Vol. 12(8), pp. 268-282, August 2018
DOI: 10.5897/AJEST2018.2474
Article Number: 190BA7458051
ISSN: 1996-0786

http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

Management status and perception of post quarried sites in Ndarugu Kiambu, Kenya

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Received 22 January, 2018; Accepted 22 June, 2018

In recent times, rapid changes in buildings and infrastructural development have increased demand for construction materials. Ndarugu quarries located about 35 km north of Nairobi CBD are among the main sources of building materials in Kenya. The visible evidence of stone mining are the post-quarried sites scarred along the Ndarugu ridge, which has altered the original land condition and continues to affect people who live in surrounding areas. The objectives of the current study were (i) to assess the perception of stone quarry landowners on economic and social impacts of stone quarrying and (ii) to assess status of post-quarry land and factors influencing rehabilitation efforts. Data was collected through interviews guided by questionnaire undertaken along a transect parallel to river Ndarugu ridge where quarrying is concentrated, by sampling alternate homestead and company head. The data collected were analysed using frequencies and association between variables. From the analysis, majority of the respondents (47.1%) were small-scale farmers while 78.8% earned less than KSh. 30,000 (300 USD) per month. Quarrying was in progress in many of quarry sites, while the oldest was quarried 28 years ago. Creation of employment opportunities and opening up of the interior areas for business development were perceived as the main positive impacts of quarrying while influx of new migrants and dust pollution were perceived as the main negative impacts of stone-quarrying. Backfilling with local soil was main environmental repair method identified although a large percentage of the quarried land (95.2%) had not been repaired fully. Crop farming and trees planting were the most preferred post quarry land use. Lack of financial support services and lack of a compulsive legal framework were perceived as main limitations to environmental repair. Matching the quarrying activities with effective landscape management strategies to reduce negative impacts is recommended.

Key words: Land owners, stone quarrying, quarrying impact, rehabilitation method, post quarry land use.

INTRODUCTION

Quarrying is among the leading anthropogenic activities that result in alteration of the landscape (Dentoni et al., 2006; Flavenot et al., 2014). It has been on the rise due to increased demand for building material for agricultural, domestic, industrial and other uses as a result of rapid urbanization and population growth (Dong-dong et al., 2009; Olusegun et al., 2009; Unde et al., 2010; Lad and Samant, 2014). Stone quarrying operation involves

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removal of the overburden, drilling and stone cutting; and sometimes blasting and crushing of rocks. The quarrying operations and the quarry landscape scars left behind impact the environment and the social-economic well-being of the people living around quarried lands (Chatterjee, 2010; Bamgbose et al., 2014; Lad and Samant, 2014). The negative impacts of quarrying on the environment include loss of biodiversity (Unde et al., 2010; Darwish et al., 2011), dust pollution, water pollution, landscape aesthetic disruption (Dentoni et al., 2006; Dentoni and Massacci, 2007), underground water pollution, lowering water table, land degradation, increase erosion and landslides, destruction of habitats and air pollution from fumes, smoke and noxious gases (Weston et al., 1999; Jim, 2001; Kaliampakos and Mavrikos, 2006; Dong-dong et al., 2009; Chatterjee, 2010). Quarrying significantly alters the ecosystems and ecological relationships that are irreversible (Milgrom, 2008). Quarrying has negative impacts on the aesthetic and visual values on the landscape as it leaves behind quarry scars that require to be rehabilitated (Menegaki and Kaliampakos, 2006; Dong-dong et al., 2009; Misthoset et al., 2018). Abandoned quarries, however, have some positive impacts on the environment that include acting as a water reservoir when well maintained and provides habitat refuge for valuable flora and fauna (Jefferson, 1984; Flavenot et al., 2014).

The communities have different perceptions of the quarrying and mining activities, and the post quarried land use. Wanjiku et al. (2014) in a study on occupation health of quarrying found that the quarry workers and quarry owners perceived the quarrying activities was the source of poor health conditions. Olusegun et al. (2009) also found that communities around quarrying zone were aware of the risks associated with their quarrying activities. Kaliampakos and Menegaki (2001) identified that perception of quarrying impact could influence stopping of quarrying activities as it occurred in Attica basin, Greece. Perceptions of post quarry land use from the communities around the quarry areas are usually related to beneficial use to individual as well as to the community (Ambrose-oji et al., 2009; Kryzia and Kryzia, 2017).

Quarrying activities impact the life of the communities living around the quarry zones and those working in the quarry (Nartey et al., 2012). The negative impacts on the socioeconomic status includes increase in health complications and diseases such as pneumonia, eyes and ears infections and other respiratory illnesses associated with the dust, smoke, fumes and noise emitted in the quarrying operations; accidents and health hazards due to existence of quarry pits (Olusegun et al., 2009; Nartey et al., 2012; Saliu et al., 2014; Wanjiku et al., 2014); increase in conflict in the society; water source pollution; loss of agricultural productive land and illegal stone extraction (Lad and Samant, 2014). The vibration from rock blasting and moving machinery damage houses, roof tops and catalyses landslides that cause fatal accidents and losses to the surrounding communities (Bamgbose et al., 2014). The increase in the number of abandoned quarries provides an area for water accumulation, that is, a breeding site for mosquitoes and freshwater snails that further spread diseases to the surrounding population if the water is not treated (Hilson, 2002). Mining also destroys traditional cultural sites which are of intangible value to the communities such as pilgrimage routes and traditional prayer caves. Post quarry land use rehabilitation has also not considered the traditional cultures that were destroyed during the mining activities and thus total loss of such cultures (Svobodova and Hajek, 2017). Quarrying impacts the society positively too in various ways such as employment creation (Weston et al., 1999; Chigonda, 2010).

Sustainable development in the twenty-first century aims at conserving the environment and maximizing benefits from natural resources. Quarry re-greening and rehabilitation focus on reducing the impact of quarrying, enhancement of sustainable development and increasing economic gains from the abandoned quarries (Dong-dong et al., 2009; Mendes et al., 2014). There are many environmental repair approaches geared towards quarried land to enhance its economic value (Dal Sasso et al., 2012). The different quarry sites have different degree of disturbance, thus priorities in rehabilitation should focus on the hierarchy of impacts (Mhlongo and Amponsah-Dacosta, 2015; Mavrommatis and Menegaki, 2017). The environmental and socioeconomic negative impacts of quarrying are the main source of conflicts between quarrying firms and the communities living around the quarrying zones (Lad and Samant, 2014). Understanding the perceptions of the communities around quarry area on issues related to quarrying and post quarried land state is crucial as it influences their relationship with quarrying firms and the post quarry status of the quarried land (Lad and Samant, 2014).

