vegetation Diversity

Floristic Composition

Herbaceous species was the highest with 41% in charcoal burning sites (Figure 3a and b). Concurring studies by Okach et al. (2019) in a humid savanna found that in grazing areas, herbaceous cover often exceeded 45% during peak growing seasons. Similarly, Abebe et al. (2024) in the Simien Mountains, Ethiopia, found that herbaceous species cover was higher in grazed areas compared to ungrazed areas.

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Figure 3: (a) Livestock Drinking Bays (B) Undisturbed Sites



Species Diversity Analysis

Livestock drinking bays' tree species richness and diversity was considerably lower compared to control sites (Table 13). Observable differences in tree diversity and richness was, however, not statistically significant (p>0.05). A study by Kauffman *et al*. (2022) in the USA similarly found that riparian vegetation species richness and diversity was higher in the ungrazed reaches as compared to the grazed reaches. The findings also concurred with a study by Schulz *et al*. (2019) that found that grazing at high intensities significantly reduced almost all measures of alpha and beta diversity in the tree layers.

Table 13: Trees' Diversity for Livestock Drinking Bays

	Species Richness	Shannon-Weiner index	Simpson index
Site 1	1	0	0
Site 2	3	1.1	1
Site 3	3	1.1	1
Site 4	1	0	0
Site 5	1	0	0
Control 1	7	1.83	0.92
Control 2	7	1.74	0.82
Control 3	4	1.1	0.64

A study by Mathewos and Berhanu (2023) in Ethiopia also found that tree species richness and diversity were significantly reduced by grazing. The study observed that grazing intensity influenced the tree species diversity, with livestock drinking bays 2 and 3 that had fewer livestock signs in the bays differing marginal from the ones that had more observed signs of livestock. The more the intensity, the less diverse the site was. This was attributed to the intensity of grazing and trampling that have a deleterious effect on young trees. The mixed grazing of the livestock from goats, sheep and cattle was also attributed to the fact that they feed on a variety of vegetation species, hence exacerbating the effect. Similar observations (Török 2024) found that the impact of grazing on vegetation, including tree diversity, was dependent on the type of herbivore, grazing intensity, and the specific vegetation.

There was only 1 sapling recorded in all 5 livestock drinking bays, which indicated that grazing and trampling in livestock drinking bays was detrimental to the establishment of seedlings and

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

growth of the saplings. A meta-analysis by Wadud *et al*. (2024) on livestock effects in oak agroforestry systems revealed that livestock, particularly smaller animals like sheep and goats, significantly hindered oak regeneration and establishment. This finding is consistent with the types of livestock observed in the study area. It is therefore crucial to develop effective grazing management and integrate indigenous and traditional ecological knowledge to enhance sustainable grazing management with an understanding of local socio-economic contexts to improve grazing practices.

Shrub species richness and diversity was marginally lower in livestock drinking bays compared to the undisturbed sites (Table 14), and the marginal difference was subsequently not statistically significant ($p>0.05$).

Table 14: Shrub's Diversity for Livestock Drinking Bays

Sites	Species Richness	Shannon-Weiner index	Simpson index
Site 1	2	0.69	1
Site 2	0	0	0
Site 3	1	0	0
Site 4	0	0	0
Site 5	2	0.41	0.29
Control 1	3	1.09	0.73
Control 2	3	1.1	1
Control 3	1	0	0

Marginal observable differences in shrub richness, Shannon-Weiner and Simpson indices in all sites suggest that the shrubs are more tolerant to disturbances. Concurrent observations by Díaz-Perea *et al* (2014) on the key attributes to the disturbance response of montane cloud forest trees indicated that shrubs often possess specific regeneration traits that make them more resilient to disturbances, such as fire and land use changes, compared to other plant types. The resilience traits of shrubs to disturbances was observed in all three disturbance sites for sand harvesting, charcoal burning and livestock drinking bays, similar to the herbaceous vegetation.

