

The Spatial Distribution of Quarry Stone Mining Sites in Igembe South Sub County Meru County, Kenya

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Abstract

The objective of this study was to develop a GIS-based spatial distribution of mining site patterns in order to identify risk-prone geo-locations in Meru County's Igembe South Sub County. Data was collected using PRA methodologies and processes, primary data was collected from participants' notes to detect mining-related problems, and an informal and formal survey and pair-wise assessment was used. There has been concern about the spatial distribution of mining in affected areas. The communities and mines in the Akachiu ward are as follows: Auki, Amwamba, Nceme, Kirindine, and Tiira. Information was obtained from 300 respondents. These issues were resolved by segmenting the target population and confirming field observations. Data were analysed using the nearest neighbour analysis method and descriptive means, median, and mode statistics. Results were then presented using tables, maps, graphs, and pie charts. Results established that mining activities have damaged land in Igembe South Sub-County, reducing food production and agricultural demands and polluting water supplies in the area, including contaminated streams. Pollution and noise are present in the area. It was affirmed that the residents know the environmental consequences of mining. In light of the County Government of Meru's efforts at restoration and intervention, such as re-afforestation, the mining companies and the County Government of Meru are reviewing their methods of operation and providing alternatives to the affected areas. Mining's environmental impact should be reduced by rethinking the environmental management strategy.

Key terms: Meru, mining, patterns, quarry, spatial distribution.

INTRODUCTION

Mining contributes significantly to economic development. According to Achempong (2015), mining is an essential foundation for human growth since it generates wealth. The mining industry has made a substantial contribution to the advancement of civilisation. The industrial revolution and the infrastructure advancement in today's information have made nations depend on iron and bronze to support the advancement. Globally, mining is critical for the economic development of a nation (Chen et al., 2022). Recently, mining countries have drawn their attention to sustainable mining practices. Sustainable mining practices emphasise mining that has minimal negative social-environmental impacts. For instance, Mourinha (2022) notes that in American, Asia and Europe mining sectors, emphasis has been drawn towards minimising surface water impacts, minimising groundwater impacts, use of environmental indicators in mining, and emerging mining technologies that minimise environmental impacts. Many countries in Europe and India have passed various government regulations on sustainable mining practices addressing areas such as the volume of waste generated during mining, mine closure planning, managing the environmental impacts of mining, land use planning, and energy use management (Kimijima, 2022).

Igembe South, Sub-County, Meru County, is located on the windward slope of Mt. Kenya. Rain-fed agriculture is essential to the people's survival. Individuals without work are increasingly turning to alternative income methods, such as sand and quarry stone mining, because their cash crops, such as khat, are not being purchased in significant amounts, and their revenue from tea and coffee is low (Wanjiku, 2015). The construction sector relies heavily on sand and quarry stones. Because of the growth of cities, sand and quarry stones are becoming increasingly attractive. Quarry stone extraction has long been done along the Maua-Kangeta-Meru Road. Mining for quarry stone has benefited Maua, Kangeta, and Karama. Mining operations, notably sand mining, in Meru National Park have led to the creation of similar communities (Makhura, 2021).

Sand and quarry stone mining have risen rapidly as a result of the establishment of the County Government and the rapid expansion of towns. This mining, if not

done correctly, may have adverse consequences on the land. Human actions such as extracting natural resources and displacing workers, as described by MacFortone (2016) and Mitchell (2016), alter the nature of the terrain. Extraction of sand and quarry stones destroys underground aquifers, affecting the quality and quantity of surface water accessible for human and animal use and the aquatic ecology, not to mention riparian vegetation. Environmental damage from faster soil erosion on nearby areas and roadways, social and health issues such as high school dropout and prostitution, and the spread of venereal diseases are among the consequences. Local employment is one of the social and economic benefits.