Quarrying activities in Kenya have increased in the recent past due to increased demand for quarrying material for urban development. However, there is little research on the impacts of quarrying activities on the quarry landowners. Profiling of quarried land within the different quarry zones has not been fully documented. Therefore, the current research aimed to assess the perception of quarry landowners on positive and negative impacts of quarrying; post quarry land uses and the limiting factors to quarry rehabilitation.

MATERIALS AND METHODS

Description of the study area

The study was undertaken in Ndarugu area, Juja sub-county, Kiambu County in Kenya, located about 36 km northeast of Nairobi and about 12 km from Thika town (Figure 1). The quarries are embedded in agricultural and natural fields within a region that is

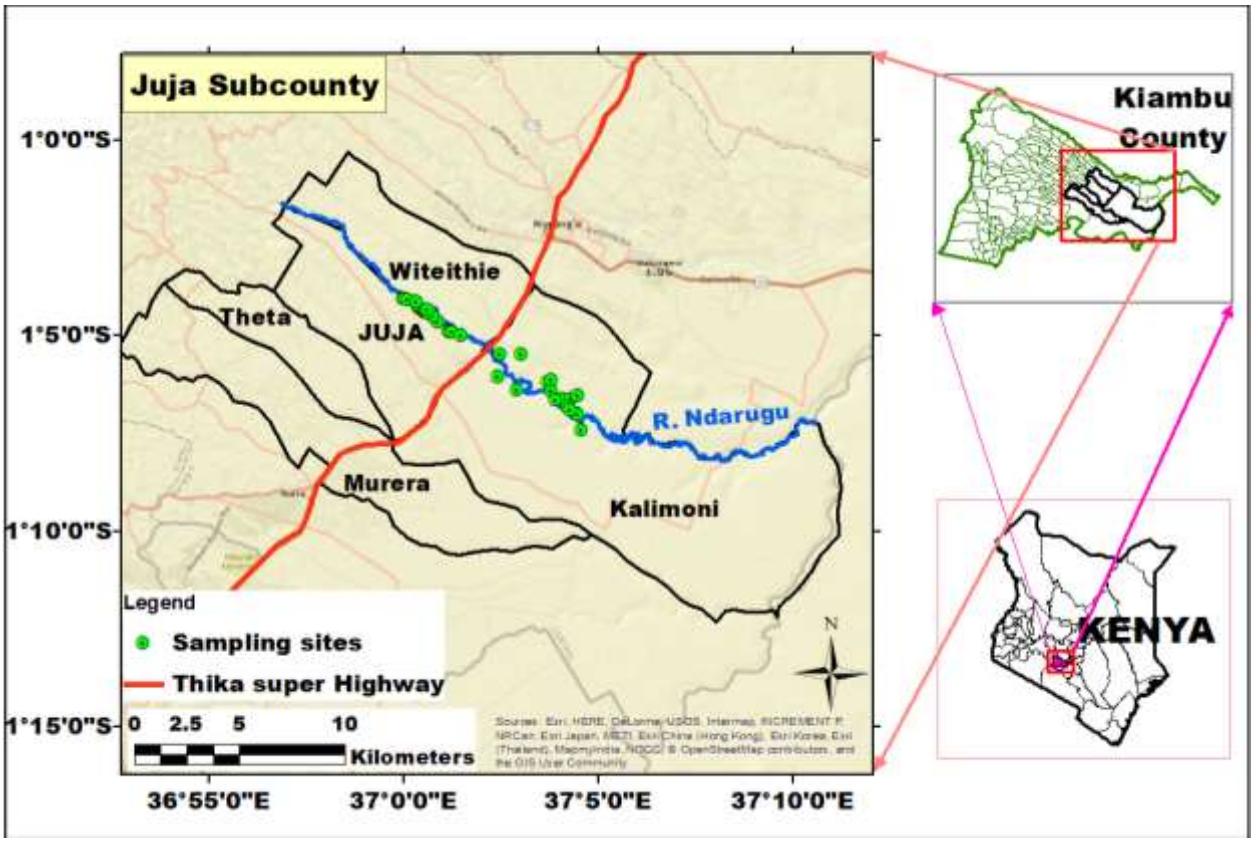

Figure 1. The location of River Ndarugu ridge in Kiambu County, Kenya, where the study was undertaken.

experiencing increasing density of settlements. The quarry zone strip is subdivided into two sections by the Thika superhighway, eastern and western sides, which enhance transportation of the quarry products. The area got its name from River Ndarugu whose ridges have an outcrop of soft volcanic rock that is easy to shape providing a favourable site for quarrying. The abundance of soft volcanic rock is responsible for the presence of many quarrying companies in the area. Juja has a population of 117,138 people according to KNBS (2013) with a population density of 652.04 km^{-2} according to Kenya open data survey (Ngure et al., 2015). The area was initially a coffee plantation zone, but now the main economic activities are quarrying and small-scale farming.

Sampling and data collection

The business of quarrying in this locality usually involves two parties, the land owner, and the quarrying company. Often, the landowner is also the quarry operator. Because the owner determines the usage of land, the target respondents in this study were quarry landowners who have settled on the land. Data was collected through interviews guided by a semi-structured questionnaire. From the reconnaissance and site observations, most of the homes consisted of more than one households and they constituted a homestead of several households of related family members. Therefore, sampling was done for homesteads by following a selected transect that was parallel to river Ndarugu ridge where quarrying activities were concentrated and homes set. The selection was done systematically for every other homestead and interviewing head of the homestead or the land owner.

The interviews were conducted face to face by the lead author assisted by a local in both English and the local language that was spoken by the community. A pilot survey test was undertaken before the actual survey to test the validity and reliability of the information collected by the data collecting tools. The test helped in further refining the questions to ensure they were understood uniformly by all the respondents. A total of 36 interviews that were guided by a semi structured questionnaire were conducted on landowners of whom 34 were homesteads heads, and 2 were company managers.

In each case, consent was first sought to participate in the survey from the respondents and then provided the explanation for the purpose of the survey which was to investigate the environmental and social impacts of quarrying and management of post-quarried land. After developing a rapport with the respondent, each interview took about 12 min to complete allowing ample time to express their true experience. The interviews were undertaken between February and May 2015 and March and April 2016. Visits were done during the day but in cases where the randomly selected landowner was away on other duties, arrangements were made to meet at their convenient times.

Data analysis

For analysis purposes, data from the questionnaires filled during the interview were checked to ensure completeness, then coded and entered into spreadsheet using Statistical Package for the Social Sciences (SPSS) software version 23. Qualitative data analysis and interpretation of perceptions were carried out by

Table 1. The socio-demographic characteristics of quarry land owners.

