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Original Research Article

The Influence of Area of Vegetation Cleared for Artisanal Gold Mining on Higher Plants Species Richness and Abundance in River Yala Middle Basin Kenya

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Abstract: Artisanal gold mining has expanded rapidly across many river basins globally with significant implications for water resources and local livelihoods. This study interrogated the influence of the area of vegetation cleared for artisanal gold mining on higher plants species richness and abundance in River Yala middle basin using a cross sectional descriptive research design, spatial measurements of area of vegetation cleared for 321 plots where artisanal gold mining is practiced were quantified and analysed alongside the total number of different higher plants species and the total number of higher plants species. A household questionnaire was used to obtain information on the names of higher plants species found in plots cleared of vegetation for artisanal gold mining. Regression analysis was employed to determine the strength and significance of relationship between area of vegetation cleared for artisanal gold mining and higher plants species richness and abundance. The findings demonstrated a strong statistically significant relationship between the area of vegetation cleared for artisanal gold mining and higher plants species richness and abundance. The results showed that; 74 %, $r^2 = 0.74$, $p < 0.05$, of variation in higher plants species richness and 61 %, $r^2 = 0.61$, $p < 0.05$ of variation in higher plants species abundance can be explained by the area of vegetation cleared for AGM. This results revealed that, ecologically sensitive native species such as *Prunus Africana* (0.8 %), *Cordia africana* (1.1 %), *Khaya anthotheca* (1.4 %), *Syzygium cordatum* 0.5 %and *Diospyros abyssinica* 1 % were rare or absent in plots with vegetation cleared for AGM. Pioneer and exotic species such as *Eucalyptus camaldulensis (16 %), Grevillea robusta* (11 %) and *Mangifera indica 6.8 %* dominated areas of cleared vegetation due to; agroforestry practices, fast regeneration, growth and tolerance. Whereas plots cleared of vegetation for artisanal gold mining exhibited lower species richness and abundance of indigenious trees such as *Markhamia lutea* 3 %, *Croton macrostachyu 1.2* %, *Albizia coriaria 0.8* % *and Ficus exasporata 0.5* %, this therefore reinforces need for integrated basin resource management strategies to safeguard biodiverty in artisanal gold mining areas.

Keywords: Higher Plants Species, Higher Plants Species Richness, Higher Plants Species Abundance, Area of Vegetation Cleared for Artisanal Gold Mining.

INTRODUCTION

Artisanal gold mining practices are greatly increasing alongside gold mining which is gaining popularity as a source of livelihoods for 40.5 million people worldwide (Morgane., 2018). Globally 87 % of the riparian vegetation has been destroyed mainly in the 21st century through AGM mining practices (Davidson., 2014). De Souse *et al.,* (2018) elucidated that in Peru Amazon basin, even decades after abandonment vegetation in gold mined areas had not recovered.

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Habitat fragmentation through deforestation from mining areas causing a loss of biodiversity among animals and plants globally. (Arya., 2021; Chakaraborty *et al*., 2021). allude to the fact that, the most significant causes to species extinction are habitat loss induced by deforestation, climate change and exotic species invasions. Velga., (2022) connotes that mining sites had significantly lower biomass and plant cover. The critical environmental issues above have linked deforestation to habitat destruction, vegetation structure and loss in biodiversity an ecological perspective. This therefore limits on how the area of vegetation cleared for AGM a quantifiable spatial metric relates to changes in higher plants species richness and abundance. This therefore gave the current study a lee way to interrogate the influence of area of vegetation cleared foe AGM on higher plants species richness and abundance.

Riparian vegetation loss practices such as deforestation in mining areas, urbanization and agricultural practices along the stream edges have been reducing complex natural forested riparian cover into bare riparian zones hence destroying habitats that support aquatic biota (Huchett, 2010). Vegetation loss through mining operation leads to destructions of habitats that support a rich biodiversity (Sonter *et al.,* 2017). Torello, and Zanini, (2019) posits that, riparian vegetation loss through AGM leads to decreased entry of woody debris and silting of the channel which leads to the loss of macro and micro habitats and consequently as alluded by Chang (2022), this leads to the reduction of environmental heterogeneity on a stream scale. AGM has destroyed more than 2000000 acres of primary rainforest in the Peruvian Amazon in the past decade leading to the loss of forest biodiversity. Vegetation loss associated to AGM in the Ecuadorian Amazon is more prone to serious irreversible damage to the environment which has serious effects on biodiversity in riparian areas (Carioes *et al., 2022*). These studies emphasize on biodiversity loss induced by vegetation clearance in mining areas on a global scale, little has been explored on linking area of vegetation cleared in AGM areas on higher plants species on a regional scale.

Riparian vegetation loss practices such as deforestation in mining areas, urbanization and agricultural practices along the stream edges have been reducing complex natural forested riparian cover into bare riparian zones hence destroying habitats that support aquatic biota (Huchett, 2010). Vegetation loss through mining operation leads to destructions of habitats that support a rich biodiversity (Sonter *et al.,* 2017). Torello, and Zanini, (2019) posits that, riparian vegetation loss through AGM leads to decreased entry of woody debris and silting of the channel which leads to the loss of macro and micro habitats and consequently as alluded by Chang (2022), this leads to the reduction of environmental heterogeneity on a stream scale. Vegetation loss associated to AGM in the Ecuadorian Amazon is more prone to serious irreversible damage to the environment which has serious effects on biodiversity in riparian areas (Carioes *et al., 2022*). These studies emphasize on biodiversity loss induced by vegetation clearance in mining areas on a global scale, little has been explored on linking area of vegetation cleared in AGM areas on higher plants species on a regional scale.

African case studies show consistent declines in plant biodiversity at mining sites compared to undisturbed areas. Significantly higher woody plants species richness and diversity in undisturbed forest than in artisanal gold mining sites has been alluded to in Burkina Faso showing that control sites averaged 59 species and mined sites averaged 38 (Kouame *et al*., 2024). In Ghana Abugre *et al*., (2025) resonates that Oda River Forest Reserve expansion of illegal mining correlated with substantial forest cover loss of nearly 6 decline over five years with decline in plant soecies diversity and complete vegetation absence in heavily mined zones. These findings collectively underline the negative directional trend between AGM intensity and vegetation biodiversity at local scale, but few regional studies systematically investigate how area of vegetation cleared for AGM influence on species richness and abundance gradients across landscape.

Arya (2021) connotes that AGM has contributed to negative environmental impacts including destruction of flora. The upsurge of illegal mining has notable consequences on forest resource degrading wildlife, habitat destruction (Emmanuel *et al., 2018*). Agariga *et al.,* (2021) ascertained the environmental consequences of deforestation in Ghana. Mining has caused extensive deforestation. Efects of ASGM on flora diversity and plant species richness in Tanzania and Ghana has been alluded to as; reduced species diversity and richness, (Mutembei*,* 2020: Asare *et al.,* 2021 These studies have scored on giving an insight on the influence of vegetation loss to ; reduced floral species diversity and richness; However the studies are descriptive in nature as opposed to the current study which involved a rigorous analysis of quantitative data through the regression model to establish the quantifiable influence of area of vegetation cleatred for AGM on higher plants species richness and abundance.