However, in livestock drinking bays, unlike the other two types of disturbances, herbaceous species were more dominant than the other vegetation species, that is, trees, shrubs, grasses, seedlings and saplings in drinking bays as well as in other disturbance sites (Table 15).

Table 15: Herbaceous Species Richness for Livestock Drinking Bays

Sites	Herbaceous Richness	Tree Richness	Shrub Richness
Site 1	1	1	2
Site 2	5	3	0
Site 3	3	3	1
Site 4	3	1	0
Site 5	2	1	2
Mean	**2.8**	**1.8**	**1**

This indicated a shift in dominance from grasses, shrubs and trees to other herbaceous species in livestock drinking bays suggest that grazing pressure and trampling was detrimental to trees, saplings, seedlings grasses and shrubs and it inhabited their growth. Comparably, Gebremedhn

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

et al. (2023) in Sahel discovered that with increasing grazing pressure, the plant species composition shifted from being dominated by grass cover to being dominated by forb cover. Similarly, Chaichi *et al*. (2005) in Iran found that grazing over the years had an increase in broad-leaf herbs as compared to grass. Additionally, experimental studies of grazing on grasslands found that grazing significantly reduced biodiversity and multifunctionality in more arid steppes. This reduction was associated with a shift towards herbaceous vegetation, particularly in areas with higher aridity (Zhang *et al*., 2023). Concurrent findings by Kariuki (2010) in Laikipia, Kenya, indicated that grazing influenced the community species composition to a certain extent. Shift in vegetation type and dominance of invasive shrubs suggest that there is a need to initiate effective management practices, such as rotational drinking bays, in order to maintain the ecological integrity of the riparian habitats

Ground cover in livestock drinking bays varied with the grazing intensity and presence of invasive shrubs, while the canopy cover was lower than in the control sites (Table 16). In livestock drinking bays, grass species accounted for most of the ground cover, while the canopy cover was accounted for by the mature trees used as cattle shade.

Table 16: Canopy and Ground Cover for Livestock Drinking Bays

Site	Canopy cover %	Ground cover %
Site 1	0	13
Site 2	20	70
Site 3	25	36
Site 4	1	70
Site 5	1	22
Control 1	70	60
Control 2	30	90
Control 3	40	67

Overall, canopy cover and ground cover in livestock drinking bays was lower than in undisturbed sites. These results were corroborated by Smith *et al*. (2012), who reported that visual estimates of ground cover in the Midlands region showed that grazing resulted in a reduction of ground cover, increasing the bare grounds and changing the plant species composition. This was also supported by a study by Xu *et al*. (2014) in Northern China that found that increased grazing intensity decreased vegetation height, affecting canopy cover, and it reduced plant species abundance, affecting above-ground biomass. The observed low % ground cover in livestock drinking bays also concurred with the finding of Chaichi *et al*. (2005) that in Iran, ground cover decreased from 38 to 9.5% at the end of the grazing period and with Bellows (2003), who reported that grazing in America's coastal regions led to a decrease in herbage cover. Despite the observable difference in ground cover and canopy cover, which showed that undisturbed sites had higher ground and canopy cover, they were not statistically significant($P>0.05$)

Livestock drinking bays had a strong negative impact on tree diversity. 75.69% of the variability in tree diversity was attributed to the impact of cattle drinking bays, and the variance was statistically significant. For shrub diversity, livestock drinking bays had a moderate negative correlation. They accounted for 23% of the variability in shrub diversity. The drinking bays had a strong negative impact on sapling and seedling diversity, accounting for 54.76% of the variability in seedling and sapling diversity. This variability was statistically significant. There was a weak negative correlation between livestock drinking bays and

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

herbaceous diversity, accounting for 2.89% of the variability in herbaceous diversity in the sites (Table 17).