Variable	Frequency (No)	Frequency (%)	Variable	Frequency (No)	Frequency (%)
Gender			**Marital status**		
Male	24	66.7	Single	1	2.9
Female	12	33.3	Married	33	97.1
Age			Level of education		
18-25	1	2.9	Primary school	16	47.1
26-35	8	23.5	Secondary school	10	29.4
36-55	12	35.3	College certificate	3	8.8
56-65	3	8.8	Diploma	3	8.8
> 65	10	29.4	Degree	2	5.9
Homestead size			**House hold size**		
1-2	23	67.6	1-3	14	41.2
3-4	6	17.6	4-6	11	32.4
4-5	2	5.9	7-9	2	5.9
> 5	3	8.8	>9	7	20.6
Occupation			**Average monthly income**		
Small-scale farmer	16	44.4	<10, 000	10	30.3
Quarry stone dealers	8	22.2	10,000-30,000	16	48.5
Small scale business	3	8.3	30,000-50,000	5	15.2
Contractor	2	5.6	50,000-100,000	2	6.1
Stay at home	2	5.6			
Company manager	2	5.6			
Transportation sector	1	2.8			
Marketing	1	2.8			
Masonry	1	2.8			

content analysis to analyse respondent's perception on open ended questions where the main themes were identified. Principal component analysis (PCA) was carried out to remove redundant variables from both the dependent and independent variables, and to identify variables that had highest influence on respondents' responses to the issues under investigation. Kaiser-Meyer-Olkin (KMO) was used to measure the sampling adequacy while Bartlett's test of sphericity was used to test data suitability for reduction. The dependent variables were then associated with group independent variables (gender, age and livelihood means). To assess descriptive relationships, Kruskal Wallis, Chi-square and Mann Whitney tests were used to examine statistical relationships and differences between grouped variables.

RESULTS AND DISCUSSION

Landowners' socio-demographics

All the targeted 34 homesteads and 2 companies responded to the semi-structured questionnaire during the survey. Although, male respondents were the dominant gender (66.7%; n=24) in decision making in the quarry zone, a good percentage of women also were involved in decision making relating to quarrying activities. About 35.3% (n=12) of respondents were between 36 to 55 years old followed by the age group of above 65 years old (29.4%; n=10). The greatest number (67.6%; n=23) of the homesteads surveyed had one or two households followed by those with three or four households (17.6%, n=6). On household size, 41.2% had between 1 and 3 persons per household followed by the 4 to 6 persons category (32.4%; n=11). Overall, the level of education attainment was low with 47.1% of the respondents (n=16) having a primary education, while 29.4% had secondary education. Table 1 presents the summary of socio-demographic characteristics of quarry landowners.

From the principal component analysis of the socio-demographic characteristics, 3 principal components were extracted with an Eigen value of greater than one that explained 67.3% of the respondents' variation in the various issues covered in the survey. The factors with the highest loading in the first three components were used for further analysis and included age, homestead size and occupation.

Land ownership and land use

On land ownership, 55.6% (n=20) of the respondents'

Table 2. The relationship between social demographic characteristics with land ownership and land size.

Social demographic factors		Land ownership (in % frequency)[a]		Land size (in % frequency)			
		Private	Family	<1 acres	1-3 acres	4-5 acres	>5 acres
Age	18-25 (n=1)	100(1)				100(1)	
	26-35(n=8)	25(2)	75(6)		50(4)	50(4)	
	36-55(n=12)	50(6)	50(6)	8.3(1)	66.7(8)	25(3)	
	56-65(n=3)	33.3(1)	66.7(2)	66.7(2)		33.3(1)	
	> 65(n=10)	40(4)	60(6)	20(2)	80(8)		
	Total	14	20	5	20	9	0
Homestead size	1-2 (n=23)	47.8(11)	52.2(12)	13(3)	56.5(13)	26.1(6)	4.3(1)
	3-4(n=6)	33.3(2)	66.7(4)	16.7(1)	66.7(4)	16.7(1)	
	4-5(n=2)		100(2)	50(1)		50(1)	
	> 5(n=3)	33.3(1)	66.7(2)		100(3)		
	Total	14	20	5	20	9	0
Occupation	Transportation sector(n=1)		100(1)			100(1)	
	Contractor(n=2)	50(1)	50(1)		50(1)	50(1)	
	Farmer(n=16)	56.3(9)	43.8(7)	18.8(3)	68.8(11)	12.5(2)	
	Quarry stone dealers (n=8)	50(4)	50(4)		50(4)	50(4)	
	Small scale business (n=3)		100(3)	33.3(1)	33.3(1)		
	Stay at home (n=2)		100(2)	50(1)	50(1)		
	Marketing (n=1)		100(1)		100(1)		
	Masonry (n=1)		100(1)				100(1)
	company Manager(n=2)	100(2)			50(1)		50(1)
	Total	16	20	5	20	8	2

The number in brackets represents the number of respondents in that socioeconomic category. [a]Land ownership was classified as private referring to individually owned or company owned and family land that referred to land managed by more than one related family.

land was family owned (two or more related nuclear families), while 44.4% (n=16) was privately owned (one nuclear family, single individual or company). Most of the homesteads thus had more than one person to be consulted on issues relating to quarrying as land was majorly managed at family level. A larger percentage of respondents in >65, 56-65 and 26-35 years categories headed family owned land (Table 2).

Most of the small-scale farmers (56.3%; n=9) and company (100%; n=2) had privately owned land while a large proportion of members of the other occupation categories had family owned land. There was no statistically significant difference in land ownership amongst the occupation categories (X2 (1) = 6.44, p =0.375). About 52.2% of homestead with less than 2 households and those with 4-5 household had family owned land.

About 58.3% (n=21) of the landowners had a land size of between 1 and 3 acres, 22.2% (n=8) had 4-5 acres, while 13.9% (n=5) had <1 acres. About sixty nine percent of the farmers had 1-3 acres, while only one of the companies had more than 5 acres. No significant variation was found between the occupation categories for the land size owned (x^2 (1) = 10.52, p =0.105). A large percentage of the older generation (>65years) had between 1-3 acres of land similar to the 36-55 years category.

Majority (97.2%; n=35) of the landowners had a portion of their land quarried, and only one respondent (2.8%) had land that had been cleared ready for quarrying. About 52.8% (n=19) of the respondents practiced crop farming while 58.3% (n=21) practiced poultry farming. Agricultural activities, apart from quarrying, were the other main economic activities that were undertaken by the quarried land owners. Most of the respondents (52.8%; n=19) had their permanent residence in the same land being quarried. A large percentage of quarried land owners lived at a close proximity to the quarry zones thus were exposed to the impacts of quarrying activities. Even so, a good percentage of the quarry land owner had alternative homes far from the quarry zone, which may be crucial in avoiding exposure to the negative impacts related to quarrying. Other land uses identified are shown in Figure 2.

