Chapter

Impacts of Stone Quarrying on Local Vegetation in Mount Korok Area, Juba, Central Equatoria State, South Sudan

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Abstract

This study was carried out in three quarry sites at Mount Korok, also known as Jebel Kujur area, which is located within Juba Town Council in Central Equatoria State, South Sudan. The main aim was to assess the impact of quarrying activities on the local ground cover vegetation, mainly grasses and low-lying non-woody herbaceous plants. The methods used included, besides direct observations, iron frame quadrats of $1 \times 1\ m^2$ in size, for random sampling of attributes and community characteristics of the plants in three different sites. The first site was an old, abandoned stone-quarrying site; the second was where quarrying work was actively going on at the time of the study; and the third was an area never before exposed to stone quarrying (hence, acting as a control). Data were analyzed using descriptive statistics such as frequency distribution, density measures, diversity indices, and correlations. The research was carried out during the wet season when most plants were green and at different stages of flowering and/or fruiting from July through September, 2020. The results revealed that over 44 species of ground cover plants were identified, some of which were more abundant and had the widest distribution and frequency in the three study sites, including *Cynodon lemfuensis, Cyperus rotundus, Bracharia ramose, Merremia pinata, Cyanodon dactylon*, *and Digitaria fernatad*, whereas others were limited to one site or the other. Results also indicated that though stone-quarrying activities have impacts on ground cover plants, however, they are not the only factor affecting ground cover plants. More than 80% of the impacts on ground cover plants are caused by factors other than stone quarrying but were not identified during this study. It was therefore recommended that future studies in the area on the same theme should isolate the effects of stone quarrying on ground cover plants from these other operating factors through discriminant functional analysis.

Keywords: quarrying activities, ground cover plants, environment, discriminant analysis, game reserve

1. Introduction

A quarry is a surface mining-operated area, which produces enormous quantities of gravel, limestone, and other materials for industrial and construction applications [1]. It is a form of land use and part of the local heritage where non-metallic rocks and aggregates are extracted from land [2–4]. Generally, the effects of dust emission from quarries have both micro-spatial and regional dimensions. Air pollution and ground vibration arising from blasting, crushing, and emission of noxious gases have negative impacts on human health and well-being [3]. Several studies have been conducted on the negative impact associated with the environmental effects of quarry activities. One of the biggest negative impacts of quarrying on the environment is the damage to biodiversity, especially the damage caused to plants by pollution resulting from quarrying activities that include necrosis (dead areas on leaf structure), chlorosis (loss or reduction of chlorophyll leading to yellowing of leaf), epinasty (downward curvature of the leaf due to higher rate of growth on the upper surface), and abscission of leaves, that is, premature fall [5–9].

The main focus of this study is to assess the extent of impact of stone-quarrying activities on the ground vegetation, specifically grasses and low-lying herbaceous plants in the Mt. Korok area and its environs within Juba County, Central Equatoria State, South Sudan. The study area constituted a core area of the now-defunct Juba Forest and Game Reserve. The investigation was carried out with the view to provide baseline information on the subject. Moreover, it was hoped that the information obtained would be used to guide policy and management, decision making, and development of mitigation strategies. In addition, the information generated by this study would contribute to the pool of information that many future researchers will use to develop further research concepts and projects.

1.1 Specific objectives were

1. To generate baseline data describing structural composition of grasses and herbal plant communities around the quarrying sites

2. To determine the structural composition of species density, diversity, present ground cover, and frequency distribution at each of the selected site

3. To formulate measures to curb quarrying operations in the area including their impacts on the local environment and to suggest measures that can minimize impacts of quarrying operations

1.2 Quarrying as a human activity

For thousands of years, man has used stone for building, whether it was for monuments, religious buildings, or houses. Early on, man's use of stone and his primitive quarrying would have had little lasting impact on the environment. It was a good material with which to build castles, walls, churches, and important buildings since it was strong and weather resistant [9]. Over the past century, quarrying of building stones and other building material has been on the rise due to increased demand for building material [10]. This has been enhanced by the increased and expansion rate of urbanization locally and internationally [10, 11]. Quarrying is

undertaken in different parts of the world, and it impacts the environment and the socio-economic status of the people [12].

The impact on the social economy can be either positive or negative [12–14]. However, the environment is negatively impacted through loss of biodiversity, dust pollution, water pollution, lowering of the water table, soil erosion, and noise pollution [10, 13, 15, 16]. The Victorians, for example, used stone for all their major buildings, and with better transport and new technology, they were able to meet the increasing demands, probably with little thought to their impact on the environment [17, 18]. Today, it is estimated that over 13 million people in about 30 countries across the world are engaged in quarrying, with about 80 million to 100 million people depending on the extractive activities for their livelihood [19].

Quarrying, like many other man's activities, is a process that undergoes different steps, and it involves physically going out into the field and searching for stone; this is then followed by the actual excavation of stone/minerals from the ground [20]. This is achieved in many different ways, depending on what type of stone it is and what you want to take out of the ground. This activity degrades the land after it is quarried, so it is important to study it in order to asses it and to avoid great damage to the environment [18, 20].

As reported in [18, 20, 21], these activities, unfortunately, cause significant impact on the surrounding environment. The extraction process in advanced situations normally depends on heavy machines and explosives, where both processes are normally associated with air pollution, noise pollution, damage to biodiversity, and habitat destruction [14, 22–24]. In addition to water [25], fertile soil is dislocated and interrupted, leaving a big, gaping landscape [26, 27]. The impact can range from scarcely perceptible to highly obtrusive, and the impact can similarly vary widely depending on how quarrying stone was done, the method of quarrying, and the characteristics of the quarry site and its surroundings [28].

One of the biggest negative impacts of quarrying on the environment is the damage to biodiversity, which, essentially, refers to the range of living species, including fish, insects, invertebrates, reptiles, birds, mammals, plants, fungi, and even microorganisms, and quarrying activity has the potential of destroying the habitats and species it supports [7, 23, 24, 29]. Even noise pollution can have a significant impact on some species and affect their successful reproduction, though with careful planning and management, it is possible to minimize the effect on biodiversity, and in fact, quarries can also provide a good opportunity to create new habitats or to restore the existing ones [2, 30].

Dust pollution from quarrying operations both on site and on roads affects the local air quality as well as may lead to serious health. The main potential impacts of dust are visual impacts, coating/soiling of property (including houses, washing bays, and cars), coating of vegetation, contamination of soils, water pollution, change in plant species' composition, loss of sensitive plant species, increased inputs of mineral nutrients, and altered pH balances [24, 28, 31] .

Development requires the utilization of available resources, but very often, it does not check the effects of resource utilization on the environment, [24, 32]. However, quarrying in most developing countries suffers from a number of constraints including a lack of basic knowledge and safety precautions, poor working conditions, low socioeconomic status, lack of clear quarrying legislation, and environmental degradation that call for special attention [4, 5, 33]. On the other hand, quarrying has played a critical role in improving the livelihood of people living in rural areas and town suburbs by creating additional job opportunities and helping to generate additional

income [4, 34]. In Africa, East Asia, Southeast Asia, and Latin America, accessibility to natural resources plays a critical role in the livelihood conditions of people; since the formal sectors in developing countries have very little potential in terms of job creation, the informal sector has become an attractive alternative for achieving livelihood needs [4, 35, 36].

1.3 Quarrying activity in South Sudan: past and present

Stones have been quarried in Sudan and South Sudan since the ancient times, at least the beginning of the 14th century and probably long before that. There are multiple records of stone uses in those times; in the middle of the 15th century and after that, stones or quarried stones were used as tools in daily life, for instance, in putting up shelters and many other things, and it was also as much a matter of prestige as of the availability of materials [37]. Most of the stone quarrying was on a small scale and took place close to where the stone was wanted. However, from the recent times, some stone quarries were established due to great demand both locally and further afield in South Sudan for roads and building constructions, especially during the autonomous government in the then Southern Sudan and after the independence of South Sudan in 2011 [38, 39].