Table 17: Spearman Correlation for Livestock Drinking Bays

Type	P	ρ2	p-value
Tree diversity	-0.87	0.76	0.005*
Shrub diversity	-0.48	0.23	0.23
Herbaceous diversity	-0.74	0.55	0.04
Seedlings and Sapling diversity	-0.17	0.03	0.69

The strong negative correlation indicated that tree diversity was impacted by livestock disturbances on the drinking bays. Livestock overgrazing and trampling in drinking bays greatly reduced tree diversity, seedling and sapling diversity and can lead to decreased habitat complexity, affecting species that rely on trees for food and shelter and hindering vegetation reestablishment and regeneration. The moderate negative correlations for the shrub diversity, as seen in other disturbance types, indicate that they might be more resilient or quick to recover from the disturbances than other species. The overall significant negative correlations for tree and herbaceous diversity highlight the critical impact of disturbances on these vegetation types. In addition to effective management strategies such as rotational drinking bays, education of the community on alternative sources of livelihood may lift the livestock pressure on the riparian habitat. Further experimental research on the rotational drinking bays would be recommended to study the effectiveness of this suggestion as an ecological control measure.

SUMMARY AND CONCLUSION

Summary

Vegetation data analysis revealed that the selected anthropogenic disturbances had a negative impact on vegetation composition, structure, diversity and density. Sand harvesting sites had low tree and shrub species richness and diversity as compared to undisturbed sites. Sand harvesting activities had a strong negative impact on tree diversity, accounting for 53% of the variability in tree diversity, a moderate negative effect on shrub and herbaceous diversity, accounting for 20% and 34% of the variability, respectively. Sand harvesting activities had a weak positive impact on sapling and seedling diversity, accounting for 0.49% of the variability. Charcoal burning activities had a strong negative impact on tree diversity, accounting for 53% of the variability, a moderate negative effect on shrub and herbaceous diversity, accounting for 20% and 18.49% respectively of the variability. Overgrazing and trampling in livestock drinking bays had a strong negative impact on tree diversity, accounting for 75.69% of the variability, a moderate negative impact on seedling, sapling and shrub diversity, with the overgrazing and trampling on livestock drinking bays accounting for 54.76% and 23% respectively of the variability.

Conclusion

Anthropogenic disturbances had a negative impact on vegetation diversity. Although all the disturbances had deleterious effects on vegetation diversity, in all, shrubs and herbaceous species showed trends of tolerance than other species. In sand harvesting sites and charcoal burning sites, there was high seedling and saplings for the abandoned sites, indicating the resilience of the habitat and ability to recover and reestablish in the absence of disturbances and with protection. However, in livestock drinking bays, the study did not record the presence of saplings and seedlings. Indicating that grazing and trampling in livestock drinking bays was detrimental to the establishment

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

of seedlings and growth of the saplings. The study instead observed a shift in dominance of herbs and other herbaceous species from grasses and shrubs in the livestock drinking bays.

Suggestion for Further Research

The study suggests further research on:

- Long-term research on the identified anthropogenic disturbances to monitor their effect on vegetation variability
- Research on how climate change may exacerbate riparian vegetation degradation, using precise climate and hydrological data

REFERENCES

Aabeyir, R., Adu-Bredu, S., Agyare, W. A., & Weir, M. J. (2020). Allometric models for estimating aboveground biomass in the tropical woodlands of Ghana, West Africa. *Forest Ecosystems, 7*(1), 1-23. https://doi.org/10.1186/s40663-020-00234-9

Abebe, B., Ashagrie, M., & Eshete, G. (2024). Effects of livestock grazing on herbaceous species composition and biomass in the Simien Mountains National Park, Ethiopia. Israel Journal of Ecology and Evolution. https://doi.org/10.1163/22244662-bja10087

Ako, T. A., Onoduku, U. S., Oke, S. A., Essien, B. I., Idris, F. N., Umar, A. N., & Ahmed, A. A. (2014). Environmental effects of sand and gravel mining on land and soil in Luku, Minna, Niger State, North Central Nigeria.

