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EXAMINING AND DOCUMENTING SPATIAL ATTRIBUTES OF POST-MINE BROWNFIELDS IN KISUMU CITY, KENYA

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Abstract: *Landscape residues after mine/quarry closure are usually scarred, distressed and disturbed. These landscapes referred to as brownfields are found in different sizes with negative spatial characteristics that pose ecological, social and visual problems. They are perceived as barriers, problem spaces and obstacles to beneficial land uses but with a lot of hidden potential for fast spreading urban developments. The rehabilitation of these post-mine brownfields is only possible after analysis of their spatial attributes and assessing their effects within the neighborhoods and city at large. The purpose of the study is to examine the spatial attributes of four former stone mining quarries within Kisumu City, Kenya. The study postulates that effective and successful reintegration of post-mine sites into beneficial uses through rehabilitation is only possible after analyzing the spatial attributes and effects they pose on the environment. The study was carried out through a case study of four post-mine brownfield sites purposively selected because of long history of stone mining and at the time of the study had stopped quarrying. Each of these sites became a unit of analysis upon which the study was anchored. The spatial attributes examined in this study included location, access, size, ownership and tenure, topography and drainage, flora and fauna, land uses, activities on site and lastly views within the sites. Onsite observation by the researcher was used to collect the primary data on spatial attributes. Photography and documentation using field observation guide was used to collect and present the primary data in addition to interviews with key informants that included the quarry land owners and officials charged with management of mining and environment. Desk review was undertaken to gather information on brownfields in different contexts. The study findings are presented through photos, tables and figures. The study revealed that the four sites were located within peri-urban areas under private land ownership. The sizes ranged from 0.45 to 1.2 hectares approximately. Negative attributes included uncontrolled dumping of wastes, waterlogging, untamed vegetation and unpleasant visual quality that affected aesthetics of immediate surrounding areas. The study recommends provision of alternative waste disposal areas if rehabilitation of the sites is to be planned and implemented into beneficial reuse options.*

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Keywords: *Spatial attributes, Post-mine brownfields, Kisumu City, Peri-urban, spatial planning*

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INTRODUCTION

Spatial analysis of brownfields is very important in the redevelopment of brownfields and should not be considered in isolation. The location of brownfields close to a major road network may be an important factor in the development of relatively large brownfields (Novasak et al. (2013). Hagiou & Konstantpoulou (2011) stress that detailed examination of the post-mine sites in terms spatial characteristics to form a database is the first useful tool for making decisions regarding the most suitable rehabilitation solutions for the abandoned quarry lands. Herberle & Wernstedt (2006) add that brownfields are placed and rooted in certain geographical space and time. Their location is hierarchically and functionally structured and therefore brownfields have to be perceived in their spatial context. We should therefore take into account site-specific attributes when assessing them. Site-specific factors and general factors such as location factors are among the most important in identifying and analyzing the relative importance of each brownfield.

Utilization of brownfields depends on many factors among them the availability of spatial information. This includes size, type of brownfields, infrastructure, and any possible contamination. This calls for good documentation of spatial information as inventories (Ferber et al., 2006). According to Contaminated Land Rehabilitation Network for Environment Technologies CLARINET (2007), the physical characteristics of the post-mine brownfields are one of the key elements in the determination of the after use of the post-mine brownfields during reclamation. Each brownfield has its unique physical attributes in terms of location, size, depth, drainage, landform, vegetation, etc. and are very important in determining the best reuse during reclamation. In general, considerations of after use operate at two levels: strategic land use planning and detailed site specific planning decisions. According to Hersch et al. (2010), site specific planning and assessment are integral to the proposed after-use of the site. They are interactive processes that ensure that constraints and aspirations are effectively addressed. This

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ensures proposals for rehabilitation are appropriate for the site. Specific planning aspects that include landform, drainage and vegetation have to be integrated at an early stage of the planning phase for any rehabilitation reuses.

Frantal et al. (2012) state that some experts and researchers have emphasized that brownfields reclamation is a highly individual process. This means each project is specific and no generalization is possible. Hersch et al. (2010), emphasize that the physical dimensions of the site can have a significant effect on its highest and best use during rehabilitation. If the site is too small and irregular in shape or has topographical challenges, traditional reuse options like residential are limited. Brownfield site access to primary transportation routes also has a positive effect on its future monetary value. Locations near public transportation routes or along major transportation corridors generally have higher values than those with poor access to transportation (Hersch et al., 2010). According to Kuter (2013), there is no unique reclamation planning scheme for the post-mining landscapes as each site is different and reclamation depends on site-specific characteristics that differ with each site and locality. Brownfields found in different areas have varying spatial attributes in terms of sizes, previous uses, locations, different effects to the environment. It is therefore vital to understand each brownfield in its own context before appropriate land use option for reuse is considered. Ramani et al. (1990) state that the process of integration of post-mining sites starts with reconnaissance, site investigations until the final reuse option for the site is determined after engaging several stakeholders at different stages of the planning process.