Quarrying activities

A total of 60 quarry sections were identified from the survey. The oldest section was first quarried 28 years

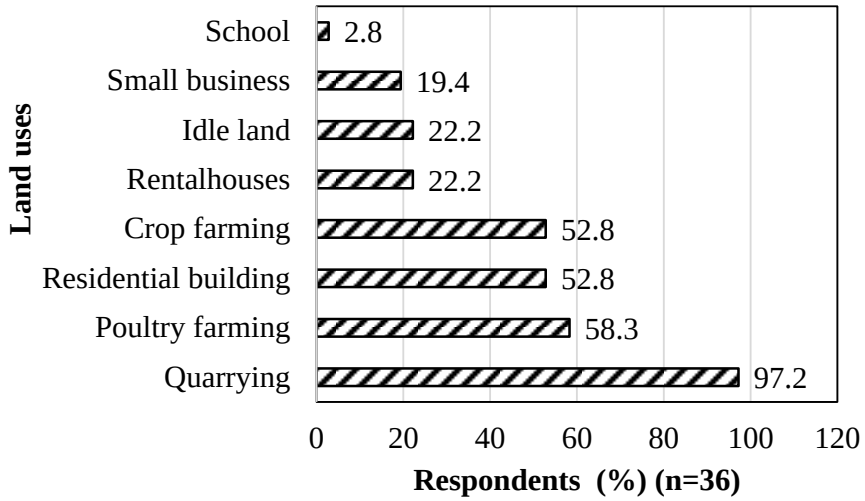

Figure 2. Land uses in different respondents' land.

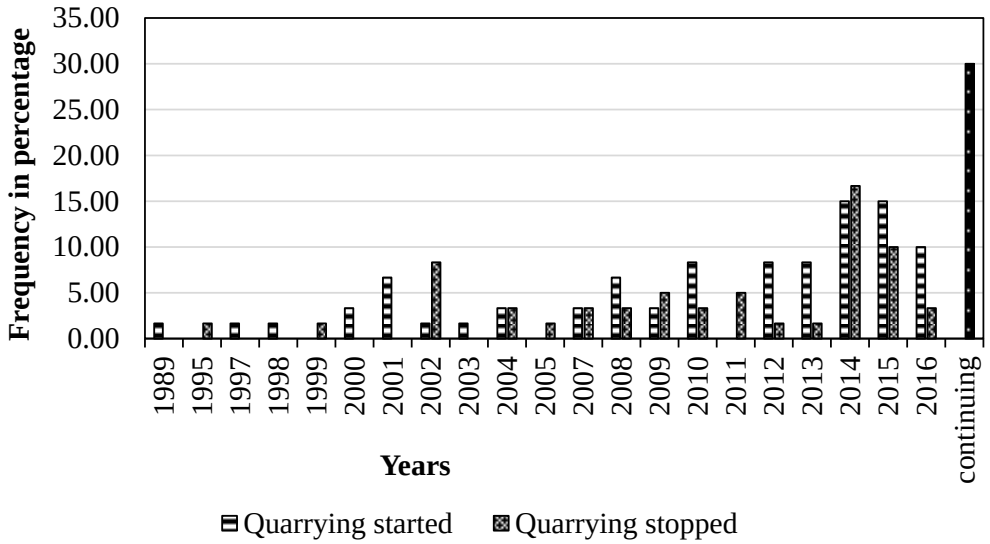

Figure 3. The frequency of quarrying beginning and closure in different years and those ongoing quarrying (n=60).

ago revealing the long-term economic value of the quarry zone. The highest number of newly opened quarry sections was recorded in 2014 and 2015 each accounting for 15% of all the sections identified. The highest closure of quarry sections was in 2014 of about 16.7%, and the lowest were in 1995, 1999, 2005, 2012 and 2013 as shown in Figure 3. Some (30%) of the quarried sections identified were still being quarried. The increase in quarrying sections and the high number of ongoing quarrying portray the increased quarry activities within the study area.

Table 3 shows the association between quarrying activities and socio-demographic factors. The greatest number (75%; n=27) of the respondents rented their land out to quarrying firms while 22.2% (n=8) undertook quarrying by themselves (Table 3). Half (50%; n=4) of those who did quarry by themselves were quarry stone dealers. Sixty six percent of the respondents (n=24) had less than 50% of their land being quarried. Quarrying in many of the homesteads (80.6%; n=29) was undertaken in 1-2 sections, 13.9% (n=5) done in 3-4 sections, while 2.8% (n=1) was done in more than 6 sections. The highest number of section per land owner was 6 sections which were in land owned by company management.

Homesteads with 1-3 households had the highest number of land owners (60.9%; n=16) who had less than 50% occupied by quarry. A large proportion of the members in all the homesteads categories had less

Table 3. Status of quarrying activities categorized based on socio-demographic factors of landowners in Ndarugu area.

Social demographic factors		Portion of land under quarrying (in % frequency)		Who did quarrying (in % frequency)[a]		No. of quarry sections (in % frequency)			Quarrying duration in years				
		<50%	≥50%	Owner	Rented out	1-2 sections	3-4 sections	>6 sections	<1	1-2	3-4	5-6	>6
Age	18-25 (n=1)	100(1)	0	100(1)	0	100(1)	0	0	0	100(1)	0	0	0
	26-35(n=8)	37.5(3)	62.5(5)	37.50(3)	62.5(5)	62.5(5)	37.5(3)	0	13(1)	63(5)	13(1)	0	13(1)
	36-55(n=12)	66.7(8)	33.3(4)	16.67(2)	83.3(10)	83.3(10)	16.7(2)	0	0	50(6)	33(4)	8(1)	8(1)
	56-65(n=3)	100(2)	0	50(1)	50(1)	100(2)	0	0	0	100(2)	0	0	0
	> 65(n=10)	80(8)	20(2)	0	100(10)	100(10)	0	0	30(3)	40(4)	20(2)	0	10(1)
	N	22	11	7	26	28	5		4	18	7	1	3
Homestead size	1-2 (n=23)	60.9(14)	39.1(9)	21.74(5)	78.3(18)	82.6(19)	17.4(4)	0	13(3)	57(13)	22(5)	4(1)	4(1)
	3-4(n=6)	66.7(4)	33.3(2)	33.33(2)	66.7(4)	83.3(5)	16.7(1)	0	0	67(4)	17(1)	0	17(1)
	4-5(n=2)	100(1)	0	0	100(1)	100(1)	0	0	0	0	100(1)	0	0
	> 5(n=3)	100(3)	0	0	100(3)	100(3)	0	0	33(1)	33(1)	0	0	33(1)
	N	22	11	7	26	28	5		4	18	7	1	3
Occupation	Transportation sector(n=1)	100(1)	0	0	100(1)	0	100(1)	0	0	0	0	0	100(1)
	Contractor(n=2)	50(1)	50(1)	0	100(2)	100(2)	0	0	0	50(1)	50(1)	0	0
	Farmer(n=16)	86.7(13)	13.3(2)	20(3)	80(12)	93.3(14)	6.7(1)	0	20(3)	53(8)	13(2)	7(1)	7(1)
	Quarry stone dealers(n=8)	25(2)	75(6)	50(4)	50(4)	62.5(5)	37.5(3)	0	0	75(6)	25(2)	0	0
	Small scale business(n=3)	100(3)	0	0	100(3)	100(3)	0	0	33(1)	33(1)	0	0	33(1)
	Stay at home(n=2)	50(1)	50(1)	0	100(2)	100(2)	0	0	0	50(1)	50(1)	0	0
	Marketing(n=1)	0	100(1)	0	100(1)	100(1)	0	0	0	0	100(1)	0	0
	Masonry(n=1)	100(1)	0	0	100(1)	100(1)	0	0	0	100(1)	0	0	0
	Company Manager(n=2)	100(2)	0	50.00(1)	50.0(1)	50(1)	0	50(1)	0	50(1)	0	0	50(1)
Total		24	11	8	27	29	5	1	4	19	7	1	3