2. Materials and methods

2.1 Description of the study area

The area is characterized by a crystalline basement (age: Precambrian) and a hilly and more or less dissected country with well-defined drainage and occasional development of rapid erosion at headwaters [40]. The major physical feature of the reserve is the hilly and rocky outcrops of Mt. Korok itself (also known locally as *Jebel Kujur*, meaning the witch's mountain), which in other parts form very steep and non-negotiable cliffs with trees growing out of their cracks.

Map of the area (see **Figure 1**) encompasses the former Juba Forest and Game Reserve (JFGR). This reserve was established during the British colonial rule in 1939 for the protection of both the unique fauna and flora of the area. It is located to the west of Juba (the capital city of South Sudan) not more than 10 km away from the original Juba town center. The northern boundary of the reserve extends from the mouth of river Lurit to a point on it due north of the summit of Korok Mountain and, from the east, the west bank of *Bahr el Jebel* (The River Nile); the southern boundary is river Dorodo (*Khor Ramla*) from its source to its mouth, and finally, the western boundary is represented by the straight line joining the western limits of the northern and southern boundaries, that is, the town of Juba with its extensions inside the original protected area [41].

The abrupt increase in the population of Juba town as a result of the influx of people from rural areas and the returnees from neighboring countries, following the Peace Agreement of 2005 and the subsequent independence of South Sudan in 2011, has caused a total destruction of JFGR as people scrambled for land to build houses and grow crops. With the subsistent mode of living and their direct dependence on the traditional resources, tree felling, quarrying, charcoal mongering, cultivation, and hunting became rampant and have seriously denuded and deteriorated the area. In the absence of functional laws for protected areas at the time of independence, coupled

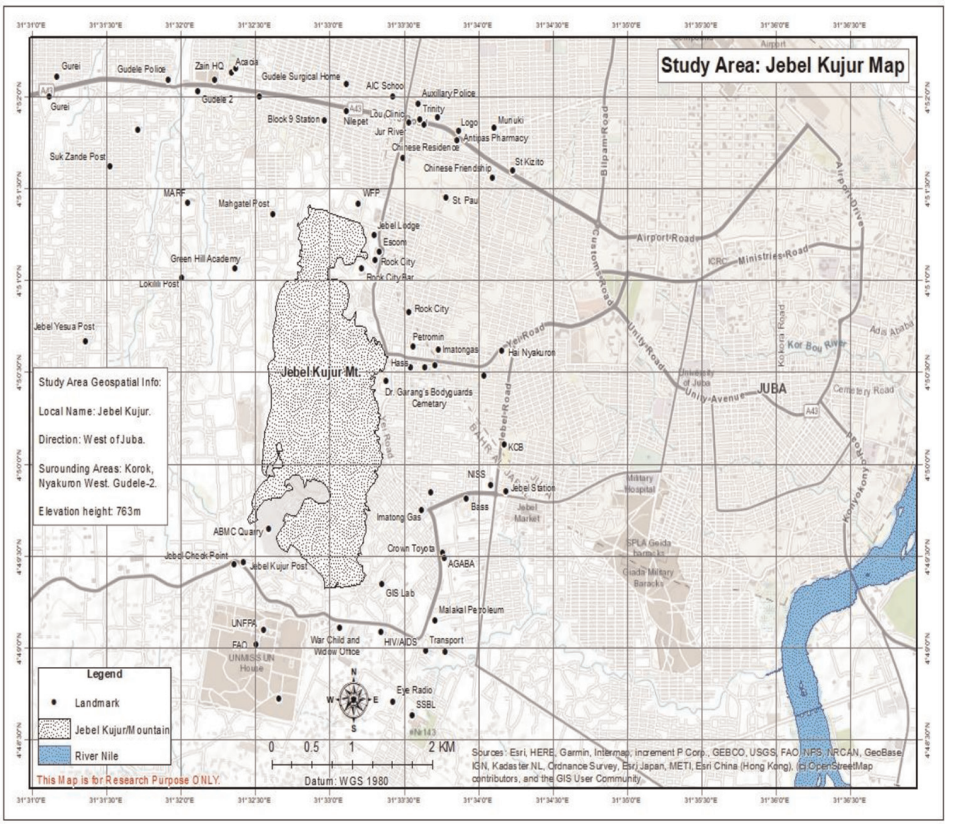


Figure 1.
Map of the study area.

with the ecstasy and euphoria of independence, the Mt. Korok area was gazetted for human habitation the Juba Forest, and Game Reserve was abolished. The degree of environmental degradation that ensued and the disappearance of flora and fauna of the area resulting from human influences have not been properly described or quantified. So, this study is an attempt to describe an aspect of such degradation based on stone-quarrying activities.

The climate is tropical with two distinct wet and dry seasons in a year. The wet season is from April to October and the dry one from November to March. The temperatures are hot all the year round. The minimum temperature ranges from 17 to 25°C during the rainy seasons and the maximum from 25 to 40°C during the dry seasons, with February being the hottest, reaching the maximum of (40°C). Rainfall during the year can reach a total of 1000 mm. Precipitation of more than 1739 mm has been recorded. Rainfall from April to October can reach 99.09 mm per month. Therefore, the climate is characterized as being tropical due to proximity to the equatorial zone within the Central Equatoria state and has savannah vegetation (Directorate of Metrology, South Sudan, 2020).

When the reserve was first established, many different animal species existed therein, including mammals, for example, lion, hyena, leopard, elephant, giraffe, and many kinds of antelopes as well as primates, notably baboon, colabus monkey, vervet

monkey, and others. There was also a huge assortment of birds, reptiles, and amphibians. On the other hand, the area was thickly vegetated with woodland savannah species, for example, trees and shrubs such as *Acacia hookii, A. mellifera, A. seiberiana, A. gerrardi, A. senegal*, *Zizphus spina christi, Z. abyssinica, Piliostigma thoingii, Harisonia abyssinica, Grewia mollis. Tamarindus indica, Celtis integrifolia, Kaya senegalensis, Euhporbia candelabra, Boswelia spp, Xemania Americana Acacia hookii, A. mellifera, A. seiberiana, A. gerrardi, A. Senegal*, *Zizphus spina christi, Z. abyssinica, Piliostigma thoingii, Harisonia abyssinica, Grewia mollis, T. indica, Celtis integrifolia, Kaya senegalensis, Euhporbia candelabra, Boswelia spp,* and *Xemania Americana* and many grass and herbaceous plant species such as *Hyperrhenia spp, Sprobalus spp, Themeda trianda, Chrysopogon aucheri, Piracharia ruziziensis, Andropogan spp, Cenchrus cililris, Cynodon dactylon, Entropogon macrostachyus, Solanum incanum, Impomea cordofana, Trifolium semifilosum*, *Cyanthla orthacantha*, *Dosmodium uncinatum*, and *Indigofera scliperi* to name but a few [41, 42].

2.2 Research design

This study was carried out during the rainy season in the period from June 11 to September 27, 2020. In this study, following initial visits to the area and conducting a pilot survey, three sites were identified and selected to suit the purpose of this study. The first was Site 1, an area that was formerly subjected to stone-quarrying activities but was now abandoned for over seven years (see **Figure 2**).

The second was Site 2, an area where active stone quarrying work was going on at the time of this study (see **Figure 3**) and where it was visibly badly trampled by trucks and pedestrians working on the site and was therefore affected by road pollution including dust, oil spills, and leftover garbage.

The third was Site 3, an area where there had never been any form of stone quarrying activity before and or during the time of this study (see **Figure 4**).