Past industrial mining activities in Kisumu City have left behind acres of derelict sites within the urban area and peri-urban areas. The sites are considered as brownfields and some are within residential neighborhoods like Migosi, Nyawita and Mamboleo. The abandoned post-mine sites take up vital land that would otherwise be utilized in a beneficial way, are hazards due to crime and other social evils and are not aesthetically appealing due to illegal dumping of wastes within them (K'oyoo et al., 2022a; 2022b). Currently, information regarding the types of brownfields in Kisumu City, their spatial characteristics that are important in planning for land-use options for reuse through reclamation is not known. This constitutes the knowledge gap that this study hopes to bridge. The study specifically intends to address the site-specific attributes of the four post-mine sites within Kisumu City. Reviewed literature point to the fact that each post-mine brownfield should have its site-specific spatial attributes analyzed in its own context and this forms important part of the planning process for the rehabilitation reuse option that may be implemented. The fact that each post-mine site has its site-specific characteristics (Kuter, 2013) imply that similar studies that have been done in other contexts cannot directly and fully inform the re-planning of post-mine brownfield rehabilitation in Kisumu City owing to varying spatial attributes and other site-specific characteristics. The authors in this paper argue that continued presence of post-mine brownfields in their abandoned, disused state without planning for their reuse into beneficial land uses through rehabilitation means that the physical, ecological and social problems they pose will continue to be felt within their localities. We posit that adequate information on the spatial attributes through

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inventorying is an important first step towards planning for the rehabilitation of these abandoned landscapes that pose a lot of problems within their locations.

The study sought to examine spatial attributes of the four post-mine sites that was addressed through a documentation and analysis of aspects on geographical location including GPS coordinates, access/transport link, history of the site, land ownership structure, size and depth of the quarry pits, topography of the quarry location, drainage within the quarry pit, views within the quarry, neighborhood, flora, fauna and activities on-site. At the time of this study, the few studies that had information regarding spatial attributes of post-mine brownfields in general were very few and not within African context. This study therefore sought to fill this existing gap in information regarding the spatial attributes of these abandoned and disused sites that have latent potential within their localities. This study therefore intended to examine and documenting spatial attributes of post-mine brownfields in Kisumu City, Kenya.

METHODOLOGY

The cross sectional research approach was used to examine and document spatial attributes of post-mine brownfields in Kisumu City. Reconnaissance study was conducted between 2016 and 2017 to identify and locate the post-mine brownfields within the study area of Migosi, Nyawita, Wathorego and Kanyawegi sub-locations.

All the four brownfields under study were identified and selected for study using purposive sampling method due to their large sizes. Each brownfield became a sample site due the fact that they were existing sites of former stone mining areas and that they no longer had mining activities ongoing. Other studies on brownfields have defined a brownfield neighborhood as a 500 meter (0.3 mile) circular radius around a brownfield (Pearsall, 2010; Fisher (2011). Essoka (2010), considered a slightly larger radius of 0.5 mile to allow for more general understanding of socio-economic character of areas adjacent to brownfields. This study was based on households that are living within the 500 metres from the boundary of the brownfield within each of the four sub-locations. According to KNBS (2009), the four sub locations where the four post mine sites are found have a total of 13,127 households. A total of 3300 households constituting a quarter number for all the households within the four sites was used to calculate the total sample size for all the four sites. Sample size calculation was according to Mugenda & Mugenda (2013), for population less than 10,000.

Selecting the households for each brownfield site was based on the sampling frame above with a total of 96 households for all the four sites. The number of households that constituted the sample for each sub location was therefore Migosi 35 households, Nyawita 30, Wathorego 21 and Kanyawegi 10 households Random sampling was used to collect data from the households from

the boundary of each site and in the subsequent radii within the 500 metres boundary. Five concentric circles were drawn in GIS were used to approximate the various radius for data collection around each site. Data was collected from the respondents within each diameter of the concentric rings around each site with each first household being selected randomly and others within the ring picked randomly at various ends all-round the diameter. Proportional stratified sampling technique was used to calculate the number of households to form the sub samples to be interviewed within each of the four sub locations of the study area. Respondents within the various radii were distributed equally. All respondents were picked and included to form the sample size where the household members were willing to participate in the study. Data collection was limited to the various boundaries of each sub location even in cases where the 500 metres radius overlapped into the other neighboring sub location like in the case of Migosi and Nyawita.