According to Mbathi et al. (2019), the temporary community gains proportion is relatively low. Previous studies have not adequately investigated the spatial distribution and impact of quarry stone mining. They have methodological, conceptual and contextual limitations. For instance, Kibii (2020) studied the social and environmental impacts of stone quarrying in Tuluongoi Sub Location Baringo County. The study by Kibii (2020) failed to investigate the spatial distribution of mining sites. It was based in a different county and analysed data using frequencies and percentages, which did not allow for testing the hypothesised relationships between the variables. A study by Nyakeniga (2021) assessed the environmental effects of stone quarrying activities in Nyambara Location Kisii County. The study only investigated the environmental impacts of mining, unlike the current study that investigated the spatial distribution of quarry stone mining and its social, economic and environmental impacts.

The study was contextualised in a different county and failed to chart out the spatial distribution of mining sites. As a result, the spatial distributions of mining sites, as well as the social, economic, and environmental repercussions on the people of Igembe South Sub County, Meru County, were investigated in this research. The government of Kenya has recently promulgated various regulations, such as the Mining Act of Kenya (2016), meant to curb the adverse effects of Mining in Kenya. Regardless of these regulations, recent studies are yet to evaluate the spatial distribution and impact of quarry stone mining on the environment and social and economic activities.

Therefore, the spatial distribution and impact of quarry stone mining in Kenya since the promulgation of the regulations remains to be discovered. Extant studies have been faulted on several aspects. First, Okla's (2017) and Assumma et al. (2022) studies were contextualised in other countries and hence have a minimal application to Kenya. Second, the studies by Simpson Jr and Dussubieux (2018) had methodological limitations since they predominantly used descriptive statistics and critical literature reviews, which did not allow testing of hypothesised relationships. Further, Blachowski and Buczyńska (2020) did not focus on the social, economic, and environmental effects of mining.

Despite recent government regulations aimed at, detrimental the negative impact of mining, extant studies report glaring inefficiencies in mining that could impact human activities. Extant studies have not investigated the spatial distribution of quarry stone mining sites as well as the social and economic advantages to communities from land mining regions; therefore, they did not establish the study outcomes. The current study was intended to fill these gaps. The general objective of this study was to develop a GIS-based spatial distribution of mining site patterns in Meru County's Igembe South Sub County. Therefore, the Hypothesis of the Study was stated that there is no spatial distribution of quarry stone mining sites in Igembe South Sub County, Meru County.

LITERATURE REVIEW

Several scholars, such as Yaw (2018), conducted a case study of mining sites in Accra, Ghana. The study found that mercury mining was clustery distributed depending on the deposits. This meant that their average distance from each other was less than that of a hypothetical random distribution. The economic activities were highly concentrated along the larger deposits of mines. The study was conceptualised in a different country from the current study. A similar study by Okla (2017) examined the spatial distribution and impacts of mining development minerals in the greater Accra metropolitan area, Ghana. The study found that mining is a lifeline for millions of rural households. In contrast to the current study, the study was conceptualised in a different country. Further, it needed to adequately investigate the spatial distribution and impacts of mining development minerals in greater Accra using methodologies such as

nearest neighbour, which was utilised by the current study.

Magara (2020) confirms this by attaching five per cent of the gross domestic product of Ghana to mining. Mining is crucial in the economy of developing countries and provides the main source of employment, food and income to their rural populations. According to FAO (2019), besides this global perspective, mining also has a pivotal role in Sub-Saharan Africa. This is because recent surveys suggest that it is a primary source of livelihood for ten per cent to twenty-five of urban households. In Kenya, 8 per cent of the gross domestic product is dependent on mining. (World Bank, 2018). Previous studies have not been conceptualised in Igembe South, which is one of the nine sub-counties that make up Meru County. Due to the land's fertility, it is a Meru administrative Sub-County with an enormous acreage and the highest population. Further, extant literature has not examined the spatial distribution of quarry stones mining sites. The studies have failed to determine the socioeconomic impacts of quarry stones; for instance, Tropek et al. (2020) investigated the technical reclamations of post-mining sites in black coal spoil dumps.