According to KBS (2019) the major contributors to environmental degradation are, poor land use practices such as deforestation and degree of environmental enforcement of environmental laws which comparatively lead to loss in biodiversity. The greatest losses of vegetation occurred in the period 1990-2000 when at natural scale 0.8 % of forest was lost (KBS 2019). In Kenya AGM has recently become a relevant activity beginning the year 2008 as newly explored gold bearing reefs were discovered in places such as Kakamega, Siaya, Migori, Nandi and Vihiga counties with massive loss in biodiversity being registered (Burreto *et al.,* 2018). Besides this, the legal frame work of 2016 has legalized AGM in order to make it a sustainable venture through minimizing of environmental degradation. Non the less the bureaucracy involved in miners being allowed to engage in AGM is more time consuming making room for AGM sector to be porous to illegal mining. This therefore culminates into AGM practices leading to land degradation (Odhiambo 2010). Odumo *et al., (*2014) insinuates that vegetation clearing in AGM areas has led to environmental deterioration. Ogola *et al.,* (2018) documented environmental impacts of artisanal mining in Migori, including vegetation loss and soil degradation Non the less, explicit assessments on vegetation species richness and abundance in relation to spatial extent of cleared vegetation are notably absent from the current Kenyan literature. This is therefore a critical omission given that habitat loss and vegetation removal are principal mechanisms through which biodiversity declines occur, and such empirical understanding is necessary to guide conservation and land use policies in AGM areas.

On River Yala middle basin Omusula (2019) focused on sand mining and its influences on livelihoods and posits that, mining is characterized by massive deforestation which has led to the loss of biodiversity on River Yala buffer zone. Oduor *et al.,* (2019) reported biodiversity decline in Kakamega due to forest clearance, while Atieno *et al.,* (2020) linked gold mining to vegetation clearing in Vihiga. Kitula *et al.,* (2021) found that artisanal mining reduces plant regeneration capacity, while Onyango *et al*., (2022) reported that ASGM in Siaya undermines riparian biodiversity. Ondayo *et al.,* (2023) further confirmed that artisanal mining in Kakamega and Vihiga reduces vegetation cover and species diversity. Were *et al.,* (2024) demonstrated that mining in western Kenya drives both biodiversity loss and ecosystem fragmentation. Oduor *et al.,* (2019) reported biodiversity decline in Kakamega due to forest clearance, while Atieno *et al.,* (2020) linked gold mining to vegetation clearing in Vihiga. Kitula *et al.,* (2021) found that artisanal mining reduces plant regeneration capacity, while Onyango *et al*., (2022) reported that ASGM in Siaya undermines riparian biodiversityAt the Middle Yala Basin. site specific studies such as; Achieng *et al*., (2019) documented wetland vegetation degradation from artisanal mining in Vihiga, while Oduor *et al.*, (2020) showed that forest clearings around Kakamega reduce plant richness. Nyamweya *et al*., (2021) reported biodiversity losses in riparian habitats along River Yala, while Okeyo *et al.,* (2022) found that artisanal gold mining fragments local habitats, undermining regeneration. Ondayo *et al.,* (2023) provided evidence of vegetation clearance in Kakamega gold belts, while were *et al.,* (2024) quantified ecosystem service loss tied to habitat destruction. Finally, Asare *et al*., (2025) confirmed that artisanal mining in western Kenya consistently reduces floristic richness. . Going by these scientific literatures there is paucity of peer reviewed literature that directly links vegetation cover loss in AGM areas to higher plants species richness and abundance in River Yala Middle Basin, hence the need for more studies to postulate on the influence of area of vegetation cleared under AGM on higher plant species richness and abundance.

Statement of the Problem

Artisanal gold mining has expanded rapidly across the developing countries where it serves as a major source of income. Despite this artisanal gold mining practices are recognized as significant drivers of vegetation clearance which has led to habitat destruction and loss in biodiversity. River Yala Middle Basin is endowed with a rich biodiversity specifically (Kibiri, Yala and Kakamega) regions which is home to many flora plant species which provide; wild fruits, timber and wood fuel. However, this is threatened due to AGM tree cutting practices which could be affecting higher plant species distribution. Despite this, numerous studies have documented the general environmental impacts of artisanal gold mining such as soil contamination, water pollution and deforestation, there is limited quantitative understanding of how area of vegetation cleared for artisanal gold mining influences on higher plants species richness and abundance .However, it is unclear whether plant communities exhibit linear declines in abundance and richness with increasing cleared area, or whether threshold responses, species turnover or dominance shifts occur at specific spatial scales of disturbance. Therefore the purpose of this study was to investigate the influence of area of vegetation cleared for AGM on higher plants species richness and abundance. Understanding these relationships will provide insights into biodiversity loss patterns, inform ecological restoration frameworks and contribute to sustainable use of land as a resource and planning in mining affected landscapes.

Purpose of the Study

Artisanal gold mining is a rapidly expanding land use activity across many tropical and sub tropical regions. It is mainly characterized with extensive vegetation clearing and habitat degradation. While its socioeconomic contributions are well recognized, its ecological consequences on higher plants species communities remain insufficiently quantified. Vegetation clearance associated to artisanal gold mining can alter species composition, reduce habitat heterogeneity and disrupt regeneration processes thereby affecting plant species richness and abundance. Therefore the purpose of this study was to investigate the influence of area of vegetation cleared for AGM on higher plants species richness and abundance. This research sought to provide quantifiable empirical evidence of the ecological impacts of vegetation clearing on higher plants species richness and abundance. The findings intend to contribute to a better understanding of how artisanal gold mining practices influence plant diversity patterns and to inform land management ecological restoration strategies and biodiversity conservation policies in mining affected landscapes.

MATERIALS AND METHODS

The Surveys carried out on the Sub – basins within River Yala middle basin extending from Study Area 0.80N, 34.3^{0}E and 0.5^{0}N, 34^{0}E. This covers three counties namely; Siaya, Vihiga and Kakamega where AGM practices are prevalent. A variety of higher plant species, such as riparian vegetation, agroforestry species, and native trees species, are found in River Yala Middle Basin. *Markhamia lutea*, *Croton macrostachyus*, *Albizia coriaria*, *Ficus sycomorus*, and *Prunus africana* are among the native tree species found. Species like papyrus, reeds, and sedges (*Typha spp.)* predominate in riparian and wetland vegetation. In addition we have a widespread of agroforestry and cultivated tree species in the basin, including *Cypress*, *Grevillea robusta*, *Eucalyptus spp.,* *Mangifera indica*, and *Persea americana*. (KCIDP)2018-2019; VCIDP 2018-2019; SCIDP 2018-2019).