Three approaches were used to collect primary data i.e. questionnaire, observation guide and photography and lastly interview schedule for key informants. The respondents were asked their perception on various effects of the post-mine sites within their neighborhoods. Structured questionnaires which consisted of open and close ended questions were used during the data collection process. The questionnaires were administered by the researcher and involved first identifying himself then clarifying the purpose of the study. On site observation was carried at random times of the day for each of the four sites under study. Direct observation involved checking on dumping of wastes. Observation and digital photography helped the researcher to cross check some of the responses from the respondents done through questionnaire. The reconnaissance was carried out by interviewing the area sub-chiefs who are well versed with the location, number and landowners of the brownfields within their areas of jurisdiction.

In terms of data analysis, both quantitative and qualitative data analysis procedures were used to analyze the collected data. Quantitative data was analyzed using descriptive statistics including percentages. Analyzed data was presented using texts, tables and figures. Key informants included quarry land owners, director of city planning, director of environment at County Government of Kisumu, senior officer at Kisumu Urban Project, Physical planner at Ministry of Lands, Director of National Environment Management Authority (NEMA) Kisumu County, Mines and explosives officer at Ministry of Mining and a private practicing planner. The data from the key informants was collected through various interview schedules that consisted of open ended questions. Qualitative data was then categorized, transcribed and presented based on the study major thematic areas.

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RESULTS

Demographic Characteristics of the Respondents

Apart from the researchers field work through on-site observation the following key respondents were engaged to provide vital information regarding the spatial attributes of the four post-mine brownfields.

Table 1

Key Informants

Key informant	Organization
Director of Environment	County Government of Kisumu, Environment Department
Director NEMA	NEMA, Kisumu County office
Mines and Explosives officer	Ministry of Mining ,Mines and Geology Department
Land valuer	Ministry of Lands, Physical Planning Department
Brownfield/quarry landowners	Nyawita (2 no.), Migosi (1 no.), Wathorego (1 no.) & Kanyawegi (1 no.).

Spatial Attributes of the Brownfields

The aim and purpose of the study was to examine the spatial attributes of the four post-mine brownfields in Kisumu City. The information on the different spatial attributes is vital in planning for the rehabilitation/rehabilitation of the post-mine brownfields to ensure successful reuse. Each post-mine brownfield was analyzed independently in terms of its spatial attributes due to the unique characteristics of each of them. The different spatial attributes examined included location, size, ownership, topography, drainage, flora and fauna, views within the site, fauna, activities on-site and land uses around the brownfield. The information on spatial attributes helps in making planning and design considerations when implementing the preferred viable options. It is important to understand the spatial attributes as they contribute to the effects on the environment and are important in determining viable reuse options during reclamation/rehabilitation.

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Location, access and size

Table 2
Location, coordinates, size and depth

Spatial attributes	Post-mine brownfields.			
	Migosi	**Nyawita**	**Wathorego**	**Kanyawegi**
Geographical location	Kondele Location approx. 80 metres off Kisumu-Kakamega Road next Migosi junction.	Kondele Location approximately 350metres off Kisumu-Kakamega Road.	Kajulu West Location approx. 30m off Kisumu-Miwani road.	Kisumu South West Location approx.150m off Kisian-Bondo road.
Reference Coordinates	GPS: Latitude 0.076459^{O}S Longitude 34.776818^{O}E	GPS: Latitude 0.079958^{O}S Longitude 34.773090^{O}E	GPS:Latitude 0.055182^{O}S Longitude 34.793487^{O}E	GPS:Latitude 0.102105^{O}S Longitude 34.646405^{O}E
Size of the quarry pit	Approx. 0.45 ha	Approx. 1.2 ha	Approx. 0.65ha	Approx.0.8 ha
Depth of quarry pit	Shallow ends at 3m, deepest ends approximately 10m.	Deepest end 12 metres. Most areas quarried between 5m & 10m depth.	Shallow ends 3-5 metres. Deepest ends approx. 10-15 metres	3-6 metres at shallow parts. 5-10 metres at deepest parts