The underlying idea was to sample grass and indeed all low-lying herbaceous plants covering the ground in these selected sites within Korok area by the use of a 1 ×



Figure 2.
Site 1, formerly quarried site now abandoned. Source: field survey, 2020.



Figure 3.
Site 2, actively quarried. Source: field survey, 2020.



Figure 4.
Site 3, an area never subjected to quarrying before. Source: field survey, 2020.

1 m iron frame quadrat, so as to assess the impacts of stone quarrying on the aspects of biodiversity, specifically grass and low-lying plants within those delineated areas.

2.3 Data collection techniques

Impacts of stone quarrying on ground cover vegetation in Korok area were described through the collection of data on abundance, frequency distribution, diversity, and ground cover of grass and herbaceous plants. The objective was to determine how density varied between sites as a consequence of stone-quarrying activities or the absence thereof. A 1 m^2 quadrat was used to estimate the density of grasses and low-lying herbaceous plants in these sites. 100 m^2 of Korok area was delimited, and the number of grass species and other low-lying plant cover within 10 randomly placed

quadrats was then counted. The random placing of the quadrats within the area was achieved by the use of a random number table to define the upper left-hand corner of each quadrat. This sampling protocol was repeated at the three chosen sites, and it followed that:

1. Density of grass species was measured by counting the number of individuals of the study species within each quadrat. Only the plants rooted within the quadrat were counted.

2. Visual estimate of percentage cover was made within each quadrat rather than for the whole study area, and later on, these were summarized and extrapolated for the whole area following Domin and Braun-Blanquet scales for visual estimates of cover [43].

3. Frequency of occurrence was calculated as the percentage of the quadrats placed in which the species were observed [44].

4. Grass species and low-lying herbal plants were measured by harvesting the above-ground parts of the plants—which were cut at a certain height from the surface of the substratum, usually at or close to the ground level. A knife, scissors, shears, saw, or chainsaw was used, depending on the grass type. The plant materials were then taken to the laboratory, in bags or sacks when possible, and then sorted into species for purposes of determining diversity indices [43].

2.4 Data analysis

2.4.1 Analyzing community diversity

To determine three important community characteristics:

- Species richness within each site
- Species diversity within each site
- The similarity of grass and herbaceous plant communities between sites

Species richness is simply the tally of different grass species that were identified in a site. Species diversity is a more complex concept. In this work, a standard index called Simpson's Reciprocal was used:

$$D = \sum p_i^2 \quad (1)$$

Where p_i = the fractional abundance of the ith species on a site.

Thus, the higher the value, the greater is the diversity. The maximum value is the number of species in the sample, which occurs when all species contain an equal number of individuals. Because this index reflects not only the number of species present but also the relative distribution of individuals among species within a community, it can reflect how "balanced" communities are in terms of how individuals are distributed across species, sometimes referred to as "evenness" [45, 46]. As a result,

two communities may have an identical complement of species, and hence species richness, but substantially different diversity measure if individuals in one community are skewed toward a few of the species, whereas individuals are distributed more evenly in the other community.

2.4.2 Analyzing community distinctiveness

Another important perspective in ranking sites is how different the communities are from one another. The simplest available measure of community similarity used here was the Jaccard Coefficient of Community Similarity (CC_J), to contrast community distinctiveness between all the possible pairs of site [27]:

$$CC_J = c/S \tag{2}$$

Where *c* is the number of species common to both communities and *S* is the total number of species present in the two communities.

This distinctiveness or similarity index measures the degree to which the species and relative abundance are shared between different grass communities. And the index ranges from 0 (when no species is found in common between communities) to 1 (when all species are found in both communities). In other words, completely similar communities have an index of 1, while completely dissimilar communities have an index of 0. This index was calculated to compare each pair of sites separately, that is, compare Site 1 with Site 2, Site 1 with Site 3, and Site 2 with Site 3 for a total of three comparisons.

2.4.3 Testing for difference of observed median densities

To test if the medians of the observed densities at the three sites were significantly different, a Kruskal-Wallies test was run to compare the medians. And the null hypothesis in this case was that there was no significant difference in the median densities of grass and herbaceous plants species at the three chosen sites.

2.4.4 Calculation of prominence value (PV)

This is a measure of distribution and abundance for each species. This value weighs species abundance by its frequency of occurrence at sample points within each study site [47]. The formula involved is:

$$PV = D \times \sqrt{F} \tag{3}$$

Where PV = number of individuals (D) of each species from all counts in each site multiplied by the square root of frequency of occurrence (F).

Cover is a measure of the area covered by the above-ground parts of plants of a species when viewed directly from above [44]. Because the vegetation may be layered, the cover of all species often sums to more than 100%. In this study, cover was assessed and analyzed according to Domin and Braun-Blanquet scales for visual estimates [43].

2.4.5 Ground cover estimation

Although density and frequency indicate numbers and distribution, they do not indicate size, volume of space occupied, or amount of ground covered or shaded. These characteristics are desirable additional values that contribute materially to an understanding of the importance of a species in a stand, since they are closely related to dominance [48]. Cover can be estimated with some success or may be accurately determined by various devices for measurement and recording. When vegetation is stratified, the cover must be considered in terms of the stratum, zone, or site to which the species belongs. For rapid estimation as well as for analysis of results, there is a distinct advantage at times in using cover classes rather than the specific values; classes of the following number and magnitude are commonly used, covering: (a) less than 5%, (b) 5–25%, (c) 25–50%, (d). 50–75%, and (e) 75–100% [48].

3. Results and discussion

3.1 Plant cover species identified

Principally, the grass family is undoubtedly the most important plant family, and the fifth largest plant family on earth [49]. The largest plant families (in decreasing order) are the Asteraceae (sunflower family), Fabaceae (legumes), Orchidaceae (orchids), and Rubiaceae (gardenia family). **Table 1** shows the grass and other

Family	Species	Stone quarry**		
		Site 1$^{\alpha}$	Site 2$^{\beta}$	Site 3$^{\theta}$
Nyctaginaceae	*Boerhavia diffusa*	+		
Poaceae	*Dactyloctenium aegyptium*	+		
	Urochloa poicoides	+		
	Brachiaria ramose	+	+	
	Eragrostis biflora	+		
	Cymbopogan validus	+		
	Digitaria longiflora	+		
	Urochloa mosambiansis	+		
	Urochloa oligotrich	+		
	Digitaria fermata		+	
	Eragrostis ciliaris		+	+
	Panicum laetum		+	
	Cymbopogan spp 1?*			+
	Eragrostis pseudosenerantha			+
	Eragrostis spp 1?*			+
	*Hyperrhenia spp1?**			+
	Aristida pallida			+
	Eragrostis spp 2?*			+

Family	Species	Stone quarry**		
		Site 1$^{\alpha}$	Site 2$^{\beta}$	Site 3$^{\theta}$
	Cymbopogan spp 2?*			+
Acanthaceae	*Monechma ciliatume*	+		+
Graminae	*Cynodon lemfuensis*	+	+	+
	Cynodon dactylon	+	+	+
	Chloris pychothrix		+	
	Chloris virgate		+	
	Chloris gayana		+	+
Anaranthaceae	*Achyranthes aspera*	+	+	+
	Amaranthus graecinzans			+
Asclepiadaceae	*Leptodenia hastate*	+		
Rubiaceae	*Mitracarpus scaber*	+		
Fabaceae	*Crotalaria podocarpa*	+		
Euphrbiaceae	*Euphorbia herta*	+	+	+
Commelinaceae	*Commelina colona*	+		
Pedaliaceae	*Sesamum alatum*	+		
Cyperaceae	*Cyperus rotundus*		+	+
	*Cyperus ssp 1?**			
Mollugnaceae	*Limeum pterocarpum*		+	
Convolvulaceae	*Merremia piñata*			+
Capparaceae	*Cadapa farinose*			+
Salvadoraceae	*Salvadora persica*			+
?	Spp 1?††	+		
	Hibiscus spp. 1?*	+		+
?	Spp 2?††	+	+	+
?	Spp 3?††		+	+
?	Spp 4?††		+	

Species not positively identified.$^{\alpha}$Old, abandoned quarrying site. Site where species existed is marked (+).$^{\beta}$Site with active quarrying operations.††Species not identified but noted.$^{\theta}$Site not quarried before (control).*

Table 1.
A checklist of grass and non-woody herbaceous plants identified at three stone quarrying sites in Korok area.

herbaceous plant species identified during field observations in three locations at Korok area.