In contrast to the current study, the related studies used different methodologies to analyse data. For instance, Huang et al. (2019) investigated mining and tourism spatial patterns and economic contributions in biodiversity hotspots in China but only used chi-square tests, while the current study used the average nearest neighbour distance tool. The average nearest neighbour distance tool is used to calculate the centroid of each feature and that of its nearest neighbour. This concept classifies features as clustered if their average distance from each other is less than that of a hypothetical random distribution and dispersed if their average distance is more than that of the random distribution. Divide the actual distance travelled by the expected distance travelled to get the index. (To compute the spread, a random distribution of the same number of features covering the same total area is employed). A similar study by Winnier (2019) researched mining sites in Migori, Kenya. Specifically, it examined the spatial distribution of mining sites in their counties and found that they were clustered. However, in Igembe South Sub County and

Kenya in general, Meru County has yet to be discovered. Therefore, the spatial distribution of mining sites has been determined as either cluster or dispersal.

METHODOLOGY

Igembe South is between latitude 0.2664°N to 0.379534°S and longitude 37.953°E to 38.001°E. It is one of the Sub-county of Meru County. It is an electoral constituency in Kenya. It is one of nine sub-counties of Meru County. It covers an area of 270.7 square kilometres and has a population of 145301 people. The sub-county is bounded on the south by Tigania central sub-county and to the North by Igembe central sub-county. A descriptive design was used. According to the Kenya National Census (2009), the sample size was justified because the researcher's time and resources were insufficient to cover the entire territory, which has a population of 145,301 people and 40 communities. The whole population is

divided into 3635 people in each community. Five towns were chosen based on their distance from mining sites or containment posts (Table 2). For the survey, 70 participants were selected randomly from two settlements that were 0.5-1.5 kilometres distant from the mine sites. Sixty (60) responders came from a single community 0.5-1.5 km from the mine commitment site, whereas fifty (50) came from two (2) settlements, each further away (that is 1.5-3km away). This was done to investigate whether there were any differences in how people reacted to the effects of mining in different areas depending on how close they were to the mine. As a result of this allocation, there are 300 people in total. The views acquired from the overall sample of 300 respondents represented the views of the entire community because the five (5) villages included in this survey were scattered throughout the sub-county and not concentrated in a single location. The sample's specifications are shown in Table 1.

Table 1: Distribution of Sample

Community	Distance from the mine site	Number of respondents	Per cent %
Auki	0.5-1.5km	70	23.33
Amwamba	0.5-1.5km	70	23.33
Name	0.5-1.5km	60	20
Kirindine	1.5-3km	50	16.67
Tiara	1.5-3km	50	16.67
Total		300	100

Source: (Researcher's field sample survey, 2021)

Because these settlements are so close to the mines, the researcher took larger samples from Auki (70), Amwamba (70), and Nceeme (60), as shown in Table 2. The Igembe South sub-county mining site is also close to Kirindine and Tiara, with Kirindine and Tiara being the closest (0.5-3.0km). This was done to see how different respondents' reactions to the effects of mining on their communities were. Five (5) members of the Nyambene County government's health department, the General Hospital (Maua), were approached for essential information. A group of ten (10) mineworkers from various mine departments were also questioned for details on their health problems. The self-administered respondent questionnaire was constructed using information acquired on the benefits of land mining sites in order

to obtain substantial data and consequences on communities' social, economic, and environmental well-being. The instrument had been subjected to a two-day trial period prior to data collection. The validity and variability of the instruments, clarity, relevance, and time necessary to deliver the questionnaires were determined by piloting. It also assisted researchers in administering and analysing questionnaire items, training research assistants, and fine-tuning the research instrument. The spatial distribution of quarry stone mining sites in Igembe South is vital. The data required was a map of Igembe South Sub-County showing mining sites, global positioning system coordinates and distance from one mining site to another. The method of data collection includes a Global positioning system and opisometre.

The method of data analysis was the nearest neighbour statistics. The nearest neighbour statistics formula is

$$R_n = 2d \sqrt{\frac{n}{a}}$$

where R_n = the nearest neighbour statistics
 d = the mean observed nearest neighbour distance,
 n = The total number of points, a = The total area.