Nyawita's post-mine brownfield is located approximately 4.1 kilometres from the city centre and 350 metres off the Kisumu-Kakamega Road within Kondele Location. The main access/transport link leading to the brownfield is an all-weather murram road from Kisumu- Kakamega tarmac road. Main entry is from the northern part of the brownfield and is sloping gently into the quarry land. According to a middle aged son of the quarry owner the abandoned quarry land has a total acreage of approximately five acres. The area was confirmed and proved by the two land owners. Depth of brownfield hole varies approximately between 5 metres on the shallow end next to the entry and 12metres at the deepest end of the quarry. Most parts of the brownfield were quarried to depths of 5-10 metres and they show rugged stone within its walls. At the time of the study the quarry land was not fenced at some points on its boundary that were still vacant and not occupied by residential houses. These unfenced areas were a big threat in terms of cases of accidental fall in. Some residential houses have iron sheet fences and wall fences to prevent the risk of falling into the quarry.

Migosi's post-mine brownfield is located approximately 4.6 metres from the city centre and 80 metres off Kisumu-Kakamega road next to Migosi junction road to Kenya–Re estate. The abandoned quarry is approximately 0.45 hectares in size. The site is accessed by all-weather

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murram roads that branch from Kisumu-Kakamega road and the other from Migosi junction road that leads to Kenya Re-estate. According to a middle aged local the quarried land was originally larger than what is presently visible as the quarry area. Part of the quarried land was back filled by the owners of the plots that had been allocated under the Migosi site and service scheme when they were constructing the bungalows around the quarry boundary. Quarrying was done to depths of approximately 3 metres on the shallow ends and about 10 metres on the deepest parts.

Wathorego post-mine is located approximately 8 kilometres from the city centre and 200metres from Obwolo junction off Kisumu-Miwani road. It is accessed by tarmac road from Mamboleo junction and is 30metres off the tarmac road. According to land owner its approximately 0.65 hectares for the three different quarried areas that are adjacent to each other. Quarry depths vary approximately between 3 to 5 metres on the shallow ends and 10-15 metres on the deepest end. Kanyawegi post-mine brownfield is found approximately 17 kilometres from the city centre and 150 metres off Kisian Bondo road. It's approximately 0.8 hectares in size. According to an official of the company the exact area of the quarried is not known but depths of quarrying were done to 6 metres for most areas of the quarry pit. At the time of the study the post-mine was not fenced on any of its boundaries and was closely bounded by an access road that was used by motorcycles and pedestrians.

Ownership and tenure

According to a middle aged son of the land owner of Nyawita post-mine site at the time of the study, the land is still under the ownership of the two private owners under separate freehold titles. Approximately a fifth of the quarry is owned by one owner while the largest part (four fifths) is owned by the other private owner. The owners are aware of their boundaries within the abandoned quarry pit. Migosi post-mine is currently owned by a private owner under lease hold. Wathorego post-mine and is owned under freehold title by a private limited company and the quarrying has been done within an area of about 2 acres while the Kanyawegi post-mine is also owned by private limited company under freehold title.

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Topography and drainage

Table 3
Topography and drainage

Spatial attributes	Post-mine brownfields.			
	Migosi	**Nyawita**	**Wathorego**	**Kanyawegi**
Topography of quarry location	Gentle slope from the highest point on the eastern side towards the lowest part on western side	Gentle slope from lowest point on northern end to the highest point on southern end.	Highest point on northern side and with gentle slope towards southern side.	High topography area surrounded by immediate areas of gentle slope.
Drainage within Quarry pit	No outlet for drainage of surface runoff hence 100% waterlogged.	Towards the lowest point within the quarry at the entry point on northern end at the outlet.	No outlet for drainage of surface runoff.	Outlet at the lowest point near entry and water logging at deepest part of pit

From Table 3 above, topography within the Nyawita quarry site is gentle slope towards the northern side. On-site observation shows that the main drainage point for surface run-off is at the main entry point to the quarry pit located at the northern end and was the lowest end of the quarry pit. According to a middle aged son of the post-mine water logging due to the blocked outlet on the northern side poses a big health risk due to waterlogging. On-site observation revealed that Migosi post-mine brownfield had no outlet for surface runoff and hence was entirely waterlogged and swampy and hence covered by dense and long papyrus reeds within its entire area. The brownfield location is on a gentle slope from the western side to the eastern side. The waterlogged swampy nature provides a good breeding ground for mosquitoes, dangerous fauna like snakes and a major source of air pollution from the dumped wastes within it due to foul smells.