In **Table 1**, a total of 44 species of grasses and low-lying non-woody herbaceous plants were identified at three study sites within Korok area. In this study, a list-count quadrat was used as mentioned earlier, that is, a simple tabulation of the species present, where the species were identified and their numbers counted. The species identified were then grouped into 16 families, though the number of families could be more since there were certain species that were not positively identified. The family

Poaceae contained the majority of the species identified:18 (41%). Members of other families were not so common in the area. Notably, some species were conspicuously common and occurred in all the three sites; these included two grass species, namely, *Cynodon lemfuensis* and *Cynodon dactylon* (family Graminae); three of the non-woody herbaceous plant species: *Achyranthes aspera* (family Amaranthaceae) and *Euphorbia hirta* (family Euphorbiaceae); and a third species that was not identified properly and is referred to as *Spp2* (see **Table 1**). Others were observed in any two sites only, whereas there were those that occurred only in Site 1, Site 2, or Site 3.

It is worth noting that of all the species identified in the three study sites altogether, herbaceous plants constituted about 30% and grasses 70%. Site 1 (which was an old abandoned quarrying area) contained 25% of all the plant species (both grasses and herbaceous plants). Usually, herbaceous plants are invaders that tend to recolonize an area that was formally disturbed but now left to rest [50]. Site 2 contained about 14% only of all the grass and herbaceous plant species identified; and these belonged to three families (two grasses: families Poaceae and Graminae and one herbaceous plant: family Mollugnaceae). And the species that were found only in this site included: *Brachiaria ramose*, *Digitaria fernosa*, *Chloris pychothrix*, *Chloris virgate*, and *Limeum pterocarpum*, and they are disturbance tolerant [51]. Site 3 (an area not subjected to stone quarrying before) contained about 23% of all the grass and non-woody herbaceous plant species belonging to four families, three of which were non-woody herbaceous plants (family Convolvulaceae, family Capparceae, and family Salvadoraceae) and one grass family with seven species (family Graminae). Characteristically, the two sites where no stone-quarrying activities existed (Site 1 and Site 3) had a strong presence of and higher densities of non-woody herbaceous plant species.

3.2 Community structure: diversity, species richness, and similarity

In analyzing and discussing the community structure of the local vegetation ground cover, the focus is on three community characteristics, namely:

- Species richness within each site
- Species diversity within each site, and
- The similarity of plant communities between sites

Species richness is simply the tally of different plant species that are observed in a site. Species diversity is a more complex concept. In this study, it was obtained using a standard index, the Simpson Reciprocal Index (see **Table 2**); the higher the value, the greater is the diversity. So, the results showed that Site 1 (an old, abandoned quarry area) had the greatest diversity followed by Site 3 (a non-quarry area), whereas Site 2 (an actively quarried area) had the least diversity. Because this index reflects not only the number of species present but also the relative distribution of individuals among species within a community, it can reflect how 'balanced' communities are in terms of how individuals are distributed across species [27]. As a consequence, two communities may have a more or less identical complement of species, and hence species richness (just as in the case of Site 2 and Site 3) but substantially different diversity measures if individuals in one community are skewed

Species	Site 1^{α}	*pi*	pi^2	Site 2^{β}	*Pi*	pi^2	Site 3^{θ}	*pi*	pi^2
Boerhavia diffusa	12	0.0667	0.0044						
Dactyloctenium aegyptium	6	0.0333	0.0011						
Urochloa poicoides	1	0.0056	0.0000						
Brachiaria ramose	2	0.0111	0.0001	66	0.2833	0.0802			
Eragrostis biflora	9	0.0500	0.0025						
Cymbopogan validus	3	0.0167	0.0003						
Digitaria longiflora	2	0.0111	0.0001						
Urochloa mosambiansis	2	0.0111	0.0001						
Urochloa oligotrich	5	0.0278	0.0008						
Digitaria fermata				92	0.3948	0.1559			
Eragrostis ciliaris				50	0.2146	0.0460	7	0.0292	0.0009
Panicum laetum				7	0.0300	0.0009			
*Cymbopogan spp 1?**							8	0.0333	0.0011
Eragrostis pseudosenerantha							10	0.0417	0.0017
*Eragrostis spp 1?**							5	0.0208	0.0004
*Hyperrhenia spp1?**							25	0.1042	0.0109
Aristida pallida							2	0.0083	0.0001
*Eragrostis spp 2?**							12	0.0500	0.0025
*Cymbopogan spp 2?**							8	0.0333	0.0011
Monechma ciliatume	4	0.0222	0.0005				11	0.0458	0.0021
Cynodon lemfuensis	97	0.5389	0.2904	244	1.0472	1.0966	57	0.2375	0.0564
Cynodon dactylon	2	0.0111	0.0001	42	0.1803	0.0325	15	0.0625	0.0039
Chloris pychothrix				7	0.0300	0.0009			
Chloris virgate				2	0.0086	0.0001			
Chloris guayana				1	0.0043	0.0000	3	0.0125	0.0002
Achyranthes aspera	2	0.0111	0.0001	5	0.0215	0.0005	8	0.0333	0.0011
Amaranthus graecizans							3	0.0125	0.0002
Leptodenia hastate	1	0.0056	0.0000						
Mitracarpus scaber	4	0.0222	0.0005						
Crotalaria podocarpa	9	0.0500	0.0025						
Euphorbia herta	2	0.0111	0.0001	5	0.0215	0.0005	26	0.1083	0.0117
Chloris guayana				1	0.0043	0.0000	3	0.0125	0.0002
Achyranthes aspera	2	0.0111	0.0001	5	0.0215	0.0005	8	0.0333	0.0011
Amaranthus graecizans							3	0.0125	0.0002
Leptodenia hastate	1	0.0056	0.0000						
Mitracarpus scaber	4	0.0222	0.0005						
Crotalaria podocarpa	9	0.0500	0.0025						

Species	Site 1^{α}	*pi*	pi^2	Site 2^{β}	*Pi*	pi^2	Site 3^{θ}	*pi*	pi^2
Euphorbia herta	2	0.0111	0.0001	5	0.0215	0.0005	26	0.1083	0.0117
Commelina colona	2	0.0111	0.0001						
Sesamum alatum	3	0.0167	0.0003						
Cyperus rotundus				35	0.1502	0.0226	126	0.5250	0.2756
*Cyperus ssp 1?**							36	0.1500	0.0225
Limeum pterocarpum				5	0.0215	0.0005			
Merremia piñata							94	0.3917	0.1534
Cadapa farinose							32	0.1333	0.0178
Salvadora persica							2	0.0083	0.0001
Spp 1?††	8	0.0444	0.0020						
*Hibiscus spp 1?**	3	0.0167	0.0003				2	0.0083	0.0001
Spp 2?††	1	0.0056	0.0000	22	0.0944	0.0089	6	0.0250	0.0006
Spp 3?††				4	0.0172	0.0003	2	0.0083	0.0001
Spp 4?††				8	0.0343	0.0012			
$\sum$	180		0.3065	233		1.4476	240		0.5644
Simpson's Reciprocal Index	= 1/D (and D = $\sum p_i^2$)		3.2628			0.6908			1.7719

**Species not positively identified.* $^{\alpha}$*Old, abandoned quarrying site.* $^{\beta}$*Site with active quarrying work.* $^{\theta}$*Site not quarried before (control).*††*Species not identified but noted.*

Table 2.
Comparing grass and other herbaceous plant species diversity, species richness, and community similarity indices among the three stone-quarrying sites in Korok area.

toward a few of the species, whereas individuals are distributed more evenly in the other community.