Equally we have a total of 1790 households who are practicing AGM in River Yala Middle Basin (KNBS 2019)

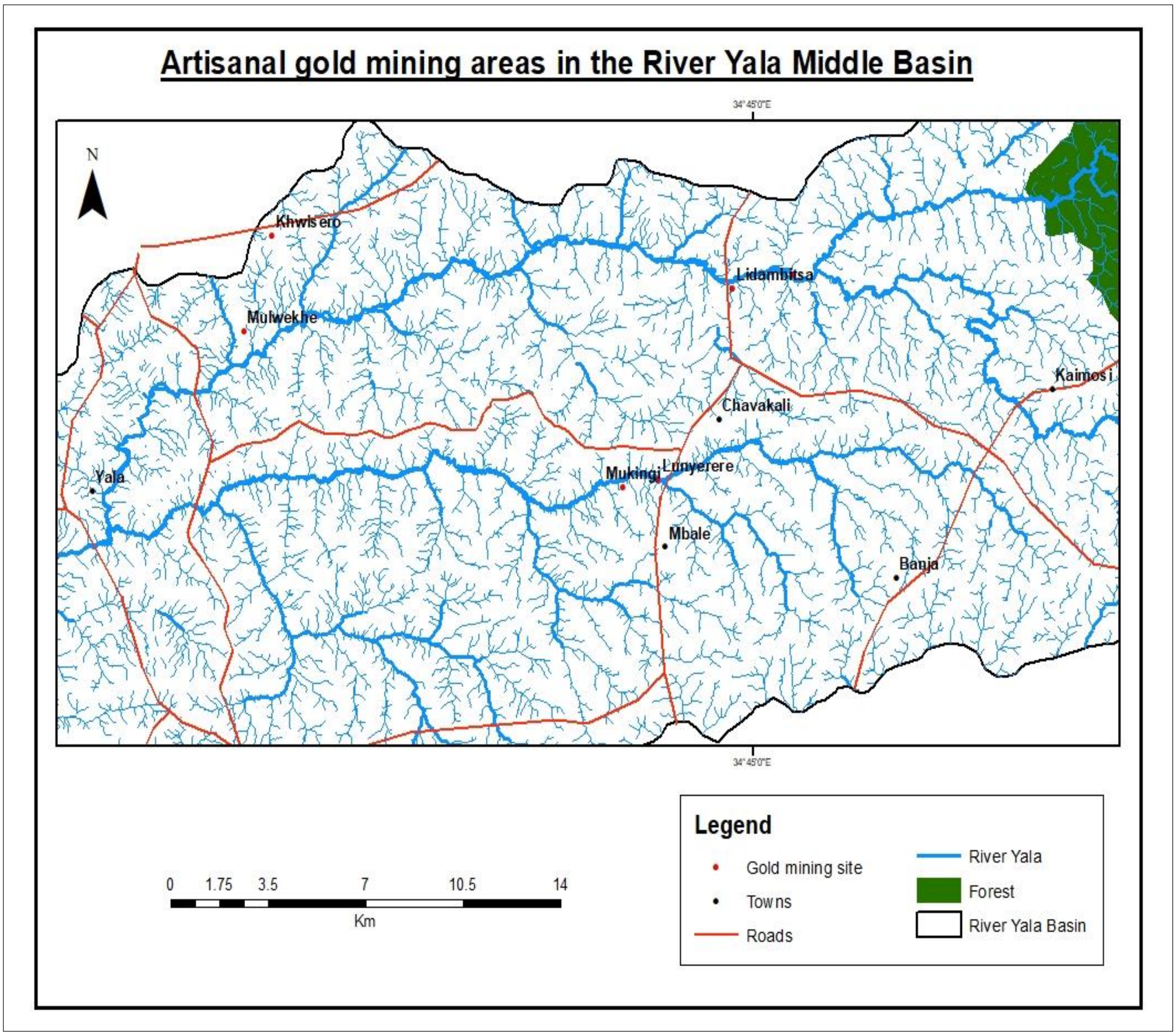

Figure 1: River Yala Middle Basin

Research Design

The study employed a cross sectional descriptive research design since AGM was already taking place over a wider area and data was obtained over a short period of time.

Study Population, Sampling and Data Collection

The specific sample size depended on the extent of AGM activities within the River Yala middle Basin data availability. The sample population for this study consisted of geographical areas and environmental parameters within the Middle Yala Basin, specifically focusing on Sub-basins affected by artisanal gold mining (AGM) practices. Stratified sampling aided in the generation of a representative division of River Yala Middle basin into four zones guided by; Upper, Upper Middle, Middle Lower and Lower zones. Area based sample frame was generated guided by; Sub – basins of high significance AGM practices, Sub- basins of Moderate AGM practices and Sub – basins with minimal AGM practices. Based on the area based sample frame, for equal representation, the study therefore picked on four Sub-basins which were studied scientifically; Lidambista, Lunyerere, Khwiselo and Ramula. Purposive sampling was applied in the identification of the five constituencies with 11 wards covered by the four basins of study identified. Therefore the areas of mining constituted these constituencies; Kakamega South, Vihaga, sabatia, Khwisero and Slaya. The Wards where gold mining in the above stated constituencies is as follows: Kakamega South: Eregi, Iguhu, Vihiga: Central Maragoli and South Maragoli; Sabatia: Lyaduywa, Chavakali, Khwisero; Kisa West and Kisa East. Siaya; Central Sakwa and Ramula. For equal representation stratified sampling aided in the selection of two wards from each constituencies for the study purpose. Therefore according to KCDP, (2019), VCDP, (2019) and SCDP, (2019) the households engaged in AGM from the ten wards are 1790; Since the study population is less than 10000, Therefore a sample size of 321 households was considered using Fisher's *et al*., 1984 formulae. Simple random sampling was used to obtain 321 respondents from the 1790 artisanal gold miners from every ward. Every artisanal gold miner from the 10 wards was given a number then the list of numbers was randomized through a computer program Microsoft Office Excel. The 321 numbers were randomly selected based on a computer program proportional to each ward's household population engaged in AGM. Therefore the 321plots were considered for study. Data collection was a fundamental step in understanding the influence of area of vegetation cleared for AGM on higher plants species; richness and abundance in River Yala Middle Basin of Vihiga, Kakamega and Siaya Counties, Kenya. Purposive sampling aided in the identification of key informants drawn from the three counties of the study area. They included four; area chiefs, village elders, AGM opinion leaders, directors of environment, officers from NEMA and officers from the Ministry of Petroleum and Mining interviewed. One officer from key departments of; Kakamega Forest, Water Services. Primary data collection methods adopted included; questionnaire, observation, field measurement, counting, recording, and photography. They collected data on names of higher plants species, total number of different higher species, total number of higher plants species per plot and area of vegetation cleared for artisanal gold mining. These methods were appropriate for data collection because data was obtained by measuring (area of vegetation cleared for AGM, counting of the total number of different higher plant species, counting of total number of higher plants species per plot.