According to the post-mine land owner for Wathorego water logging is a major problem within the site during rainy seasons due to the deep depths that have been quarried without drainage outlet for surface run-off. The post-mine is located within an area of steep slope within the highest part being on the northern part while the southern is at the lowest part. The largest quarry pit among the three pits, has the greatest problem of drainage of surface run-off and it exhibits waterlogging at the middle deepest part. Presence of water logging within the deepest end is a threat to safety of children who may drown when swimming within the quarry. Kanyawegi post-mine is located within a high topography in reference to the surrounding areas of gentle slope and has no outlet for surface run off during heavy rains. The post-mine has an outlet at the lowest point near entry and presence of water logging at the deepest ends of the quarry pit is evident from on-site observation.

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Plate 1: Water logging & papyrus reeds within the entire Migosi brownfield.

Plate 2: Water logging within the Kanyawegi post-mine brownfield.

Flora and fauna

Table 4
Vegetation and fauna

Spatial attributes	Post-mine brownfileds			
	Migosi	**Nyawita**	**Wathorego**	**Kanyawegi**
Flora/vegetation	Papyrus reeds Eucalyptus species,casuarina equisetifolia, water hyacinth (Eichhornia crassipes), urban agriculture: bananas,mangifera indica, sugarcane.	Papyrus reeds, lantana camara species, cassia spectabilis, cactus varieties, grass species, water hyacinth	Acacia species, lantana camara, grass,various tree,shrub species	Eucalyptus lantana camara and other tree & shub species, grass sp.
Fauna	Scavenger birds, monitor lizards, snakes, frogs.	Monitor lizards, frogs, snakes, birds.	Scavenger birds, monitor lizards	Monitor lizards, snakes, frogs, birds

According to Table 4 above, Vegetation cover within Nyawita post-mine included papyrus reeds within the waterlogged swampy area, lantana camara species, cassia spectabilis trees, cactus

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varieties, grass cover in some areas and water hyacinth (Eichhornia crassipes) within the waterlogged swampy area. Existing fauna include monitor lizards, frogs, snakes and birds. Scavenger birds were present within the dumping areas and within the waterlogged swampy part.

Plate 3: Grass cover in dry parts of Nyawita site. Source: Author (October, 2017).

Plate 4: Lantana camara & Acacia species at Wathorego site.
Source: Author. (October, 2017).

Migosi post-mine's vegetation included eucalyptus trees, Casuarina equisetifolia, papyrus reeds, water hyacinth (Eichhornia crassipes), grass species, vines. Urban agriculture in terms of edible species consists of mangifera indica, pawpaw, bananas and sugarcane planted within the compounds next to its boundary. Fauna included monitor lizards, snakes, birds, frogs. Noisy scavenger birds that feed on the dumped wastes are evident within the site. On-site observation revealed that due to lack of an outlet for surface runoff the quarry pit was entirely waterlogged, swampy and hence covered by dense and long papyrus reeds within its entire area. Vegetation within the Wathorego quarry pit includes acacia species, lantana camara shrubs, grass, and tree species next to the entry area. Fauna present included monitor lizards, snakes and various bird species including scavenger birds that visit to feed within the swampy water logged area. Kanyawegi post-mine site had vegetation that includes lantana camara, eucalyptus species, grasses and vines. Papyrus reeds were also evident on the waterlogged deep end of the quarry pit. Fauna within this site included frogs, scavenger birds, monitor lizards within the waterlogged deep ends that have papyrus reed vegetation.

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Land uses

Table 5
Zoning and existing land uses

Spatial attributes	Post-mine brownfields			
	Migosi	**Nyawita**	**Wathorego**	**Kanyawegi**
Land use zoning	Residential	Residential	Residential	Agricultural
Existing land uses	Residential, commercial	Residential, commercial	Residential, industrial	Agricultural, residential, industrial

Findings in Table 5 above show that Nyawita post-mine site is located within an area with its residential houses built within the boundary of the quarry land and consists of both formal planned permanent houses and the informal semi-permanent houses on one end. The neighborhood is densely populated according to GOK KNBS (2009) population census at the time of the study. It has been provided with adequate water supply and electricity connection. The quarry land was not fenced at some points on its boundary that were still vacant and not occupied by residential houses. These unfenced areas were a big threat in terms of cases of accidental fall in. Some residential houses have iron sheet fences and wall fences to prevent the risk of falling into the quarry.

Plate 5: Well planned residential flats and bungalows on eastern side of Nyawita post-mine site.