Diversity is one thing, but distinctiveness is quite another. Thus, another important perspective in ranking sites is how different the communities are from one another [27]. The simplest available measure of community similarity is calculated as shown in **Table 3**; this index ranges from 0 (when no species is found in common between communities) to 1 (when all species are found in both communities). So, as shown in **Table 3**, this index was calculated to compare each pair of sites separately, that is, compare Site 1 with Site 2, Site 1 with Site 3, and Site 2 with Site 3, a total of three comparisons.

It is useful to determine the average similarity of one community within a site to all the others, by averaging the (CC_j) values across each comparison in which a particular site is included. Once the calculations of diversity (species richness and Simpson's Reciprocal Index) as in **Table 2** and distinctiveness (CC_j) as in **Table 3** are made, the primary question of how the three selected sites should be ranked in terms of the extent of stone-quarrying impacts on the local vegetation cover, making an informed decision that requires reconciling the analysis of community structure with concepts of biological diversity as it pertains to diversity and distinctiveness, could be answered.

Pair of sites compared	JCC* = c/S**	Number of common species	Total species in both sites
Site 1 vs. Site 2	0.1875 ≈ 18.8%	6	32
Site 1 vs. Site 3	0.1842 ≈ 18.4%	7	38
Site 2 vs. Site 3	0.3 ≈ 30%	9	30

For detailed calculation of JCC = c/S, see (Appendix A).c = number of species common to both communities (being compared) and S = total number of species present in the two communities.*

Table 3.
Using the Jaccard Coefficient of Community Similarity, JCC = c/S [27], the contrast community distinctiveness between all the possible pairs of sites.

The decisions can be based principally on the estimates of species richness, diversity, endemicity (species found at only one site), and community similarity. However, once those decisions are made, it might also be good to look at the spatial arrangement of the selected sites and compare that to the species distributions. This might help in the interpretation of the species distributions and might give useful additional information for ranking the sites according to the damage caused by stone-quarrying operations.

3.3 Frequency distribution

As referenced in [43], under some circumstances, it may not be practicable to make actual counts, but plentifulness may be rapidly estimated according to some scale of abundance such as very rare, rare, infrequent, abundant, and very abundant. Such estimates are particularly useful when several similar stands of uniform composition are to be surveyed within a limited time, as was the case in this study. When there is time for adequate sampling, the determination of actual numbers by counting is of greater value, because it permits the expression of density, which is the abundance by number on a unit-area basis. During the field observations in this study, deliberate efforts were dedicated in order to identify and count plant species so that their density could be determined numerically. Of course, not all species with equal densities are of equal importance in a community, or need to be similarly distributed. It therefore becomes necessary to interpret density values or to specify other characters that, combined with density, serve to complete the picture. One such value is frequency. This value is an expression of the percentage of sample plots in which a species occurs [43]. Thus, frequency becomes a very useful value, when used in combination with density, for then not only the number of individuals but also how widely they are distributed in the site under study is known. Knowledge of these two quantitative characteristics, in combination, is fundamental to an understanding of the community structure.

It should be emphasized that frequency values cannot be compared unless determined with plots of equal size. The larger the plots, the higher is the frequency. In this study the frame quadrat used was of fixed size 1×1 m^2. In [44], it is asserted that frequency may conveniently be grouped into classes, for example, A (1–20%), B (21–40%), C (41–60%), D (61–80%), and E (81–100%). The results of this study showed that the total frequency for each individual species identified and counted was very low, and if the above frequency classes were to be used, then almost all species would have their frequency in the first class, that is, A (1–20%). And this does not tell much and is therefore meaningless. So, instead of expressing frequencies in terms of

percentages, it was thought better to express them in terms of prominence values (see **Table 4**), which is a measure of both abundance and distribution [47]. And in **Table 4**, six species stand out very clearly as being the most abundant and widely distributed all over the three study sites and/or at least in two sites; they are in order of magnitude from the highest to the lowest: *Cynodon lemfuensis*, *Cyperus rotundance*, *Brachiaria ramosa*, *Merremia piñata*, *C. dactylon*, and *Digitaria fernata*. Two other species, namely, *Euphorbia herta* and another that was not positively identified but

Species	Site 1$^{\alpha}$	Site 2$^{\beta}$	Site 3$^{\theta}$	Total counted (D)	Total frequency (F)	Prominence value (PV)
Boerhavia diffusa	12			12	8	33.94
Dactyloctenium aegyptium	6			6	2	8.48
Urochloa poicoides	1			1	1	1
Brachiaria ramose	2	66		68	7	179.91
Eragrostis biflora	9			9	2	12.73
Cymbapogan validus	3			3	2	4.24
Digitaria longiflora	2			2	2	2.83
Urochloa mosambiansis	2			2	1	2
Urochloa oligotrich	5			5	1	5
Digitaria fermata		92		92	2	130.11
Erograstis ciliaris	7	50	7	57	4	114
Panicum laetum		7		7	2	9.9
*Cymbopogan spp 1**			8	8	2	11.31
Erograstic pseudosenerantha			10	10	1	10
*Erograstis spp 1**			5	5	1	5
*Hyperrhenia 1?**			25	25	1	25
Aristida pallida			2	2	1	2
*Eragrostis spp 2?**			12	12	1	12
*Cymbopogan spp 2?**			8	8	1	8
Monechma ciliatume	4		11	15	3	25.98
Cynodon lemfuensis	97	244	57	398	16	1592
Cynodon dactylon	2	42	15	59	5	131.93
Chloris pychothrix		7		7	1	7
Chloris virgate		2		2	1	2
Chloris guayana		1	3	4	2	5.66
Achyranthes aspera	2	5	8	15	3	25.98
Amaranthus graecizans			3	3	1	3
Leptodenia hastate	1			1	1	1
Mitracarpus scaber	4			4	2	5.66

Species	Site 1[α]	Site 2[β]	Site 3[θ]	Total counted (D)	Total frequency (F)	Prominence value (PV)
Crotalaria podocarpa	9			9	3	15.59
Euphorbia herta	2	5	26	33	3	57.16
Commelina colona	2			2	1	2
Sesamum alatum	3			3	1	3
Cyperus rotundus	2	35	126	163	5	364.48
*Cyperus ssp 1?**			36	36	1	36
Limeum pterocarpum		5		5	1	5
Merremia piñata			94	94	3	162.81
Cadapa farinose			32	32	1	32
Salvadora persica			2	2	1	2
Spp 1?††	8			8	3	13.86
Hibiscus spp. 1?*	3		2	5	2	7.07
Spp 2?††	1	22	6	29	8	82.02
Spp 3?††		4	2	6	2	8.48
Spp 4?††		8		8	2	11.31

[*]Species not positively identified.[α]Old, abandoned quarrying site.[β]Site with active quarrying work.[θ]Site not quarried before (control).[††]Species not identified but noted.

Table 4.
Determination of prominence value (PV) for all plant species identified in the three selected study sites within Korok area.

referred to as *Spp 2*, were observably and moderately common in abundance and frequency within the study sites.