Ashraf, M. A., Maah, M. J., Yusoff, I., Wajid, A., & Mahmood, K. (2011). Sand mining effects, causes and concerns: A case study from Bestari Jaya, Selangor, Peninsular Malaysia. Scientific Research and Essays, 6(6), 1216-1231.

Bellows, B. C. (2003). Managed grazing in riparian areas. ATTRA.

Chaichi, M. R., Saravi, M. M., & Malekian, A. R. A. S. H. (2005). Effects of livestock trampling on soil physical properties and vegetation cover (case study: Lar Rangeland, Iran). Int. J. Agric. Biol, 7, 904-908.

Colón, S. M., & Lugo, A. E. (2006). Recovery of a subtropical dry forest after abandonment of different land uses. *Biotropica: The Journal of Biology and Conservation, 38*(3), 354-364. https://doi.org/10.1111/j.1744-7429.2006.00158.x

Dharani, N. (2011). *Field guide to common trees & shrubs of East Africa*. Penguin Random House South Africa.

FAO. (2010). What Woodfuels Can Do to Mitigate Climate Change. FAO Forestry Paper 162. Rome, Italy: Food and Agriculture Organization of the UN.

Garbin, M. L., Misaki, F., Ferreira, P. F., Guidoni-Martins, K. G., Soares, R. B., Mariotte, P., & Silva, A. G. (2018). Long-term regeneration of a tropical plant community after sand mining. *Ecology and Evolution, 8*(11), 5712-5723. https://doi.org/10.1002/ece3.4127

Gebremedhn, H. H., Ndiaye, O., Mensah, S., Fassinou, C., Taugourdeau, S., Tagesson, T., & Salgado, P. (2023). Grazing effects on vegetation dynamics in the savannah ecosystems of the Sahel. *Ecological Processes, 12*(1), 54. https://doi.org/10.1186/s13717-023-00454-9

Jones, A. M., Kane, J. M., Engber, E. A., Martorano, C. A., & Gibson, J. (2023). Extreme wildfire supersedes long-term fuel treatment influences on fuel and vegetation in chaparral ecosystems of northern California, USA. *Fire Ecology, 19*(1), 28. https://doi.org/10.1186/s42408-023-00128-9

Kalema, V. N., & Witkowski, E. T. F. (2012). Land-use impacts on woody plant density and

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

diversity in an African savanna charcoal production region. *International Journal of Biodiversity Science, Ecosystem Services & Management, 8*(3), 231–247. https://doi.org/10.1080/21513732.2012.681070

Kariuki, P. M. (2002). An assessment of impact of charcoal making on distribution of some tree species in Kibwezi Division (Master's thesis, Kenyatta University). Retrieved from Kenyatta University Repository.

Kershner, J. L., Archer, E. K., Coles-Ritchie, M., Cowley, E. R., Henderson, R. C., Kratz, K., Quimby, C. M., Turner, D. L., Ulmer, L. C., & Vinson, M. R. (2004). Guide to effective monitoring of aquatic and riparian resources (Gen. Tech. Rep. RMRS-GTR-121). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-GTR-121

Kirema, M. M. (2020). Effects of land use changes on Thanantu River, Tharaka North Sub County, Tharaka-Nithi County.

Kiruki, H. M., van der Zanden, E. H., Gikuma-Njuru, P., & Verburg, P. H. (2017). The effect of charcoal production and other land uses on diversity, structure and regeneration of woodlands in a semi-arid area in Kenya. *Forest Ecology and Management, 391*, 282-295. https://doi.org/10.1016/j.foreco.2017.02.022

Kondolf, G. M., Piégay, H., & Landon, N. (2007). Changes in the riparian zone of the lower Eygues River, France, since 1830. *Landscape Ecology*, *22*(3), 367-384.

Kori, E., & Mathada, H. (2012). An assessment of environmental impacts of sand and gravel mining in Nzhelele Valley, Limpopo Province, South Africa. In *3rd international conference on biology, environment and chemistry. IACSIT Press, Singapore* (Vol. 46, No. 29, pp. 137-141).