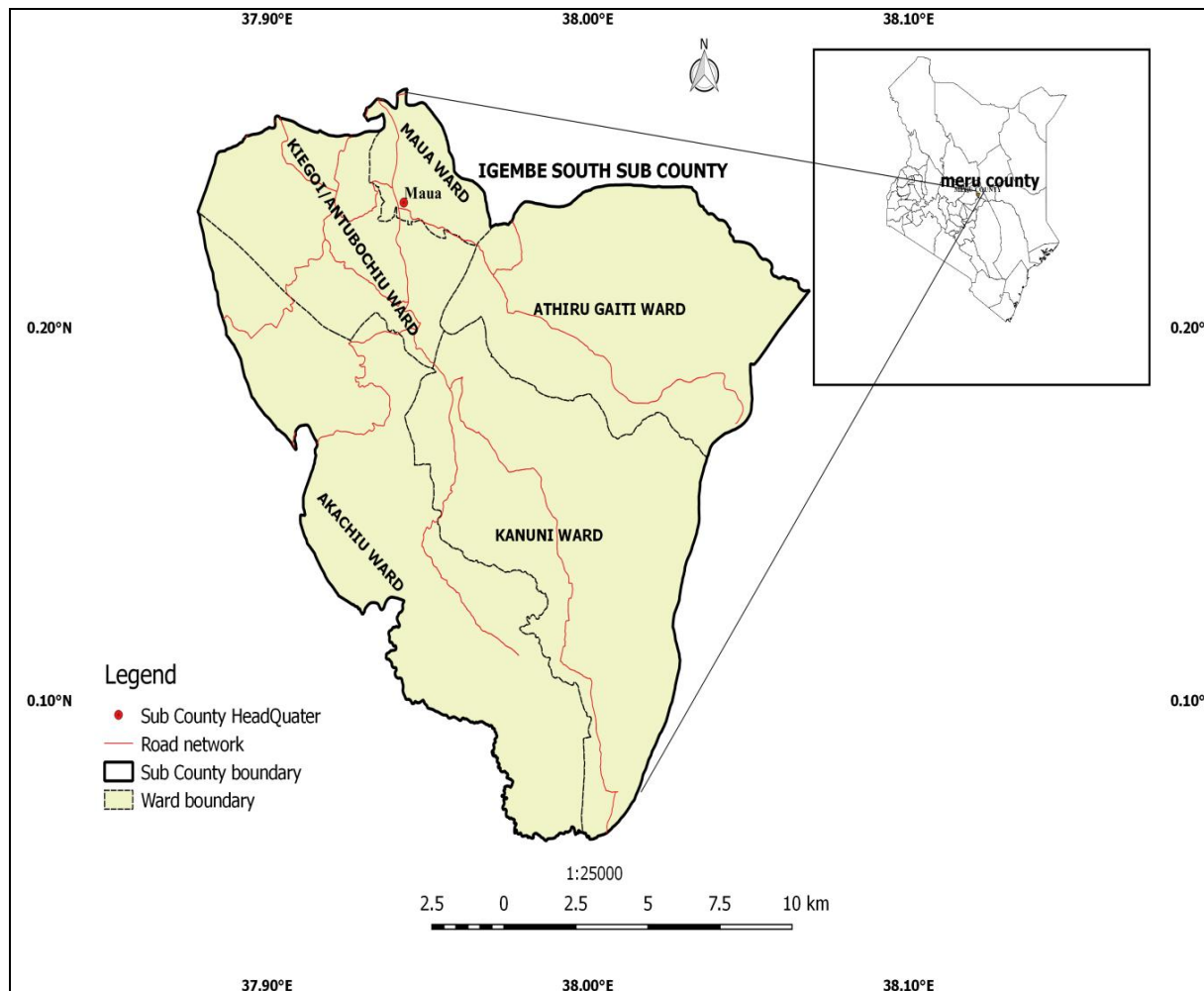


Figure 1: Map of Igembe South Sub-county

Source: Independence Electoral Boundaries Commission (2010) revised Igembe South Constituency County Assembly wards.