Data Analysis and Results Presentation

Influence of the Area of Vegetation Cleared under AGM on Higher Plants Species

For descriptive statistics, information on higher plant species; higher plants species abundance and areas of vegetation cleared for AGM was summarized using frequencies and percentages. Names of higher plants species were identified by the household heads. The species which were not identified had their leaves extracted for identification by forest officers at the Kakamega Forest Nature Resource where the local names alongside the botanical names were identified aided by the botanical dictionary. Inferential statistics was used to examine the relationship between the area of vegetation cleared for AGM in acres and total number of different types of higher plants species, total number of plants species and the calculated evenness index for each plot. Data on plant species richness, number of individual higher plant species (for abundance), and area of vegetation cleared for AGM in acres was subjected for analysis. The procedure entailed using Microsoft Excel. Statistical Package for Social Sciences Version 2017 for inferential analysis. Simple linear regression analysis tool assisted in determining the nature of influence of area of vegetation cleared for AGM on higher plants species. The areas of vegetation cleared for AGM was regressed with the respective numbers of different higher plants species (species richness and the total number of higher plants (species abundance) to generate the r^2 values. The significance level was $P < 0.05$ at 95 % confidence level. The findings were interpreted in the context of the study objective, the influence of area of vegetation cleared for artisanal gold mining on higher plants species richness and abundance the results were discussed, and presented in form of, scatter plots, and conclusions drawn based on the analyzed results.

RESULTS AND DISCUSSIONS

The Influence of Area of Vegetation Cleared for AGM on Higher Plant Species Richness

This chapter presents results, data analysis and interpretation of findings based on the objective of the study.

The researcher sought to establish the names of higher plants species present in artisanal gold mining sites in River Yala middle basin. The respondents were asked to list the names of higher plants species present in the areas designated for mining in their farms. Table 1 shows the names of higher plants species as mentioned by the respondents who participated in the survey.

Names of Higher Plants Species Present in Artisanal Gold Mining Sites

The researcher was also out to establish the names of higher plants species present in artisanal gold mining sites in River Yala middle basin. The respondents were asked to list the names of higher plants species present in the areas designated for mining in their farms. Table 1 shows the names of higher plants species as mentioned by the respondents who participated in the survey.

Table 1: Names of higher plant species in River Yala middle basin by frequencies and percentages

English	Botanical	Luo	Luhya	Frequency	Percentage
Tulip tree	Markhamia Lutea Nile	Muu	Lusiola	2840	3%
Forest fever	Cotton macrostachyus	Ngong'ngong'		1136	1.2%
Eucalyptus	Camaldulensis	Bao	Mubao	15150	16%
Coastal golden leaf	Bridelia Micrantha	Omondi	Musere	1136	1.2%
Silky oak	Grevillea robusta	Gevia	Silvia	10415	11%
Fig tree	Ficus carica	Ohingo	Omukhuyu	1420	1.5%
Chinese Alangium	Alarigium, chinense		Mutobolo	473	0.5%
Hackberry	Celtis gomphophylla		Musaa	662	0.7%
Wild Fig	Ficus thomiingii		Mukhuyu	662	0.7%
Java Cedar	Bischofia javanica		Muu	757	0.8%
White Stnkwood	Celtis Africana		Mweyu	1136	1.2%
African rubber tree	Funtumia Africana		Mutondo	662	0.7%
Drum tree	Cordia millenii		Mungoma	473	0.5%
Ehretia cymosa	Ehretia cymoso		Sikhutu	473	0.5%
Peacock flower	Albinzia gummifera		Mukhunzulu	757	0.8%
	Pouteria altissima		Mukangu	662	0.7%
	Polycias fulvia		Mwanzu	757	0.8%
Sand paper	Ficus exasporata		Museno	473	0.5%
Bush palm	Englerophytum oblanceolatum		Musamia	757	0.8%
False fig	Tripelipsium madagascariense		Mmbalakaya	758	0.8%
		Nyambud	Shibudu	475	0.5%
	Croton sylvaticus		Musutsumunamulime	473	0.5%
Cherry bearing synsepalum	Synsepalum cerasiferum		Mukhulumuru	476	0.5%
Winged Bersama	Barsama abyssinica		Mmuyundi	474	0.5%
African mahogany	Khaya anthrothecus		Mnyamakwe Buganda	1325	1.4%
Horsewood perdepis	Clausena anisate	Ogwenochuth	Shisimbari , Shitsesia	1042	1.1%
White iron wood	Teclea nobilis	Anyola	Lutaro	758	0.8%
African ebony	Diospyros abyssinica	Ochong'a	Lusui	663	0.7%
Pink cedar	Acrocarpus fraxinfolia		Kabukabusu	1136	1.2 %
	Premaanglonsis		Mungalikoro	1042	1.1 %
	Ficus lutea		Mukarakara	473	0.5 %
	Croton megalocarpus		Musina	472	0.5 %
	Antiaristoxicaria		Mulundu	662	0.7 %
	Choetacmearistata		Likhomo	759	0.8 %
	Cardia Africana		Mukomari	1043	1.1%
	Bilghia unijiguta		Shiarambasta	1136	1.2%
	Ehretia cymosa		Shikhutu	1138	1.2%
	Morusmeso zygia		Munuku	756	0.8%
	Prunus africanus		Mwiritsa	758	0.8%
	Manilkarabutugi		Ludolio	661	0.7%
	Kigeliamoosa		Murabe	760	0.8%
	Cassipourera ruwensorensis		Mukoloho	285	0.3%
	Zanthoxylum giletti		Sikhuma	284	0.3 %
	Psydrax schimperiana		Shikoye	471	0.5%
	Fagaropsis angolensis		Shingulutosto	946	1.0%
	Heinsenia diervilloides		Mmandala	947	1.0%
Waterberry	Syzygium cordatum			845	1.0%
Governor's plum	Flacoutia indica			661	0.7%
Monkey orange	Strychnos spinose			470	0.5%
Jackalberry	Diospyros mespiliformis			472	0.5%