The value in brackets represents the number of respondents in the social demographic category under the quarry activities categories. [a]Number of quarry sections represent the zone that were quarried at the same time.

than 50% of land occupied by quarrying. Only 1-2 and 3-4 categories had land with greater than 50% under quarrying. Most of the landowners in majority of the homestead categories had their land rented out for quarrying. Homesteads with 1-2 households had the highest number of landowners who had either rented out or did quarrying by themselves. In all the homestead categories, majority of the quarried land was done in 1-2 sections. A large percentage of respondents in the different homestead categories had their land quarried for 1-2 years except for the 4-5 homestead category which had one respondent whose land was quarried for 3 to 4 years.

A large percentage of respondents in the

different age categories had less than 50% of their land under quarrying except for the 26-35-year category. In all the categories of age, the majority of the land owners rented out their lands, which were quarried in one or two sections. In all the different age categories, many of the respondents' land were quarried for two to three years period. Only three respondents had their land quarried for more than six years. About 45.5% (n=5) of homestead with greater than 50% of land under quarry was headed by respondents between 26-35 years, while 36-55 and >65 years' age groups headed majority of the homesteads with less than 50% of land under quarry. A large percentage of land with 3-4 quarry sections belonged to land owners of 26-35-years category, while most of those with 1-2 quarry sections belonged to owners of over 35 years old as shown in Table 3. Age influences the number of quarry sections per land. The older generation only allowed few quarry sections while the younger generation allows for many quarry sections. 52.8% (n=19) of the respondents had their land quarried for 1-2 years followed by 3-4 years (19.4%; n=7), <1 year (11.1%; n= 4), >6 years (11.1%; n=4) and 5-6 years (2.8%; n=1)

In all the occupation categories, most of the landowners had quarrying occupying less than 50% of land except for those in quarry stone dealer's category and marketing category. 54.2% of the land with <50% quarried section belonged to small-scale farmers while most (54.5%; n=6) of those with >50% quarried area belonged to quarry stone dealers. All respondents who had <1 acre of land and 66.6% of farmers with 1-3 acres of land had <50% of their land being quarried while 50% of those with 4-5 acres have more than 50% of their land under quarrying. There was strong evidence of association (X2 (1) = 18.854, p =0.026) between the size of land owned and the proportion of the land under quarrying. The land size thus determines the portion of land that is dedicated to stone quarrying by the land owners. The larger the land size owned, the larger the portion of land that is dedicated to stone quarrying.

Half of quarry stone dealers and companies and 20% of farmers did quarrying by themselves. All the other categories rented out their land for quarrying. Majorities of the respondent in all the occupation categories had their land quarried in 1-2 sections except for company category where one had >6 sections and transportation where one had 3-4 quarry sections. A large proportion of quarried pieces of land with 3-4 sections were managed by stone quarry dealers while the majority of those with 1-2 section belonged to small-scale farmers. The land owners' occupation influences the number of quarry sections for quarry sections. An occupation that relates to use of quarry product influenced increase in number of quarry sections while occupation that depends on land productions influenced less number of quarry sections in their lands.

Majority of the farmers, quarry stone dealers and masonry, and half of contractors, stay at home land owners and company had their land quarried for 1-2 years. Half of the contractors and stay at home land owners, and the marketers had their land quarried in 3-4 years. Transportation sector, farmer, small scale business and company had one member who had land that was quarried for more than 6 years. Table 3 provides the quarrying activities categorized based on socio-demographic factors.

Respondents' perception of the environmental and livelihood impacts of quarrying

The respondents identified stone quarrying activities to have positive and negative impacts on the environment and their socioeconomic status. The mean score rating of impacts of stone quarrying is shown in Table 5. All the positive impacts had a score of greater than 2.5 and were in order of: employment (3.8), opening interior for commercial activities (3.7), increase in income (3.4), social harmony (3.3), improved infrastructure (2.9), easy access to financial loans (2.8) and access to social services (2.6).

Table 4 presents the principal component analysis of the positive impacts of quarrying, socioeconomic negative impacts of quarrying and environmental negative impacts of quarrying. From PCA of positive impacts of stone quarrying, the first two principle components had Eigen value > 1 and explained 59% of the variation in respondents' perception (Table 4). The two factors that loaded highly on the two components were access to financial loans, and improved infra-structure. There was a statistically significant difference in degree of agreement of easy access to financial loans between the different age categories of respondents at $p< 0.05$ ($p=0.036$). This is evident from the high score observed among the relatively younger respondents and low score among the older respondents with small-scale businesses assigning employment the lowest score while quarry stone dealers category scored it highest as a positive impact of stone quarrying.

Negative social impacts of stone quarrying identified, included influx of new people (4.1), change in social ethics (3.5), destruction of productive agricultural land (2.9), mismanagement of money (2.9), health and safety hazard (2.7), domestic violence (2.1) and insecurity (2.0). Cultural sites such as the caves along the river that was used for prayers and traditional activities were also lost due to quarrying as pointed out by some of the respondents. From the PCA of socioeconomic negative impacts of stone quarrying, three principle components with an Eigen value greater than one were extracted which explained 71.8% of the variation. Three factors that loaded highly were domestic violence, insecurity and influx of new people for the first, second and third components, respectively.

The negative impacts of quarrying on the environment included dust pollution (3.9), noise pollution (3.2) loss of

Table 4. The principal components that were extracted for each environmental impact category assessed.