Data analysis includes the nearest neighbour method of analysis description of means, median and mode. Where applicable, other relevant mathematical and statistical methodologies, such as Chi-Square, were used in the investigation. The results of the analysis were presented in both qualitative and quantitative terms. Each is complementing the other.

FINDINGS AND DISCUSSION

Spatial Distribution of Mining Sites and Activities

In Igembe south sub-county, the leading mining activities consist of sand harvesting and quarry stone extraction. The researcher established thirty artisanal mining sites geographically spread across the wards. Specifically, the Auki sub-location had eight sites, Amwamba had ten sites, Nceme had six sites, Kirindine had three sites, and Tiira sub-location had three sites. Akachiu ward, located in the south, had more mining sites than other wards, with twelve sites where mostly

sand harvesting was done. Alluvial mining locations were the furthest of the mining sites; the Tiira site was located approximately 15.3 kilometres south of Maua town, while the Kirindine and Nceme sites were located at 11.1 km and 8.9 km, respectively. In the Auki

sub-location of the Kiegoi/Antubochiu ward and Amwamba within the Maua ward, quarry stone mining was practised more prominently. These sites were located about 6 km and 1.5 km consecutively.

Table 2: Geographic Location of Mining Sites and Activities in Igembe South Sub County (Source: Author)

Sub location	Ward Name	Mining sites	Main Activity	Distance from Maua town
Amwamba	Maua	10	Quarry stone Extraction	1.5km
Auki Name	Kiegoi/Antubochiu Akachiu	8	Alluvial sand harvesting	6.0 km
		6	Alluvial sand harvesting	8.9km
Kirindine	Akachiu	3		11.1km
Tiira	Akachiu	3	Alluvial sand harvesting	15.3km

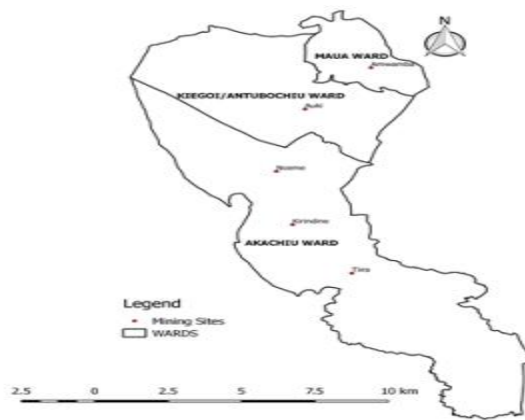


Figure 2: Spatial Distribution of Mine Sites across the Wards in the Study Area

From the visual analysis of the above map, most mining sites are majorly located along main transit routes. This can be explained by the availability of passable roads in the area. Based on the spatial distribution map, it is seen that in this area (Fig.2), there is a mining activity taking place in each ward, but more mining is observed in Akachiu ward, which has three mining sites at Tiira in the south most part, Kirindine in the middle area and Nceme in the northern part. Sedimentary rocks are primarily underlain in this area, and they are mined at various locations throughout the region. The nearest neighbour index was used to determine if the observation distribution pattern in Igembe South Sub County was uniform or not. The location of all existing mining sites was mapped by Garmin GPS device, and nearness or farness was analysed with the Average Nearest Neighbour Tool in QGIS. To generate a spatial

distribution pattern, the computed nearest neighbour ratio was compared with the standard index value.

From the computed values (Table 3), the observed mean distance among the 5 mining sites across Akachiu, Maua, and Antubochiu/kiegoi wards was calculated to be 282.16 meters with an expected mean of 121.16 meters. The location of these mining sites had a deviation of 5.682 (Z score) above the mean distance at a significance level of 0.01. Most mining sites in this area are located in high-elevation areas, especially in forested regions. The rugged terrain creates accessibility problems, and for this reason, mining activities involve quarrying of building stones and shovelling of marram soils. Most mining activities are manually done, involving the use of manpower with little or no mechanisation.