3.4 Comparing median densities of grasses and non-Woody herbaceous plants

A non-parametric test, the Kruskal-Wallies test, was used to calculate the statistic (K) of the median densities of grasses and non-woody herbaceous plant species in the three selected sites. The null hypothesis was that there is no significant difference in the median densities of grasses and herbaceous plant species in the three sites. But it was found that $K = 21.76$. Comparing this calculated statistic with the tabulated distribution of χ^2 (Appendix C) in [52] at 2 degrees of freedom (df), the calculated value of K far exceeds the tabulated critical values of 5.99 and 9.21 at both $p = 0.05$ and $p = 0.01$, respectively. We therefore reject the null Hypothesis and conclude that there is a highly significant difference between the median densities of the grasses and the non-woody herbaceous plant species in the three sites ($K = 21.76$, $p < 0.01$, Kruskal-Wallies test) (**Table 5**).

3.5 Ground cover estimation

Using the approach mentioned in Section 2.4.5 above, results of this study revealed that Site 3 (a no-quarry area) had the highest cover followed by Site 1 (a formerly quarried area but now abandoned), whereas Site 2 (an area with intense quarrying

Site 1 (old, abandoned quarrying area)	Site 2 (area with active quarrying work going on)	Site 3 (area not quarried before – control)
2 (3)	42 (19)	30 (14)
6 (4)	36 (16)	50 (20)
1 (1.5)	148 (30)	28 (17)
1 (1.5)	84 (25)	51 (21)
25 (7.5)	85 (26)	22 (6)
27 (10)	117 (28)	77 (23)
28 (17)	40 (18)	20 (5)
26 (9)	81 (24)	124 (29)
32 (15)	66 (22)	87 (27)
25 (7.5)	39 (17)	29 (13)

N.B: for detailed calculation, see (Appendix B).

Table 5.
Median densities of grass and herbaceous plant species and ranked scores (in brackets) at three study sites in Korok area.

activities at the time of this study) had the least cover (**Figure 5**). It can therefore be concluded that quarrying operations in Site 2 to a great extent are responsible for the removal of the low-lying vegetation cover in the area.

3.6 Effects of stone quarrying on relative density and abundance of grass and non-Woody plants in these three sites

By comparing plant relative density at Site 1 and Site 2 (**Figure 5**), it is clear that plants at Site 1 (which is an old abandoned quarrying area) have a higher relative

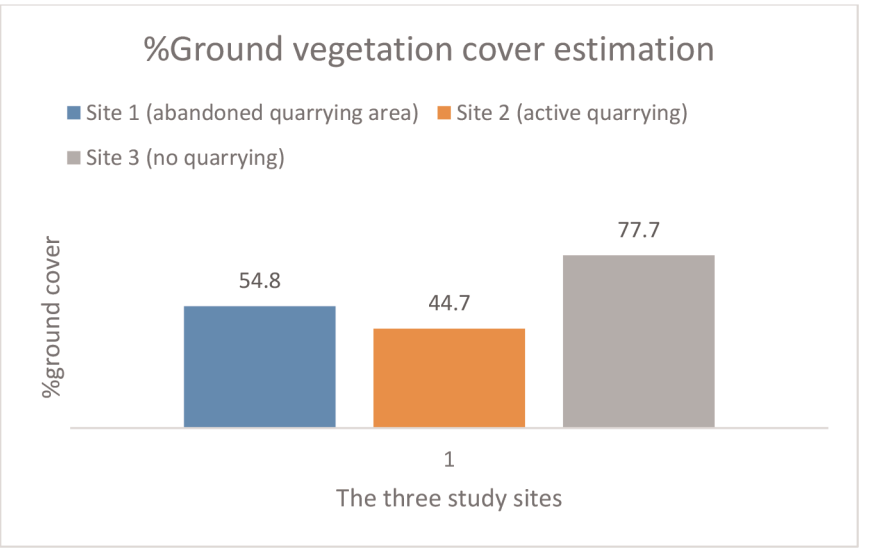


Figure 5.
Proportion of ground covered with grass and herbal plant species in each of the three study sites.

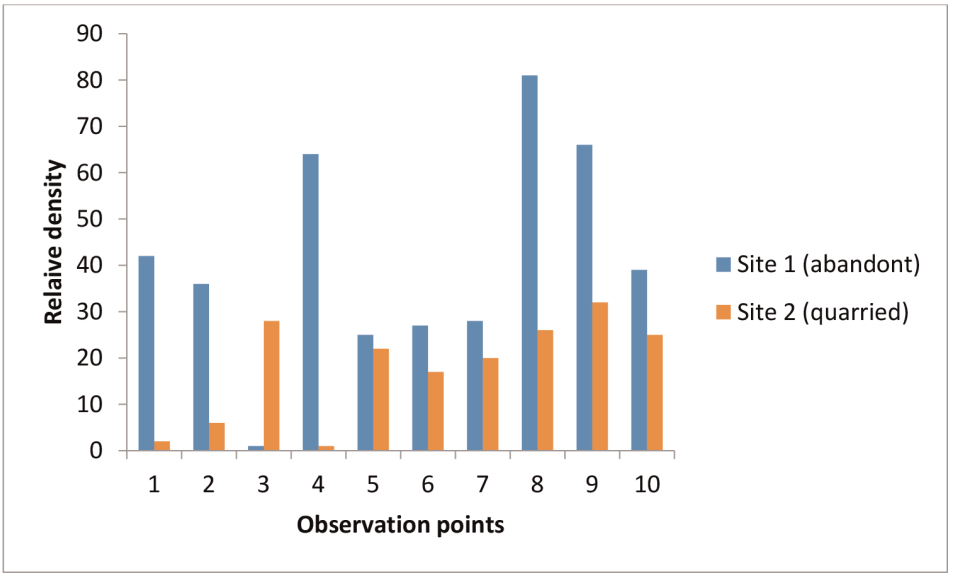


Figure 6.
Relative density and abundance of grass and herbaceous plant species in two study sites: Site 1 (abandoned quarrying area) and Site 2 (area under quarrying activities) within Korok area. (NB. Observation points are the ten sampling points in each site).

density than those at Site 2 (an area with stone-quarrying activities still going on), suggesting that stone-quarrying operations have an impact on the local ground cover (**Figure 6**).

Similarly, upon contrasting relative density of plants at Site 2 with that of Site 3 (an area with no stone-quarrying activities), the results showed that plants at Site 3 had a higher relative density than those at Site 2 (**Figure 7**). In both of these comparisons, results are consistent with the findings of previous researchers. For example, it was well documented how stone-quarrying can affect vegetation cover, which represents the main component of the ecosystem, hence the absence of balance in the volume of oxygen and carbon dioxide through photosynthetic activities [7, 25]. Likewise, it was noted that stone quarrying can indirectly affect local vegetation cover through its negative impact on the soil and pollute both surface and ground water [24, 53, 54]. In the same vein, [26] reported that stone quarrying has resulted in changes in soil properties such that soil in and around the quarrying area (0–1 km) was found to be alkaline (pH 11.2–11.7), and this was attributed to the high concentrations of hydroxyl, carbonate, and bicarbonate present in the minerals of mined materials. In addition to the physical removal of ground cover by tools used in mining and stone-cutting industries, the physiological mechanisms behind plant damage could be attributed to one or a combination of the following factors: dusts might cover the leaves with a white layer, thereby decreasing the total chlorophyll cells exposed to light and thus reducing the total photosynthetic activity [53].