Component	Total variance explained					
	Initial Eigenvalues			Rotation sums of squared loadings		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
			Positive impacts of quarrying			
1	2.743	39.189	39.189	2.470	35.281	35.281
2	1.397	19.959	59.148	1.671	23.868	59.148
			Socio-economic negative impacts of quarrying			
1	3.180	39.753	39.753	3.180	39.753	39.753
2	1.555	19.436	59.189	1.555	19.436	59.189
3	1.010	12.627	71.816	1.010	12.627	71.816
			Environmental negative impacts of quarrying			
1	2.591	51.821	51.821	2.591	51.821	51.821

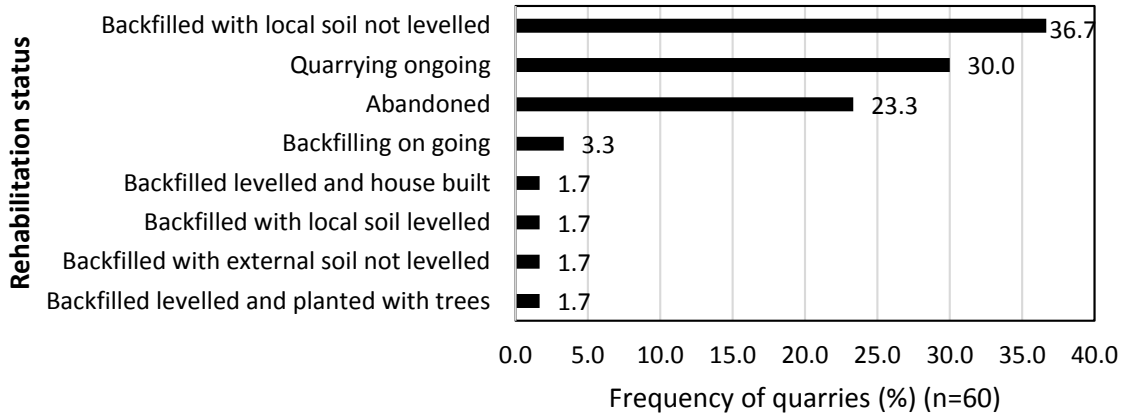

Figure 4. Rehabilitation status of quarried land and method used.

biodiversity (3.1), and water pollution (2.5). From the PCA, only one principle component with Eigen value greater than one and explained 56.8% of total variation was extracted. Three factors that loaded highly on this component were identified as loss of biodiversity, dust pollution and noise pollution. All the six negative impacts of stone quarrying (socioeconomic and environmental) were not statistically significantly different in the degree of agreement between the different categories of age, homestead size and occupation as shown in Table 5.

Quarry environmental repair limiting factors and post quarry land use

Eight rehabilitation status of quarried land were identified from the survey (Figure 4). Backfilling with local soil and not levelled was the most common rehabilitation status followed by quarried land abandonment for natural rehabilitation as presented in Figure 4. Only 5.2% of post quarried land, had been fully rehabilitated, one planted with trees and one had buildings erected. The rest of the land had been left to rehabilitate naturally through colonisation by plants.

Responsibility and knowledge of rehabilitation

Based on pre-quarry agreements, 67.6% of the quarries were to be rehabilitated by the quarrying firm while 32.4% were to be rehabilitated by the landowner (Figure 5).

Of all the respondents, 77.1% had knowledge on post quarry land use while 22.9% did not (Figure 6). Most of the respondents who were informed on post quarry land use (85.2%) identified past experience, 7.4% identified other people in the village, 3.7% identified short course study and seminars while 3.7% identified social media to be the source of knowledge. Even though a large percentage of the respondents were informed, lack of information by some of the land owners could be the

Table 5. The negative and positive impacts of quarrying categorized based on mean score by the socio-demographic factors.

Social demographic factors		Socio-economic negative impacts (mean score)			Environment negative impacts (mean score)			Positive impacts (mean score)			
		Domestic violence	Insecurity	Influx of new people	Loss of biodiversity	Noise pollution	Dust pollution	Easy access to financial loan	Source of employment	Better access to social services	Improved infrastructure
Age	18-25 (n=1)	3	5	5	5	5	5	5	5	1	3
	26-35 (n=8)	1	1	4.6	2.9	3.1	3.4	3.8	4.5	3.4	3.5
	36-55 (n=12)	2.8	2.5	4.6	3	3.3	3.8	3	4.3	3.0	3.3
	56-65 (n=3)	3	1	3.7	3	1	4.3	3.7	3	3	1.7
	> 65 (n=10)	2	2.2	3.5	3.4	3.8	4.2	1.4	2.9	1.7	2.7
	P (Kruskal Wallis)	0.061	0.26	0.212	0.799	0.088	0.74	0.036	0.105	0.223	0.514
Homestead size	1-2 (n=23)	1.9	2.1	4.3	3.3	3.4	4	2.7	4.0	2.4	2.7
	3-4 (n=6)	2.3	1.3	4	2.5	2.5	3.2	3	3	3.1	3.3
	4-5 (n=2)	4	2	3	2	1	3.5	1	2	4	4
	> 5 (n=3)	2.3	2.7	5	4	4.7	4.7	2.7	4	2.3	2.7
	P (Kruskal Wallis)	0.256	0.561	0.448	0.421	0.065	0.394	0.755	0.561	0.545	0.365
Occupation	Transportation sector (n=1)	1	1	5	1	1	2	5	5	5	1
	Contractor (n=2)	1.5	2	4.5	1.5	3.5	4	1	4.5	2.5	2.5
	Farmer (n=16)	2.7	2.2	3.9	3.3	3.3	4.2	2.7	3.7	2.7	2.9
	Quarry stone dealers (n=8)	1.3	1.8	4.9	3	3	3.1	3.6	5	2.9	3.3
	Small scale business (n=3)	1.5	2.3	4	4.7	4.7	4.7	2.3	1.7	2.3	4.7
	Stay at home (n=2)	3.5	3.5	3	4	3	4.5	1	1	1	3
	Marketing (n=1)	5	2	5	5	2	3	3	5	1	3
	Masonry (n=1)	1	1	5	1	1	4	5	5	5	1
	Company manager (n=2)	1	1	1	1	1	5	1	4	1	1
	P (Kruskal Wallis)	0.239	0.841	0.516	0.359	0.472	0.481	0.24	0.012	0.538	0.53

The score of quarrying impacts was between 1 and 5, where 5 represents is strongly agree and 1 disagree.

contributing factor to low quarry rehabilitation and noneconomic use of quarried land. It is crucial thus for the stone quarry land owners to get access to more information on post quarry use to improve quarry rehabilitation and land productivity after quarrying ceases.