English	Botanical	Luo	Luhya	Frequency	Percentage
Wild rubber	Landolphia kirkii			284	0.3%
Wild loquat	Uapaca kirkiana			284	0.3%
Mango	Mangifera indica	Maembe	Liembe	6438	6.8%
Guava	Psidium guajava	Mapera	Lipera	3977	4.2%
Pawpaw	Carica papaya	Apoyo	Lipaipai	1894	2.0%
Avocado	Persea SAmericana	Avokado	Likado	3503	3.7%
Indian Laburnum	Senna Siamea	Oyieko		947	1.0 %
Bitter leaf	Vemonia amygdalina	Hafifi	Lififi/ Olififi	1325	1.4%
P	Carica payaa P	Okeke	Lukeke	946	1.0%
G	Cucumis myriocarpus	Nyayado	Lunyayado	1136	1.2%
Repetition	Vemonia amygdalina	Oluoro chieng	Lunyolo/Oluoro	947	1.0 %
S	Zanthoxylum chalybeum	Olasi	Lilasi	758	0.8 %
Gourd	Cucumis myriocarpus	Oyumbe	Shiyumbe	759	0.8%
Repetition	Cucumis	Morakad	Shimorakad	758	0.8%
Repetition		Aringo	Lirongo/Shirongo	662	0.7 %
Rosary pea	Abrus precatorius	Ombulu	Shimbulu	754	0.8%
Repetition		Ober	Shiober	473	0.5%
Repetition		Osiri	Lusiris	474	0.5%
Water lettuce	Pistia stratiotes	Anyuongi	Linyongi	471	0.5%
Mexican sunflower	Tithonia diversifolia	Osadhi	Lisadhi	472	0.5%
G	Ageratum conyzoides	Olamu	Shilamu	475	0.5%
Aloe vera	Aloe vera	Ogaka	Ligaka	1799	1.9 %
Bitter apple	Solanum incanum	Nyakisum	Shikisum	947	1.0 %
Neem tree	Azadirachta indica	Mwa Robaine	Mwarobaine (mkilifi)	471	0.5 %
Totals				**94378**	**100**

Source: Field 20

According to (Table 1), the frequency distribution of higher plant species in River Yala Middle revealed that heavily disturbed mining zones exhibited lower species richness and diversity of indegenious tress such as *Markhamia lutea*, (3 %) *Croton macrostachyus*, (1.2%) *Cassipourera ruwensorensis* (0.3 %) and *Prunus Africana* (0.8 %) while plots in undisturbed or less disturbed areas maintained a higher richness of indigenous taxa alongside species like Cyperus papyrus, reeds, and sedges (Typha spp.) predominated in riparian and wetland vegetation.

The study findings are in agreement with assertions that, mining activities often involve excavation, vegetation stripping, and topsoil removal, leading to habitat degradation and fragmentation (Hilson, 2002). As a result, pioneer and exotic species such as *Eucalyptus camaldulensis (16 %), Grevillea robusta* (11 %) and *Mangifera indica 6.8 %* dominated disturbed areas due to their fast growth and tolerance of altered soils. In contrast, ecologically sensitive native species such as *Prunus Africana* (0.8 %), *Cordia africana* (1.1 %), *Khaya anthotheca* (1.4 %), *Syzygium cordatum* 0.5 %and *Diospyros abyssinica* 1 % were rare or absent in such plots, supporting the hypothesis that area of vegetation cleared for AGM affects on higher plants species. Similar findings have been reported in the Upper Nile basin, where exotic trees in disturbed basins altered hydrological balance and outcompeted native riparian flora (Gomani *et al.,* 2018). (Tschakert and Singha, 2007; Kitula, 2006) also posit that, in Ghana and Tanzania artisanal mining has reduced vegetation cover and led to colonization by opportunistic species (Tschakert & Singha, 2007; Kitula, 2006).

However, unlike eucalyptus, indigenous riparian trees provide diverse ecosystem services, including soil stabilization, wildlife habitat, and cultural values (FAO, 2010). Thus, their replacement by exotics trees species represent a biodiversity concern alongside reduction in ecological resilience.

In contrast, undisturbed plots maintained a more balanced composition of indigenous trees this brings to the fore the importance of intact vegetation in preserving biodiversity. For example, *Markhamia lutea (3 %)* and *Ficus spp 0.8 % Azadirachta indica* 0.5 % persisted in less disturbed mining zones, demonstrating their dependence on relatively undisturbed microhabitats.

Fruit species such as mango *Mangifera indica*, (6.8 %), guava *Psidium guajava*, (4.2%), ovacado (3.7 %) and pawpaw C*arica papaya*, (2.0 %) illustrate the tripulate role of riparian landscapes in supporting both biodiversity, household food security and resource exploitation. Their higher frequencies indicate the integration of agroforestry with riparian ecosystems, a finding consistent with agroforestry adoption studies in western Kenya (Franzel *et al.*, 2014).

The persistence of species with cultural significance, such as *Markhamia lutea* (3 %), *Prunus africana* (0.8 %) and *Ficus carica* (1.5 %), demonstrates that traditional knowledge still influences conservation practices. Similar cultural associations have been documented in Uganda, where sacred fig trees are protected despite land use changes associated to gold mining (Byg *et al.,* 2017).

The study also revealed reduced frequencies of medicinal plants in disturbed mined areas of River Yala middle basin such as; *Zanthoxylum gillettii* 0.8 %, *Cucumis myriocarpus* (0.8 %), *Tithonia diversifolia* (0.5 %) *Azadirachta indica* (0.5 %). This therefore represents both ecological and socio-economic losses, given their roles in traditional medicine and livelihoods is equivocal (Cunningham *et al.,* 2016).

While the frequency data confirms that exotic species dominate, this trajectory raises ecological concerns. *Eucalyptus* in particular is known for high water uptake, which can deplete groundwater and reduce stream flow (Mekonnen *et al.,* 2021). Its dominance in riparian gold mining settings is therefore ecologically questionable, as it may compromise the very water systems it is planted near.

While artisanal gold mining provides income to local communities, the associated vegetation clearance has long term ecological cost. The higher plants species which dominate the mining sites such as *Eucalyptus* were often encouraged for quick economic returns, yet their presence in riparian systems poses an ecological threat. This is because they drain a lot of water from the soil and may worsen water scarcity during dry seasons (Mekonnen *et al.,* 2021).

By contrast, the low frequencies of indigenous higher plant species indicate a shift toward simplified ecosystems with lower resilience. This critique is in agreement with broader findings in East Africa, where artisanal mining accelerates deforestation and alters vegetation structure (World Bank, 2019).

These findings underscore the need for policies that regulate vegetation clearance in artisanal mining zones, coupled with restoration programs promoting native riparian species to safeguard both ecological integrity and community livelihood. This is louded clearly as the accrued ecosystem services provided by higher plants species are enormous and sustain a vast populations wel beng.

Regression analysis to test the effect of area of vegetation cleared for artisanal gold mining on higher plants species richness in River Yala middle basin was carried out. The acreage of vegetation of land cleared for AGM in acres was regressed against the total number of higher plants species identified per study plot. The regression results were sought to give the nature of effect of area of vegetation cleared for AGM on higher plants species richness. Figure 2 shows a scatter plot of simple linear regression of the influence of area of vegetation cleared for AGM on higher plants species richness.