In **Figure** 8, the two sites with apparently no stone-quarrying activities, the relative density of plants therein are both high. This suggests that when an area is not disturbed through human activities such as stone quarrying, the grasses and other non-woody herbaceous plants have the potential to reclaim the area and to establish themselves. And their presence also prevents soil erosion that results from the removal of ground cover by stone-quarrying operations. Plants are exceptionally

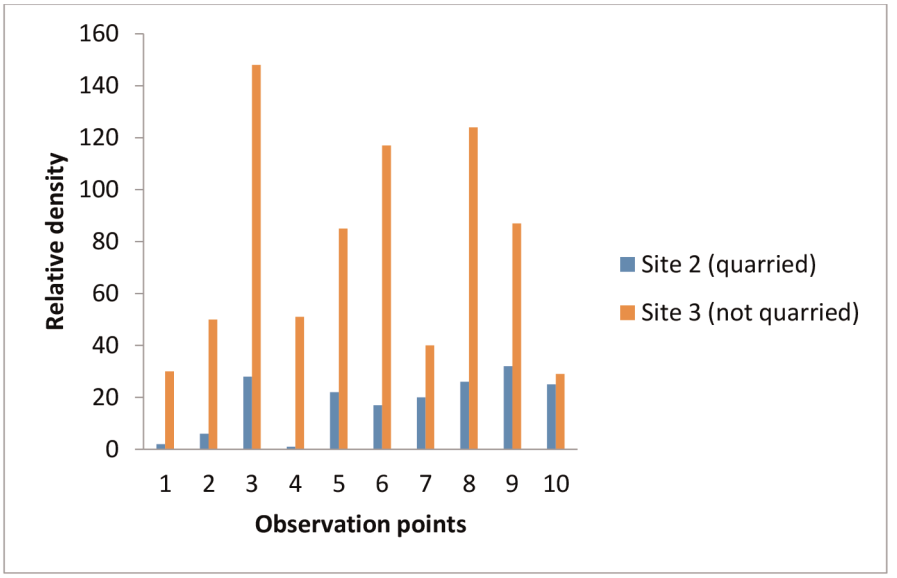


Figure 7.
Relative density and abundance of grass and forb-like plant species in two study sites: Site 2 (area under quarrying) and Site 3 (area with no quarrying activity) within Korok area.

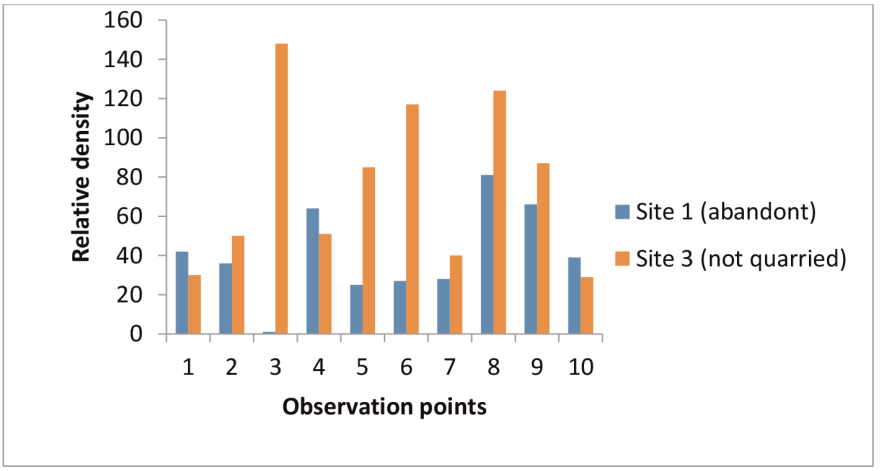


Figure 8.
Relative density and abundance of grass and herbaceous plant species in two study sites: Site 1 (abandoned quarrying area) and Site 3 (area with no quarrying activities) within Korok area.

effective in protecting the soil against the agents of erosion like water, wind, and sun. Grasses are known for being particularly effective in combating soil erosion [49]. Their growth points are very close to the ground level, and they often form stolons and/or rhizomes, which are good at stabilizing the soil [55]. If not disturbed by human activities, plant communities in the area will undergo the natural process of plant succession, which is the progressive succession of plant communities. When a disturbance like stone quarrying and the accompanying excavations takes place in an area, the area is recolonized by new, better-adapted plant communities [49]. The two sites

(1 and 3) share many species between them that are not found in the disturbed Site 2, which also suggests that the plant communities in them might be at a different level of plant succession, hence proving that stone-quarrying work is impacting the local vegetation cover negatively.

The relative densities of plants in the three sites are compared in **Figure 9**, and the difference is glaringly clear. Plants in the area with no stone-quarrying operations (Site 3) have the highest relative density, followed by those in the formerly disturbed but now abandoned area (Site 1), and, lastly, Site 2 (quarried area) plants with the least relative density.

However, despite this apparent difference in the densities of grass cover, the result of a Pearson's Moment Correlation Coefficient test (r) run to test the null Hypothesis that there was no significant difference in impacts due to quarrying activities *per se* in respect to relative plant densities between Site 2 and Site 3, a weak correlation of (r) equals 0.392 was obtained. The (r) value is far lower than the tabulated critical value of 0.632 for degrees of freedom 8 at $p = 0.05$. Therefore, the H_0 is accepted, and it was concluded that the positive correlation was statistically not significant. This suggested that although there was a positive weak correlation between the extent of stone-quarrying activities and relative density of plant constituting the local ground cover in Site 2 vs. Site 3, stone quarrying might not be the only factor affecting the densities of ground cover vegetation, notably grasses and low-lying herbaceous plants; hence, the impact is not significant. To establish this assumption, a coefficient of determination (r^2) was calculated to indicate how much other factors, besides stone-quarrying activities, influenced plant densities, distribution, frequencies, and cover. The coefficient of determination was found to be $r^2 = 0.154$; in other words, only about 15% of the impacts resulted from stone-quarrying activities in the selected study sides, meaning over 85% of variation in ground cover vegetation density was not accounted for by stone quarrying alone. It is probable that other factors such as bush burning, small-scale farming in the area, and construction work like building houses, roads, and so on could be major contributors impacting plant cover and density in the area. This must be investigated in future studies along this same theme. Unfortunately,

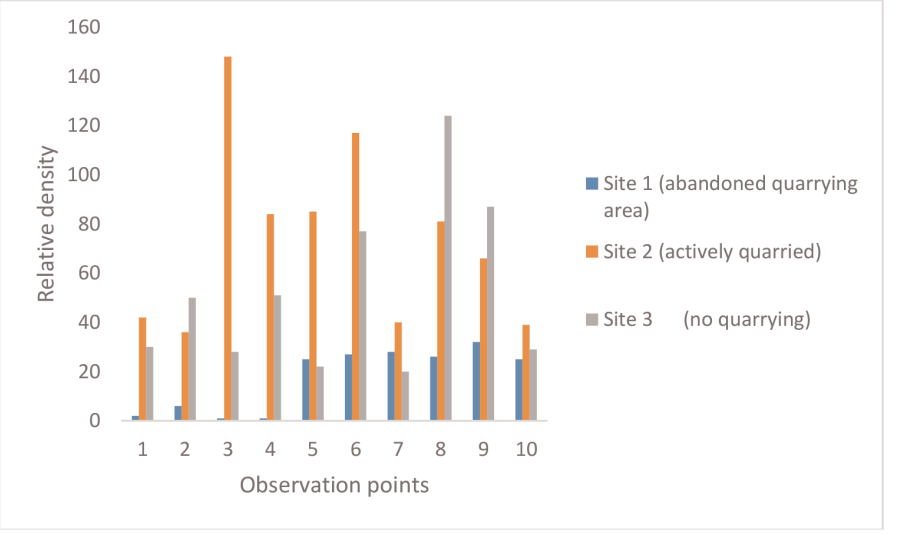


Figure 9.
Relative density and abundance of grass and forb-like plant species in the three study sites within Korok area.

given the short study period and limited finance and logistics, the kind of data collected could not be subjected to discriminant analysis technique so as to effectively isolate the negative effects of stone quarrying from other likely factors. Discriminant analysis is a powerful classification technique to discriminate the assigned observations to predefined groups [56].