Table 3: Nearest Neighbour Analysis of Mining Locations in Igembe South Sub County

Description	Value
Number of Mining sites	5
Observed Mean Distance	282.16 Meters
Expected Mean Distance	121.16 Meters
Nearest Neighbour Index (Ratio)	2.32
Z-score	5.683
P value	0.0000

According to Esri (2018), values of the nearest neighbour index, an index of 0 implies exclusively clustered distribution, an index value of 1.0 shows absolute random distribution, and an index value above 1.0 indicates a propensity to disperse. So, for our case of mining sites, the generated nearest neighbour index was 2.328, indicating that mining sites in Igembe South Sub County show a dispersed distribution pattern. Given the z-score of 5.683, there is a higher likelihood that the dispersed pattern of mining site distribution could not be the result of random Chance. The observed spatial spread of mining sites is due to the existing geological conformation, which has rocks that are mined for building stones and road construction chips. The Akachiu ward, which lies on the southern edge of the sub-county, for instance, has three mining sites: Tiira, Kirindine and Nceme. Tiira mining site, which lies south of the Kirindine site, is the farthest from the Marega sub-location within the Nceme site and is located in the upper parts, especially in the Nceme sub-location of the Athi location within the Giika location. Kirindine mining site lies in the central part of the ward in Kirindine sub-location of Kirindine location.

The study area (Igembe South) lies on an elevation of 1580 meters above sea level, with the underlying geology influenced by volcanic activity with phonolites, trachytes, basalts and pyroclastic rocks (Makhura, 2021). The topography here is hilly, with woody vegetation and rocky outcrops. The major economic activities in the area are tea farming. This area forms the eastern arm of the Nyambene hills and has the steepest slopes. Auki mining site lies in Antubochiu/ Kiegori ward and specialises in maram and building sites. It is located on a relatively low-lying landscape reachable by road leading to Maua town from Athi. This particular site is located in the Kinyanka sub-location within Kanthiari Location. The last mining site is Amwamba within Maua ward, also an important source of building stones. The Amwamba site is found in the Makiri sub-location of the Maua location.

Factors Determining Nature and Type of Mining Activities

Several factors were identified as accounting for the variations in the nature, type and intensity of open stone quarry and alluvial sand mining in the study area. This is presented in Table 5.

Table 4: Reasons for Engaging in Mining Activities in the Study Area

Factors	Frequency	Percentage
Household Basic Needs	70.08	24
Non profitable agriculture	26.25	9
Poverty	49.64	17
Level of education	29.20	10
Population increase	32.12	11
Access and availability of mining sites	14.60	5
Construction market	46.72	16
Weak mining policy	23.3	8
Totals	292	100

Based on the findings in Table 5 above, the desire to provide basic household needs to their families accounted for the greatest cause of variation in mining practices at twenty-four per cent. Although the main economic activity is Khat farming and tea picking, the decline in these commodity prices and changing lifestyles are now pushing people to engage in stone quarrying activities and alluvial sand harvesting as alternative sources of livelihood. This is in line with the findings of Abogaye (2016), who found that non-formal artisanal enterprises such as stone quarrying are becoming more popular as a way to meet household needs. On the other hand, poverty (which accounts for 17 per cent of the population) forces households to engage in stone quarrying activities since the cash generated from mining improves the living standards of the people involved. Stone quarrying activities in Nakisunga Sub County, Mukono district, Uganda, according to Tamale (2019), were a key source of income for the impoverished.

According to the World Bank (2020), more than half of the populations in transition nations are poor, with over 1.2 billion people living on less than \$1 per day. It was found that demand from the housing sector has catalysed and intensified mining activities in the Igembe South sub-county. Demand for quarry stones and alluvial sand in the towns of Maua and the satellite markets of Auki, Athi, Kimongoro, Njuune and Kamiruru have pushed the mining business up. From this table, demand from the construction market in the housing sector accounted for 16 per cent of the observed scenario. Stone quarrying and alluvial mining have increased significantly in Igembe south sub-county as a result of the development surge in recent years in Maua, Isiolo, and Meru towns.