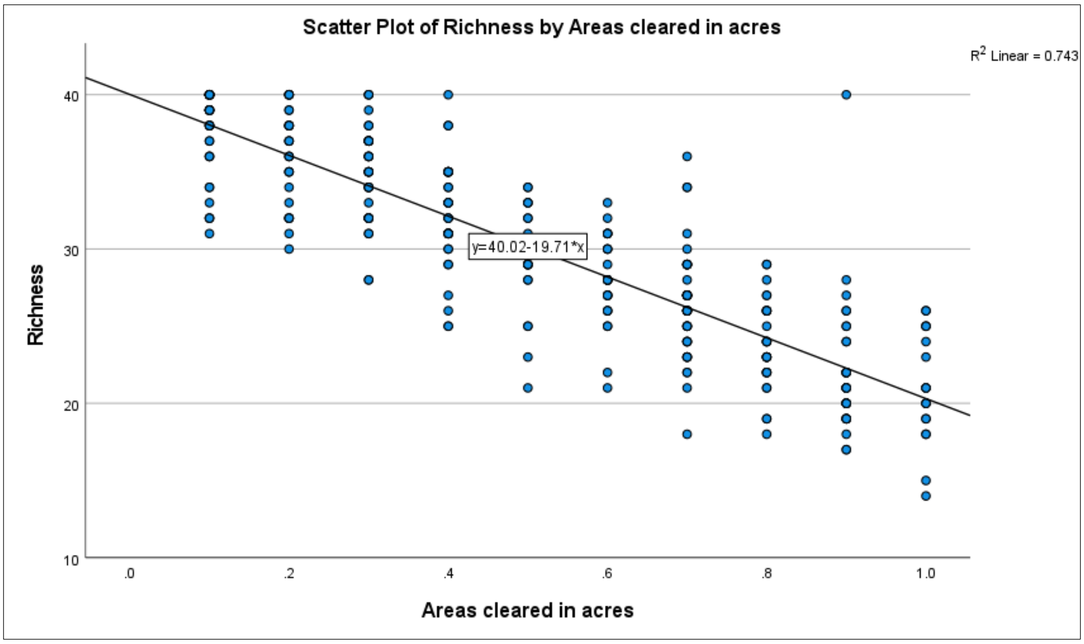

Figure 2: Scatter plot of simple linear regression results showing the influence of area of vegetation cleared for AGM on higher plants species richness

Figure 2 indicates that 74.4 % of variation of higher plants species richness in River Yala middle basin can be explained by the area of vegetation cleared for AGM. The remaining 25 .6 % can be explained by other factors not analysed by this study. These factors entail; the impending climate change adversities which are known to alter the abiotic stresses like variable temperature regimes and their associated impacts on water availability leading to higher plant species stress which is evident at local and regional scale (IPB ES., 2019). Foxcraft (2013), alludes to invasive species and edge conditions reducing native plants species richness through competition or habitant modification. Additionally, cohabitation between the area of vegetation destroyed for artisanal gold mining and the observed species richness is impacted by biotic interactions such as competition, facilitation, herbivory, and mutualistic relationships, particularly pollinators and mycorrhizae.

As proposed by (IPB ES. ,2019). The regression equation y = 39.9 – 19.5x reveals that, area of vegetation cleared for AGM affects on higher plants species richness negatively in River Yala middle basin. For every additional acre of vegetation cleared, species richness decreases by approximately 20 species units. As mining activities expand and larger areas are cleared, natural vegetation and habitats are destroyed. This leads to; Loss of plant and animal species, particularly sensitive and endemic species, Habitat fragmentation, reducing breeding and feeding grounds, altered microclimates and soil degradation**,** making recolonization difficult, Reduced primary production, affecting entire food webs chains .These impacts collectively reduce biodiversity, reflected in llower higher species richness.

Higher plants species underpins key ecosystem services in River Yala middle Basin. The decline in higher plants species richness therefore implies that, Rver Yala middle basin experience; Reduced water purification capacity, as vegetation and soil biota are lost. Lower carbon sequestration, contributing to local climate stress., weakened soil stabilization, leading to erosion and siltation of the river and loss of pollination and nutrient cycling services, affecting agriculture and fisheries downstream. Through observation it was evident that the hard wood tree species like the Markhamia lutea, gravelia and eucalyptus species were highly targeted for the construction of support shafts for miners. This is supported by plate … showing the eucalyptus tree logs to be used for shafing by miners.

This result provides quantitative evidence that artisanal gold mining practices negatively affect on higher plants species thereby impairing the ecosystem services essential for ecological stability and local livelihoods. Such findings are consistent with the Intermediate Disturbance Hypothesis (IDH), which argues that excessive disturbance causes significant reductions in species coexistence, although mild disturbances may boost diversity (Kissinger *et al.,* 2018; Sonter *et al.,* 2019; Edwards *et al.,* 2020; Hilson *et al.,* 2021; Bicknell *et al.,* 2022; Seki, 2022; Mendes *et al.*, 2023). According to the successional setback theory (Rodríguez *et al.,* 2023; Sant'Ana *et al.,* 2024), large-scale clearings reset biological succession, limiting native regeneration and instead favoring invasive and disturbance-tolerant species.

Evidence repeatedly shows that industrial and artisanal mining are substantial contributors to the loss of biodiversity worldwide through habitat fragmentation, soil degradation, and deforestation. For instance, Sonter *et al.,* (2019) assert that mining activities have caused species reductions in the Amazon, whereas Kissinger *et al.,* (2018) suggested that mineral extraction reduces floristic richness across tropical environments. While Bicknell *et al.,* (2022) and Seki (2022) shown that even artisanal activities result in significant biodiversity loss due to land removal and toxic contamination, Edwards *et al.,* (2020) and Hilson *et al.,* (2021) connected large-scale mining to long-term ecological degradation.

Mendes *et al.,* (2023) noted that artisanal mining decreases seedling density and species pools, while Rodríguez *et al*., (2023) confirmed that persistent mining reduces landscape resilience. (Sant'Ana *et al.,* (2024); Asare *et al., (*2025) further showed that AGM exacerbates biodiversity declines by transforming riparian forests into monocultures dominated by disturbedt tolerant species. These findings however contradicts the study results, demonstrating that cleared area directly predicts richness decline across African landscapes.

At the regional scale, studies in East Africa have linked mining and other forms of land clearing to biodiversity decline. Van der Ploeg *et al.,* (2019) repoted that ASGM in Tanzania reduces riparian vegetation diversity, while Mukama *et al*., (2020) observed biodiversity losses around Ugandan gold belts. Kalaba *et al.* (2021) reported that woodland clearing for extraction in Zambia reduces plant richness, while Mugisha *et al.* (2022) alluded to mining's role in disrupting regeneration in Uganda's wetlands. Chinseu *et al.,* (2023) identified biodiversity declines in Malawi linked to clearing for AGM extraction, and Mabele *et al.,* (2023) demonstrated habitat degradation across East African mining frontiers. Asare *et al.,* (2025) resonates that AGM sites in East Africa register low biodiversity consistent with the current study findings from River Yala middle basin.

In Kenya the study findings, align greatly with assertions as; Ogola *et al.,* (2018) documented environmental impacts of artisanal mining in Migori, including vegetation loss and soil degradation. Oduor *et al.,* (2019) reported biodiversity decline in Kakamega due to forest clearance, while Atieno *et al.,* (2020) linked gold mining to vegetation clearing in Vihiga. Kitula *et al.,* (2021) found that artisanal mining reduces plant regeneration capacity, while Onyango *et al*., (2022) reported that ASGM in Siaya undermines riparian biodiversity. Ondayo *et al.,* (2023) further confirmed that artisanal mining in Kakamega and Vihiga reduces vegetation cover and species diversity. Were *et al.,* (2024) demonstrated that mining in western Kenya drives both biodiversity loss and ecosystem fragmentation, corroborating the regression results from the YalaBasin.