Quarrying is a sensitive and a complex issue. On the one hand, quarrying supplies raw materials to meet many of the societies 'needs, creates employment, and contributes to the local economy [12, 57]. This part of South Sudan, that is, the Korok area, has always experienced and is still experiencing extensive quarrying activities. The residents of the area living adjacent to quarrying sites are exposed to disturbances and environmental impacts of stone quarrying: the constant traffic of heavy dumpers and the movements of lorries to and from the sites cause noise and the result of rock blasting generate dust, smoke, and fumes as well as suspended particles, all of which pollute the area. As a consequence, people who live near the quarrying areas are likely to develop respiratory diseases. Observably, in the area, quarrying activities also produce a growing number of abandoned quarry pits that are quickly filled-up with water in the rainy season and become suitable habitats for swarms of mosquitoes and freshwater snails that in turn act as intermediate hosts for *Schistosoma* and *Haematobium* that may eventually contribute to the prevalence of bilharzia, urinary problems, and malaria in people. Apart from these, land degradation and other negative impacts of stone quarrying include swamp creation, deterioration of underground water, and erosion of soil; moreover, quarrying activities such as excavation, digging, blasting, and clearing the land have direct effects on biodiversity.

4. Conclusion and recommendations

4.1 Conclusion

Quarrying and stone-cutting activities affect the general environment including destruction and removal of local vegetation cover, particularly grass and the low-lying non-woody herbaceous plants. The physical crushing, excavation, and removal of rocks produce high concentrations of particulate matter (dust), fumes, smoke, and other gaseous substances, which negatively affect vegetation in the vicinity of quarrying areas. Also, the stone-quarrying activities affect ground cover plants indirectly by affecting soil and water, which are vital resources for vegetation cover, thus exacerbating the problem. However, in the Mt. Korok area, stone-quarrying activities are not the only cause of ground cover vegetation destruction; there are other factors that equally affect the local vegetation cover, but they are yet to be determined.

4.2 Recommendations

1. This study has been limited in its extent as it was directed only toward the impact of stone-quarrying activities on the ground cover vegetation, mainly grasses and low-lying herbaceous plants. Future investigations of the same should be expanded to include the impacts on:

    a. Biodiversity in general

    b. Land environment (landscape forms, land use types)

c. Air environment (dust pollution, noise pollution)

d. Water environment (pollution of surface water and groundwater)

e. Livelihood of the communities living within or adjacent to quarrying sites in terms of their health, socio-economic status, and so on.

2. Future studies on the effect of quarrying on vegetation cover should properly isolate its negative effects on vegetation cover from the effects of other factors such as bush burning; construction works, for example, house and road building; as well as farming by using discriminant analysis, which is a powerful classification technique to discriminate the assigned observations to predefined groups.

3. Environmental impact assessment should be conducted prior to any stone-quarrying plans and should be made in compliance with the state and/or national development plan of the area.

4. Awareness campaigns should be conducted at various levels about the impacts of stone quarrying on vegetation and biodiversity in general in Korok area.

Acknowledgements

We are grateful to the School of Natural Resources and Environmental Studies, University of Juba, for supporting this study by allowing us to use the school's field tools and laboratory facility. We also thank the local government authority and the community leaders in the Mt. Korok area for granting us the permission to carry out the study in their area. Many other people also assisted us in the course of this study; to all of them, we say thank you for the support they gave us.

A. Appendix

Calculating community similarity by using the simplest measure, which is the Jaccard coefficient of community similarity to contrast community distinctiveness between all possible pairs of sites.

$$\text{Jaccard Coefficient of Community Similarity, CCJ} = c/S.$$

Where c = is the number of species common to both communities (being compared) and S = is the total number of species present in the two communities.

So, Site 1 vs. Site 2: is c/S = 0.1875, i.e., 18. 8%. 6 species are common, and total of both sites (22 + 16) − 6 = 32.

Site 1 vs. Site 3: is c/S = 0.184210526, i.e., 18. 4%. 7 species are common, and total of both sites is (22 + 23)−7 = 38. Site 2 vs. Site 3: is c/S = 0.3, i.e., 30%. 9 species are common, and total of both sites is (16 + 23) − 9 = 30.

B. Appendix

Calculating median densities of grass and forb-like plant species at the three sites in Korok area number of individual species observed (rank scores in brackets).

Site 1 (old, abandoned quarrying area)	Site 2 (area with active quarrying work going on)	Site 3 (area not quarried before – control)
2 (3)	42 (19)	30 (14)
6 (4)	36 (16)	50 (20)
1 (1.5)	148 (30)	28 (17)
1 (1.5)	84 (25)	51 (21)
25 (7.5)	85 (26)	22 (06)
27 (10)	117 (28)	77 (23)
28 (17)	40 (18)	20 (05)
26 (09)	81 (24)	124 (29)
32 (15)	66 (22)	87 (27)
25 (7.5)	39 (17)	29 (13)

n = 10	10	10	N = 30
R = 76	225	175	
R^2 = 5776	50625	30625	
R^2/n = 577.6	5062.5	3062.5	
$\sum(R^2/n)$ = 8702.6			

$$K = \left[\sum(R^2/n) \times 12/N/N + 1\right] - 3(N + 1)$$
$$= [8702.6 \times 12/30/(31) - 3(31)$$
$$K = 21.76$$

We compare K with the tabulated distribution of χ^2 (Appendix C) [52]. The degree of freedom is the number of samples less one (in this case 3–1 = 2). At 2 df, our calculated value far exceeds the tabulated critical values of 5.99 and 9.21 at both p = 0.05 and p = 0.01, respectively. We therefore reject the null Hypothesis and conclude that there is a highly significant difference between the median densities of the grass and herbaceous plant species in the three sites (K = 21.76, $p < 0.01$, Kruskal-Wallies test).

C. Appendix

Calculating the Product Moment Correlation Coefficient, r, for Study Site 2 vs. Study Site 3 at Korok area.

Site 2* (x)	Site 3* (y)	x^2	y^2	xy
42	30	1764	900	1260
36	50	1296	2500	1800
148	28	21,025	784	4144

Site 2* (x)	Site 3* (y)	x^2	y^2	xy
84	51	7056	2601	4284
85	22	7225	484	1870
117	77	13,689	539	9009
40	20	1600	400	800
81	124	6561	15,376	10,044
66	87	4356	7569	5742
39	29	1521	841	1131
∑738	∑518	∑58,793	∑31,994	∑40,084

$(\sum x)^2$ = 544,644.
$(\sum y)^2$ = 268,324.

The Product Moment Correlation Coefficient (r) is calculated as follows:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - (\sum x)^2\right]\left[n\sum y^2 - (\sum y)^2\right]}}$$

$$= \frac{10 \times 40084 - 738 \times 518}{\sqrt{[10 \times 58793 - 544644][10 \times 31994 - 268324]}}$$

$$= \frac{400840 - 382284}{\sqrt{(43286)(51616)}}$$

$$= \frac{18556}{\sqrt{2234250176}}$$

$$= \frac{18556}{47267.8}$$

$$= 0.392$$

The correlation coefficient appears weak and positive. Checking the significance of this positive correlation from appendix 5 in [52], we find that the value 0.392 far below the tabulated critical value of 0.632 for degree of freedom (n – 2), i.e., 10–2 = 8 at p = 0.05. We accept the H_0 and conclude that the weak positive correlation is statistically not significant.

D. Appendix

Calculation of Coefficient of Determination (r^2).

This is done by squaring the Product Moment Correlation Coefficient, r, [52], i.e., 0.392.

Thus, $r^2 = 0.392^2 = 0.153667$.

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