Land fragmentation for intensified farming has resulted from the high population growth (11 per cent), causing individuals to turn to stone quarrying and alluvial mining as alternative means of income. The 2019 KNBS house census shows that this area has seen an increased population. Corbin (2008) observed that population growth leads people to encroach on marginal natural resources as a way of meeting their needs, resulting in degradation. A total of 10 per cent of the respondents indicated that the Education level of the residents influenced the decision to engage in resource exploitation. Education as a tool influences

decision-making on various aspects of human life (Asare et al., 2015; Makhura, 2021). In this scenario, the participant's educational levels impact what to mine, how to transport it, and how much to sell it for. Overcrowding, climate change, price volatility of tea and khat in the area, and land fragmentation all contributed to individuals engaging in non-farm activities, particularly stone quarrying (9 per cent). Others have cleared crops and started mining sites, which generate non-taxed income and do not require one to own a transportation tool. Weak mining policy (8%) and regulation, especially by the county government of Meru, have created a gap exploited by the artisanal miners who operate non-licensed mining sites and activities. This has seen a mushroom of uneconomical alluvial sand scooping and quarry stone illegal mining sites along road reserves or deep into the Nyambene ridges. Lastly, access and availability of mining land have significantly driven the business of quarrying in the study area. Landowners are leasing out their land to private miners who extract alluvial sand and, in other places, quarry stones for selling to the developers across the county of Meru.

CONCLUSION AND RECOMMENDATIONS

Conclusion: In Igembe South Sub-county, mining takes place in three of the five available wards. Depending on the overburden, availability, and surface depth of the quarry stone and alluvial deposit, many mining methods were applied in the research region. The widely used technique for mining in the study area was underground excavation (43%) for getting quarry stones dislodged deep into the overburden. This involved the deployment of heavy machines to remove the top and sub-soil in order to reach the hard rock. At other times, human labour is employed to dig shallow tunnels through which hand excavation tools are used to break the rock. Another frequently used method was surface mining (27%), especially for the alluvial sand scooping, where the sand was scooped from shallow beds using shovels or frontend loaders. This method was used in the Kithangene quarry of Auki, where alluvial sand was harvested from the riverbeds. Dredging (23%) was not popular in this since it required heavy special task machines to expand existing quarry sites. Other methods accounted for 7 per cent, which included heating stones and blasting.

The spatial distribution of mine sites is variable across the three wards, namely, Maua Ward, Kiegoi/Antubochiu Ward and Akachiu Ward. Akachiu ward has the greatest number of mine sites, totalling fifteen sites, which are geographically located in Kirindine, Tiira and Nceme sub-locations. This was followed by Maua ward having ten specifically quarry stone mine sites situated within the Amwamba sub-location. The ward with the lowest number of mining activities was Kiegoi/Antubochiu, having eight mine sites spread geographically across the Auki sub-location. Of all mining activities in these sites, 89 per cent are concerned with quarry stone excavation, while 11 per cent are those dealing with alluvial sand mining. The greatest social benefit that communities working in the quarry received was support from forged social networks. These social systems enhanced resilience and pooling of economic resources amongst workers to provide household basic needs, recruit new members into the quarry and train young workers through apprenticeship. Economic benefits were in the form of investment and business opportunities accruing from mining-related activities.

Recommendations: Environmental assessment and audit programs should be periodically done to ensure compliance with good environmental practices. Awareness creation and sensitisation should be made a priority for the miners and local community on the benefits and impacts of excavation. There is a need for the formulation of by-laws by the county government of Meru on the exploitation of resources. Capacity building for the mineworkers should be made where new technologies and tools are demonstrated, and skills are impacted to those concerned. Mobilisation of resources towards support of artisanal mining should be done through the creation of a funds kitty to advance loans and credits to the miners. Occupational safety, health, and protection should be prioritised among quarry workers at all levels to minimise health hazards. Modernisation of extraction should be done to improve efficiency and operations in the quarries. Compensation should be made to communities whose land has been acquired or degraded by mining activities. Consultative meetings should be forged between the concerned departmental ministry and the locals to enhance public participation. Land reclamation should be done through vegetating excavated land and water drainage. Mining counties must decide on ownership, operations, maintenance, and funding modalities when considering a shared use of quarry stone projects.

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