At the Middle Yala Basin. site specific studies such as; Achieng *et al*., (2019) documented wetland vegetation degradation from artisanal mining in Vihiga, while Oduor *et al.,* (2020) showed that forest clearings around Kakamega reduce plant richness. Nyamweya *et al*., (2021) reported biodiversity losses in riparian habitats along River Yala, while Okeyo *et al.,* (2022) found that artisanal gold mining fragments local habitats, undermining regeneration. Ondayo *et al.,* (2023) provided evidence of vegetation clearance in Kakamega gold belts, while were *et al.* (2024) quantified ecosystem service loss tied to habitat destruction. Finally, Asare *et al*., (2025) confirmed that artisanal mining in western Kenya consistently reduces floristic richness. Together, these local studies reinforce the observed regression relationship Fig 4.1 and Fig 4.2 showing that increasing cleared area directly undermines higher plats species richness in the Middle Yala Basin.

Although most evidence points to negative biodiversity impacts, a few studies suggest context-dependent or opposing patterns. For example, Van der Ploeg *et al*., (2019); Mukama *et al.,* (2020) reported temporary increases in certain opportunistic species after clearing, while Kitula *et al.,* (2021) suggested that disturbed sites may show high abundance of plants which grow fast despite reduced richness. However, these studies often focused on abundance or short term colonization rather than long term richness. Moreover, many relied on coarse land cover data rather than intensive field sampling, which limited their ability to capture refined scale diversity responses. (Seki, 2022; Mendes *et al.,* 2023; Rodríguez *et al*., 2023; Sant'Ana *et al*., 2024; Asare *et al*., 2025; Were *et al.,* 2024)

By contrast, this study bridges this gap through rigorous plot level data (321 plots), robust regression modeling, and integration of theoretical frameworks such as IDH and succession. Thus, the Middle Yala Basin case provides strong empirical evidence that cleared area is the dominant driver of species richness decline, filling a methodological and conceptual gap in both global and regional research (Seki, 2022; Mendes *et al.,* 2023; Rodríguez *et al.,* 2023; Sant'Ana *et al.*, 2024; Asare *et al.,* 2025; Were *et al*., 2024)

Area of Vegetation Cleared and It's Influence on Higher Species Abundance

The study analysis also evaluated the influence of area of vegetation cleared for artisanal gold mining on higher plants species abundance in the River Yala middle basin. The acreage of vegetation of land cleared for AGM in acres was regressed against the total number of higher plants identified per study plot. Figure 3 shows the results of the regression. The results are indicated by scatter plot of the simple linear regression to test the relationship and nature of effect between the area of vegetation cleared for AGM in acres and the higher plants species abundance.

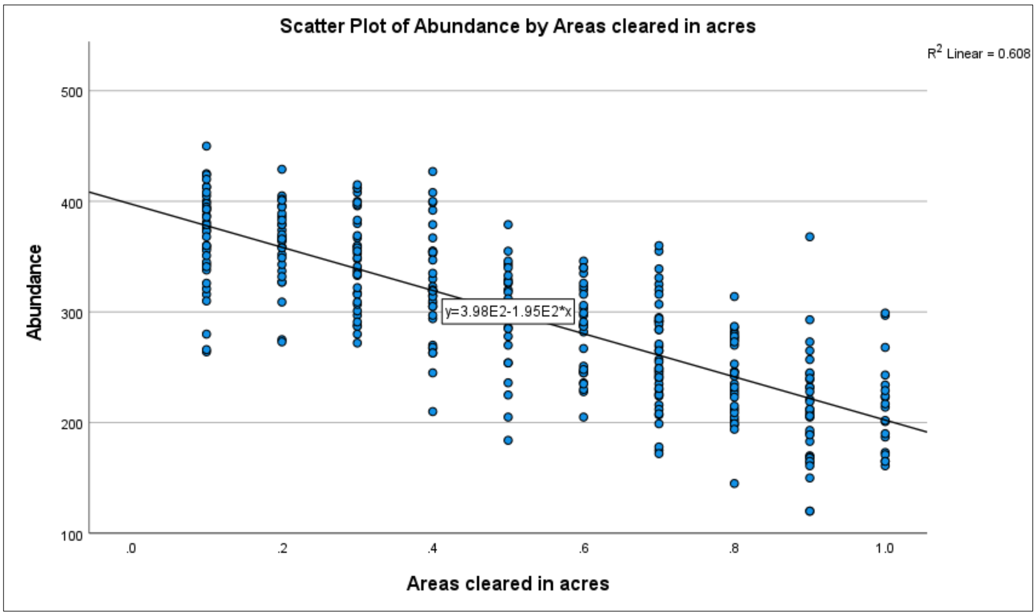

Figure 3: Scatter plot of simple linear regression results showing the influence of area of vegetation cleared for AGM on higher plant species abundance

Figure 3 results indicate that, 60.3% of the variation in higher plant species abundance can be explained by area of vegetation cleared for artisanal mining activities. The remaining 39.7 % of variation in higher plants species abundance can be explained by other factors which were not considered by this study.

These factors could constitute; Gold mining practices alter soil structure and chemistry by heavy metals like mercury, arsenic, lead, which vary spatially. These directly affect plant abundance by reducing on germination and growth Adjei *et al.,* 2018. Hydrological changes initiated through mining practices affect water infiltration, runoff and ground water these changes influence soil moisture regimes which are critical for plant abundance Mbonigaba *et al*., 2021. Frequent disturbance and soil removal during mining destroy the soil seed bank and hinder natural regeneration, leading to reduced abundance of native species Bossuyt & Honnay 2008. Also cleared and disturbed mining sites are often colonized by invasive or pioneer species that compete with native plants reducing on the abundance of the sensitive plant species Foxcroft 2013.

Mendes *et al.,* (2023) noted that artisanal mining decreases seedling density and species pools, while Rodríguez *et al*., (2023) confirmed that persistent mining reduces landscape resilience. (Sant'Ana *et al.,* (2024); Asare *et al*., (2025) further showed that AGM exacerbates biodiversity declines by transforming riparian forests into monocultures dominated by disturbed tolerant species. These findings however contradicts the study results, demonstrating that cleared area directly predicts richness decline across African landscapes.

According to Figures 3, above, the study regression analysis demonstrate a consistent and significant negative influence of artisanal gold mining on higher plants species abudance in the Middle Yala Basin. Higher plants species, abundance declined with increasing area cleared, cutting across 321 plots. Species abundance declined by 191 individuals as demonstrated in the linear model. These results imply that vegetation clearing has not only reduced the number of higher plants species present but also the density of individuals and the balance among them, thereby accelerating biotic homogenization in River Yala middle basin.