Limiting factors and preferred post quarry land use

Table 6 shows the limiting factors to quarry rehabilitation and the land owners' preferred post quarry land use. Lack of financial support and legal barriers were identified as the main limiting factors to quarry rehabilitation. Other identified limiting factors included rehabilitation parties not undertaking their responsibility, lack of technical support and poor body health (especially for the elderly land owners). Statistically (Kruskal wallis

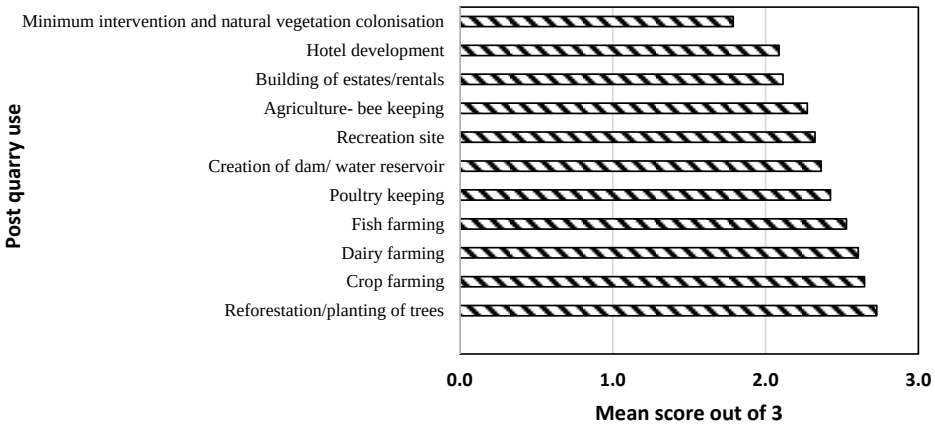

Figure 7. The identified post quarry use and their mean score out of the possible three. A score of 1 refers to least preferred, while 3 is the most preferred.

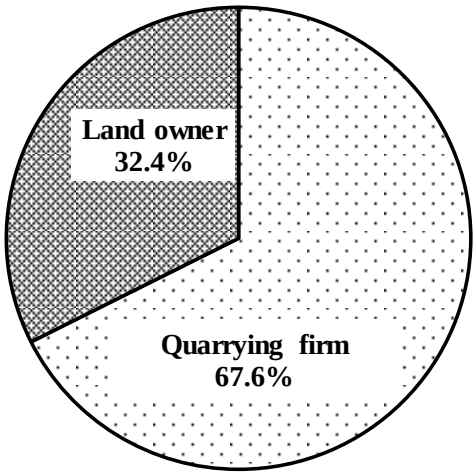

Figure 5. The percentage of parties responsible for the rehabilitation of stone quarry.

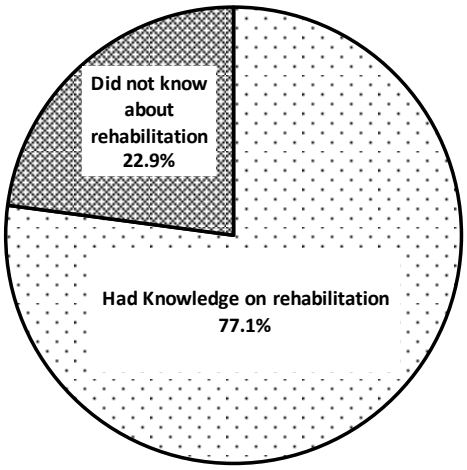

Figure 6. The knowledge on rehabilitation of quarried land.

test), there was no significance difference in perception of the limiting factors among the different categories of age, homestead size and occupation

Overall, quarry rehabilitation was perceived to have positive impacts on the environment and socio-economic wellbeing of the people. The most perceived quarry rehabilitation benefits were a reduction of health and safety hazard (score of 4.7 out of 5), increase in household income (4.6), improved land productivity (4.5), biodiversity restoration (4.5) and job creation (4.4). On preferred post quarry land uses, planting of trees, crop farming and dairy farming were the most preferred post quarry land use while natural vegetation colonisation, hotel development and building rentals or estates were the least preferred post quarry land use as shown in Figure 7. The post quarry land use perception is related to what the stone quarry landowners associated as economic development initiative such as farming which was one of the main economic activities of most of the homesteads.

From principal component analysis (PCA), to identify variables that explained most variation in respondent's perception of post quarry land use, the KMO value was 0.543, which shows the sampling adequacy. Bartlett's test of sphericity (X^2 (55) = 97.108) approved the data to be suitable for reduction as it was statistically significant. From the PCA of mean scores for the various preferred land uses, four principal components that had an Eigen value of greater than one and that explained more than 67% of the variation in respondent perception were extracted. The post quarry land use with the highest loading in each principle components was considered which were dairy farming, hotel development, the creation of dam/water reservoir and crop farming for principle components 1, 2, 3 and 4, respectively.

Table 6. Perception on quarry rehabilitation and post quarry use factors categorised by socio-demographic factors.

Social demographic factors		Party responsible for rehabilitation (in % frequency)		Limiting factors to rehabilitation (in mean score)[a]					Knowledge on post quarry use (in % frequency)		Preferred post quarry land use (in mean score)[b]			
		Owner	Quarrying firm	Technical support	Financial constrains	Law and regulation not followed	Irresponsible rehabilitation party	Poor body health	Yes	No	Crop farming	Dairy farming	Creation of dam/ water reservoir	Hotel development
Age	18-25 (n=1)	100	0	1	1	5	5	1	0	100	3	3	3	3
	26-35(n=8)	62.5	37.5	3.9	4	2.4	2.5	2.8	87.5	12.5	2.8	3	2.6	2.4
	36-55(n=12)	16.7	83.3	3.3	4.3	3.7	4	2.9	91.7	8.3	2.6	2.6	2.6	1.8
	56-65(n=3)	0	100	2.7	5	2	3.7	4.3	100	0	3	3	2	3
	> 65(n=10)	20	80	3.5	4.8	2	4.3	3	60	40	2.7	2.3	2	2.1
	P (Kruskal Wallis)	1	1	0.672	0.256	0.114	0.173	0.525	1	1	0.915	0.398	0.227	0.277
Homestead size	1-2 (n=23)	30.4	69.6	3.2	4.4	2.7	4	3	78.3	21.7	2.7	2.5	2.4	2
	3-4(n=6)	33.3	66.7	3.7	3.5	2.2	2.8	2.8	83.3	16.7	2.8	3	2.5	3
	4-5(n=2)	0	100	3.5	5	4.5	3	4	100	0	1	3	3	1
	> 5(n=3)	33.3	66.7	3.7	5	3.7	3.7	2.5	66.7	33.3	3	3	2	1.3
	P (Kruskal Wallis)	1	1	0.895	0.229	0.403	0.484	0.862	1	1	0.131	0.357	0.671	0.025
Occupation	Transportation sector (n=1)	0	100	5	5	1	1		100	0	3	3	3	3
	Contractor(n=2)	0	100	4.5	5	1	2.5	2.5	100	0	2	2	3	3
	Farmer(n=16)	12.5	87.5	3.3	4.4	2.6	3.9	3.4	68.8	31.3	2.6	2.7	2.1	2.1
	Quarry stone dealers(n=8)	87.5	12.5	3.9	3.5	3.2	3.4	2.4	87.5	12.5	3	2.8	2.6	2.1
	Small-scale business (n=3)	0	100	1	5	4	3.7	5	100	0	2.7	3	2.3	1
	Stay at home(n=2)	50	50	3.5	4.5	3	5	2	50	50	3	2	3	2
	Marketing (n=1)	0	100	5	5	4	5	1	100	0	2	2	3	2
	Masonry (n=1)	0	100	1	5	1	5	5	100	0	3	3	2	3
	company Manager (n=2)	50	50	1	1	1	1	1	0	100	1	1	1	1
	P (Kruskal Wallis)	1	1	0.333	0.681	0.489	0.339	0.338	1	1	0.299	0.376	0.413	0.315