Kouami, K., Yaovi, N., & Honan, A. (2009). Impact of charcoal production on woody plant species in West Africa: A case study in Togo. *Scientific Research and Essay, 4*(9), 881-893.

Kyalo, W. D. (2009). Impact of policy and socioeconomic factors on spatial distribution of livestock production systems in River Njoro Watershed, Kenya (Doctoral dissertation, Egerton University). Retrieved from Egerton University Repository.

Majumdar, A., & Avishek, K. (2023). Riparian zone assessment and management: An integrated review using geospatial technology. Water, Air, & Soil Pollution, 234(5), 319. https://doi.org/10.1007/s11270-023-06329-1

Malimbwi, R. E., Zahabu, E., Monela, G. C., Misana, S., Jambiya, G. C., & Mchome, B. (2005). Charcoal potential of miombo woodlands at Kitulangalo, Tanzania. Journal of Tropical Forest Science, 197-210.

Masunga, G. S., Moe, S. R., & Pelekekae, B. (2013). Fire and Grazing Change Herbaceous Species Composition and Reduce Beta Diversity in the Kalahari Sand System. Ecosystems, 16(2), 252-268. https://doi.org/10.1007/s10021-012-9611-6

Mathewos, M., Sisay, A., & Berhanu, Y. (2023). Grazing intensity effects on rangeland condition and tree diversity in Afar, northeastern Ethiopia. *Heliyon, 9*(11). https://doi.org/10.1016/j.heliyon.2023.e12345

Maundu, P., Ngugi, G., & Karanja, N. (2005). *Useful trees and shrubs of Kenya*. World Agroforestry Centre.

Mohammed, I. B., Okechuku, M., & Okindele, M. D. (2022). Environmental Impact of Sand Harvesting in Niger State, Nigeria. African Journal of Emerging Issues, 4(1), 18-26.

Muñoz Mazón, M., Klanderud, K., & Sheil, D. (2022). Canopy openness modifies tree seedling distributions along a tropical forest elevation gradient. *Oikos, 2022*(11), e09205. https://doi.org/10.1111/oik.09205

Musau, E. M., Mukiri, J., Nzogela, B., Paul, B. K., & Notenbaert, A. M. O. (2021). Assessing the environmental impacts of smallholder dairy intensification through improved feeding strategies in the Southern Highlands of Tanzania. Agricultural Systems, 191, 103137. https://doi.org/10.1016/j.agsy.2021.103137

Nasare, L. I., Opoku, S. A., Amponsah, A., Tom-Dery, D., Asante, W. J., & Baatuuwie, B. N. (2023). Effect of sand mining on riparian landcover transformation in Dallung-Kukou catchment of the White Volta basin, Ghana. *Heliyon, 9*(8). https://doi.org/10.1016/j.heliyon.2023.e12345

Ndegwa, G. M., Nehren, U., Grüninger, F., Iiyama, M., & Anhuf, D. (2016). Charcoal production through selective logging leads to degradation of dry woodlands: A case study from Mutomo District, Kenya. *Journal of Arid Land, 8*, 618-631. https://doi.org/10.1007/s40333-016-0045-9.

Okach, D. O., Ondier, J. O., Rambold, G., Tenhunen, J., Huwe, B., Jung, E. Y., & Otieno, D. O. (2019). Interaction of livestock grazing and rainfall manipulation enhances herbaceous species diversity and aboveground biomass in a humid savanna. Journal of Plant Research, 132(3), 345-358. https://doi.org/10.1007/s10265-019-01105-x

Oyoo, E. (2021). Sustainable Moderation of Sand Harvesting Effects and Conservation on Land Cover, Flora and Fauna along the Riparian Land. http://repository.rongovarsity.ac.ke/handle/123456789/2302

Sapkota, R. P., Stahl, P. D., & Norton, U. (2019). Anthropogenic disturbances shift diameter distribution of woody plant species in Shorea robusta Gaertn.(Sal) mixed forests of Nepal. Journal of Asia-Pacific Biodiversity, 12(1), 115-128.sap