Clearing vegetation for mining disturbs and removes critical plant habitats that sustain a dense plant species populations. The consequences include: Soil erosion and siltation, which degrade aquatic habitats and plants species, pollution (especially mercury and sediment runoff) that alters water chemistry and reduces aquatic life. Reduced vegetative cover, which increases temperature fluctuations and lowers habitat quality. As a result, both terrestrial and aquatic higher plants species decline in numbers, leading to reduced abundance across taxa.

The reduction in higher plants species abundance weakens essential ecosystem functions and services; water purification declines as fewer filter feeding and decomposer organisms remains, nutrient cycling becomes inefficient, affecting soil fertility and plant growth, habitat quality decreases, limiting the recovery of other species and reduced biological productivity lowers the river system's capacity to support fisheries and agriculture. This degradation revealed a cascading ecological effect of artisanal mining on the functional health of the River Yala ecosystem. Thus, artisanal mining not only reduces higher plants species variety but also diminishes population sizes, undermining the ecological balance and the delivery of vital ecosystem services in the region in River Yala middle basin as supported by Table 1 and Figures 2 and 4.2 which show that the area of vegetation cleared for AGM has influenced higher plants species richness and abundance respectively. This has been attributed to; removal of seedlings and mature higher plants species disrupting their regeneration cycle thereby reducing on their numbers and community balance. This pattern supports the successional setback theory, which explains how recurrent clearing inhibits natural regeneration and shifts communities toward dominant taxa, and the Intermediate Disturbance Hypothesis (IDH), which, at its extreme, excludes species that cannot withstand disturbance These results are consistent with international research demonstrating detrimental effects of mining.

For example, Kissinger *et al.,* (2018); Sonter *et al.,* (2019) reported mining assoiated declines in plant richness and abundance in tropical forests. Edwards *et al.,* (2020) and Hilson *et al*., (2021) further emphasized that intensive land disturbance reduces both species numbers and evenness, leading to ecological simplification. Bicknell *et al.,* (2022) demonstrated that mining accelerates homogenization of communities by favoring species which can withstand disturbance taxa, while Seki (2022) noted reduced regeneration capacity in disturbed tropical systems. Mendes *et al.,* (2023); Rodríguez *et al.,* (2023), & Sant'Ana *et al.,* (2024) all corroborated the trend that mining eliminates rare species and promotes dominance by opportunists, consistent with the sharp declines in richness, abundance observed in the Yala Basin.

When the regression analysis results for figure 2 and figure 3 is compared to the findings in Table 1, the frequencies of the higher plants species revealed that, heavily disturbed mining zones exhibited lower species richness and diversity of indigenous tress such as *Markhamia lutea*, (3 %) *Croton macrostachyus*, (1.2%) *Cassipourera ruwensorensis* (0.3 %) and *Prunus Africana* (0.8 %) while plots in undisturbed or less disturbed areas maintained a higher richness of indigenous taxa alongside species like Cyperus papyrus, reeds, and sedges (Typha spp.) predominate in riparian and wetland vegetation. Equally undisturbed plots maintained a more balanced composition of indigenous trees comprising of ; *Markhamia lutea (3 %)* and *Ficus spp 0.8 % Azadirachta indica* 0.5% which persisted in less disturbed mining zones, demonstrating their dependence on relatively undisturbed microhabitats. Apparently the two findings confirm that the area of vegetation cleared for AGM influence on the higher plants species richness and abundance.

AGM opinion leaders reported that in River Yala middle basin vegetation clearance for gold mining removes existing higher plan species communities which has lead to elimination of native plant species, loss of rare, endemic or slow growing species and local extinction of sensitive species.

It has also lead to reduction in plant species abundance this was attributed to; uprooting of entire plant populations during AGM practices, destruction of seed banks and seedlings which are buried or destroyed and the root systems and regenerative structures are destroyed thereby impeding on the vegetation from self regeneration which has affected the higher plants species abundance and richness. In River Yala middle basin, the four chiefs noted that, hard wood trees species were on high demand leading to their premature clearance. The premature clearance aided in removal of seedlings and mature higher plants species disrupting their regeneration cycle thereby reducing on their numbers and community balance.

The four chiefs also reported that during AGM vegetation clearance, the soil is made susceptible to erosion losing on the top fertile layers. Topsoil is a key component for plant growth. This has made it difficult for plant recolonization reducing on species richness due to poor germination.

It was also revealed that AGM vegetation clearance has resulted to breaking of continuous habitats into isolated patches resulting into reduced gene flow between higher plants species, smaller population sizes and increased vulnerability to local extinction.

It was also revealed that in River Yala middle basin, vegetation clearance for AGM has resulted to invasive plant species colonizing and dominating disturbed soils.

AGM vegetation clearance in River Yala middle basin has lead to long term ecological impacts with acreage of land cleared of vegetation exhibiting community composition that is permanently changed.

Through observation it was evident that AGM was a driver of plant community alteration within River Yala middle basin. The hard wood tree species like the Markhamia lutea, gravelia and eucalyptus species were highly targeted for the construction of support shafts for miners. This significantly affected their richness and abundance.

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CONCLUSION

The findings of this study demonstrate that artisanal gold mining (AGM) exerts a strong and statistically significant influence on higher plant species richness and evenness. The area of vegetation cleared for AGM explained 74% of the variation in species richness ($R^2 = 0.74$, $p < 0.05$), and 60 % of the variation in species abundance ($R^2 = 0.60$, $p < 0.05$). These high coefficients of determination indicate that vegetation clearance associated with AGM is a dominant driver of plant community alteration within the study area. The strong relationship indicated that vegetation clearance for artisanal gold mining aid in removal of seedlings and mature higher plants species disrupting their regeneration cycle thereby reducing on their numbers and community balance. It was revealed that, ecologically sensitive native species such as *Prunus Africana* (0.8 %), *Cordia africana* (1.1 %), *Khaya anthotheca* (1.4 %), *Syzygium cordatum* 0.5 %and *Diospyros abyssinica* 1 % were rare or absent in plots with vegetation cleared for AGM Pioneer and exotic species such as *Eucalyptus camaldulensis (16 %), Grevillea robusta* (11%) and *Mangifera indica 6.8 %* dominated areas of cleared vegetation due to ; agroforestry practices , fast regeneration, growth and tolerance. Whereas plots with extensive vegetation clearance exhibited lower species richness and abundance of indigenious trees such as *Markhamia lutea* 3 %*, Croton macrostachyu 1.2* %, *Albizia coriaria 0.8* % *and Ficus exasporata 0.5* %,. The significant reduction in richness and abundance further confirms strained ecosystem services provided by the affected higher plants species in River Yala middle basin.

Acknowledgement

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The authors would like to appreciate all key informants in the three counties constituting; Kakamega, Vihiga and Siaya for providing relevant and instrumental information that helped shape the current study. The household heads were also cooperative and assisted in the provision of the required information as provided for in the questionnaire.

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