[a]The score of limiting factors is out of five where 5 represents an extremely limiting factor and 1 not a limiting factor. [b] Preferred post quarry use is scored out of 3 where 3 represents most preferred and 1 being least preferred.

DISCUSSION

Land ownership and land use

From the results, it appears that the older generation in the quarry area had small sizes of land as compared to the younger generation. However, this may be due to land subdivision by the parents to their children where they end up with smaller lots. In this study area, most families were extended families constituting a homestead. More than 50% of the homesteads had two or more households. The main land use in the study area was quarrying followed by small scale farming. A large percentage of the homesteads

had land size of between 1-3 acres which was used for various purposes such as quarrying, farming and building residential areas. Of the 34-homestead surveyed, 67% had less than 50% of their land occupied by quarrying activities. The occupation of the land owners was found to influence land use for quarrying purpose. Small scale farmer used a smaller portion of their land for quarrying as compared to quarry stone dealers who utilized a large portion of their land.

Quarrying activities

The community around the quarry area had different perception on the quarrying activities. The research identified high number of new quarrying sites in 2014 and 2015 which points to increased quarrying and demand of quarrying materials, similar to the findings of Wanjiku et al. (2014) and Wells (2000) who pointed out that quarrying activities in Kenya are on the rise. Quarrying was done in sections with most land having one or two quarry sections, similar to findings of K'Akumu (2013).

Perception on the environmental and livelihood impacts of quarrying

Quarrying activities were perceived to have positive socioeconomic impacts on the landowners where creation of employment was the most perceived positive impact. The findings concur with those of Chigonda (2010) and Weston et al. (1999) who found that quarrying activities improved people livelihood through the creation of job opportunities and improvement of infrastructure. The quarrying activities were perceived to have negative impacts such destruction of agricultural land, health and safety hazard among others. Various studies have reported on similar negative socio-economic impacts of quarrying such as reduction of crop production and affects well-being of people (Nartey et al., 2012). Quarrying was found to contribute to dust and noise pollution with effect on the health of the population living around quarry zone (Bamgbose et al., 2014) and also caused loss of biodiversity due to the destruction of large areas of forest and productive land (Darwish et al., 2011). Quarrying was perceived to impact the cultural heritage practices of the community which was similar to the findings of Svobodova and Hajek (2017).

The loss of biodiversity in the study area is crucial as it affects the riparian region of River Ndarugu. The findings also concur with Darwish et al. (2011) findings where quarrying was identified to destroy a large area of forest and productive land leading to loss of the existing animal and plant species richness in the quarry zone. The loss of trees and quarrying close to the river has increased water pollution as perceived by the respondents. Stone quarrying activities increased scars of land not repaired in the quarry zone similar to the findings of Wells (2000) who identified that the artisanal quarrying in Kenya has been on the rise, resulting in increase in the quarried land that has not been fully rehabilitated.

Responsibility and knowledge of rehabilitation

The quarry firm and the landowners were the responsible parties that were supposed to rehabilitate the quarried land. The large proportion of the quarried land is not rehabilitated as it is left as quarry pits. The responsible parties thus do not accomplish their obligation which results in loss of valuable land that could be put into other economic use. There is a need for action to be undertaken in the quarry zone to enhance accountability of the responsible parties.

Knowledge on quarry rehabilitation plays an important role in enabling quarried land rehabilitation. Majority of the landowners were informed about land rehabilitation which means they can effectively utilise their land in the post quarry phase. Even so, a good percentage of the landowners were not informed about post quarry land use which points to the need for more awareness and training to equip the land owners with knowledge and skills on quarry rehabilitation.

Limiting factors and preferred post quarry land use

Financial constraints and poor policies were among the main limiting factors to quarry rehabilitation. So, there is a need for a cost-effective method of quarry rehabilitation to be developed. Lack of effective legal provisions especially in relation to the parties responsible for rehabilitating poor regulatory framework was perceived a key limiting factor, similar to findings by K'Akumu (2013) who identified hostile policy environment as one of the main factors hindering small-scale artisanal stone quarry industry in Kenya to develop and be managed effectively.

Among the post quarry land uses identified were planting of trees, crop farming and dairy farming, which can potentially increase profitability and sustainable use of post quarried land. Trees planting can be very significant in a stone quarried landscape as, it enhances species biodiversity, soil development, reduction of soil erosion and provision of other economic benefits to the landowners such as wood and firewood (Gathuru, 2011).

Conclusion

The survey aimed to assess the perception of stone quarry landowners on economic and social impacts of stone quarrying, to determine the status of post-quarry land and factors influencing rehabilitation efforts. 55.6% of the land was family owned. Majority of the homesteads had a land size of between 1-3 acres which was used for various purposes such as quarrying, farming and building

residential house. Quarrying activities in Ndarugu area were identified to have increased in the past three years as evident by more new quarry sites. Quarrying activities were perceived to have positive and negative impacts on the environment and the socioeconomic wellbeing of the people. The quarry firm and the landowners were the responsible parties for quarry rehabilitation. Most of the landowners were informed about quarry rehabilitation. Even so, the large percentage of quarried land in the area was not rehabilitated which increased the quarry scarred landscape. About 77.1% of the respondents were informed about post quarry land use, many of whom got the knowledge from past experiences. Tree planting (score 2.7 of 3) and crop farming (score 2.6 out of 3) were the most preferred beneficial post quarry land uses while natural colonization with vegetation scored the least. Lack of financial support and lack of a compulsive legal framework were perceived as main limitations to land rehabilitation. There is thus need for developing cost-effective rehabilitation methods and basic business management training of landowners. Furthermore, the increased quarrying activities should be matched with an effective landscape management to ensure lowering of the negative impacts of stone quarrying on the environment and the socioeconomic status of the people living around quarry zone.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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