Schmidt, M., Mölder, A., Schönfelder, E., Engel, F., & Fortmann-Valtink, W. (2016). Charcoal kiln sites, associated landscape attributes and historic forest conditions: DTM-based investigations in Hesse (Germany). *Forest Ecosystems, 3*, 1-16. https://doi.org/10.1186/s40663-016-0071-1

Schulz, K., Guschal, M., Kowarik, I., Silva de Almeida-Cortez, J., Valadares de Sá Barreto Sampaio, E., & Cierjacks, A. (2019). Grazing reduces plant species diversity of Caatinga dry forests in northeastern Brazil. *Applied Vegetation Science, 22*(2), 348-359. https://doi.org/10.1111/avsc.12434

Smith, A. G., Newingham, B. A., Hudak, A. T., & Bright, B. C. (2019). Got shrubs? Precipitation mediates long-term shrub and introduced grass dynamics in chaparral communities after fire. *Fire Ecology, 15*, 1-16. https://doi.org/10.1186/s42408-019-0034-5

Smith, R. W., Statham, M., Norton, T. W., Rawnsley, R. P., Statham, H. L., Gracie, A. J., & Donaghy, D. J. (2012). Effects of wildlife grazing on the production, ground cover and plant species composition of an established perennial pasture in the Midlands region, Tasmania. *Wildlife Research, 39*(2), 123-136. https://doi.org/10.1071/WR11120

Spicer, M. E., Radhamoni, H. V. N., Duguid, M. C., Queenborough, S. A., & Comita, L. S. (2022). Herbaceous plant diversity in forest ecosystems: Patterns, mechanisms, and threats. *Plant Ecology, 223*(2), 117-129. https://doi.org/10.1007/s11258-022-01200-5

Stephan, K., Miller, M., & Dickinson, M. B. (2010). First-Order Fire Effects on Herbs and Shrubs: Present Knowledge and Process Modeling

Article DOI: https://doi.org/10.37284/eajenr.8.3.3691

Needs. Fire Ecology, 6(1), 95-114. https://doi.org/10.4996/fireecology.0601095

Török, P., Lindborg, R., Eldridge, D., & Pakeman, R. (2024). Grazing effects on vegetation: Biodiversity, management, and restoration. *Applied Vegetation Science, 27*(3), e12794. https://doi.org/10.1111/avsc.12794

Wadud, A. I., Bugalho, M. N., & Vaz, P. G. (2024). Meta-analysis of livestock effects on tree regeneration in oak agroforestry systems. *Journal of Environmental Management, 364*, 121498. https://doi.org/10.1016/j.jenvman.2023.121498

Xu, M. Y., Xie, F., & Wang, K. (2014). Response of vegetation and soil carbon and nitrogen storage to grazing intensity in semi-arid grasslands in the agro-pastoral zone of northern China. *PLoS One, 9*(5), e96604. https://doi.org/10.1371/journal.pone.0096604

Zhang, L., Liu, W., & Ma, Y. (2020). Effects of meteorology and soil on the herb species diversity in plantations in a reclamation area of coal mine after 6 years. Journal of Environmental Management, 264, 110455. https://doi.org/10.1016/j.jenvman.2020.110455

Zhang, M., Delgado-Baquerizo, M., Li, G., Isbell, F., Wang, Y., Hautier, Y., & Wang, L. (2023). Experimental impacts of grazing on grassland biodiversity and function are explained by aridity. *Nature Communications, 14*(1), 5040. https://doi.org/10.1038/s41467-023-50640-5

Zhao, Y., Zhang, P., Hu, Y., & Huang, L. (2015). Effects of Re-vegetation on Herbaceous Species Composition and Biological Soil Crusts Development in a Coal Mine Dumping Site. Environmental Management, 57(2), 298-307. https://doi.org/10.1007/s00267-015-0607-91