Plate 6: Residential houses on the boundary edge of the brownfield at Migosi

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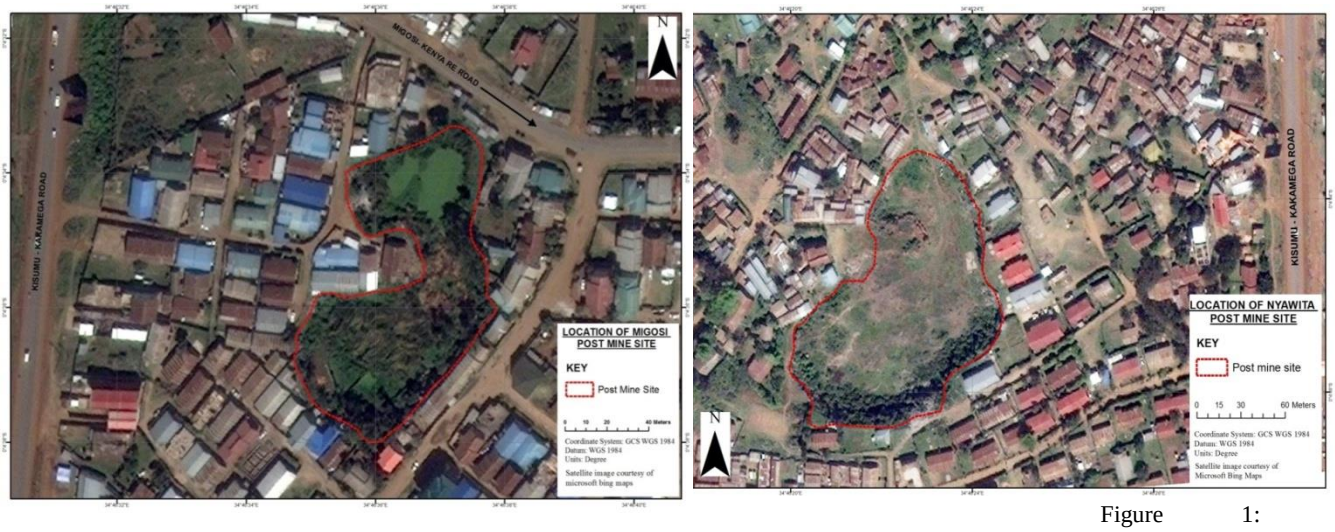

Figure 1: Satellite aerial image showing the buildings around Nyawita and Migosi brownfields respectively.
Source: Satellite aerial image (2018).

The neighborhood of Migosi post-mine site consisted of well-planned permanent residential and commercial bungalows and flats. The land uses next the quarry boundary include temporary and permanent commercial ventures and residential houses.

Wathorego post-mine site at the time of the study was surrounded by several developments with both commercial and residential buildings that have come to the vicinity of the quarry land. The eastern side of the quarry has its neighborhood consisting of residential flat houses and Ndugu Transport Company Limited that was still actively undertaking quarrying activities within Wathorego Sub-location. Construction of new residential developments around the brownfield vicinity was underway and more human habitation towards the brownfield. Presence of access paths next to the deep ends of the quarry was a great risk in terms of falling in. There southern part of the quarry has access road used by vehicles, motor cycles and pedestrians. The quarry was not fenced on three sides that is the eastern, western and the southern ends that are surrounded by residential developments. Wathorego post-mine is located within a sparsely populated area that is majorly residential but with two quarrying companies that had ongoing activities in quarrying and production of concrete products. Residential houses within the area were approximately 30 metres and beyond from the brownfield.

Kanyawegi post-mine is located within a sparsely populated area that is majorly agricultural. Residential houses within the area were approximately 30 metres and beyond from the brownfield boundary. The only residential home next to the brownfield was found 2 metres from the quarry boundary

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Activities on site

Table 6:
Activities on site

Spatial attributes	Post-mine brownfields			
	Migosi	**Nyawita**	**Wathorego**	**Kanyawegi**
Activities on-site	Dumping of wastes. Small scale urban agriculture.	Dumping of wastes. Small scale urban agriculture, Water well for domestic use.	Artisanal quarrying, dumping of wastes.	Occasional artisanal quarrying.

According to Table 6 above, on-site observation at Nyawita post-mine site revealed dumping of all types of wastes from the households within the boundary of the quarry. Human wastes present during the observation showed presence of human beings and use of the quarry for disposal of the same. Dumping was done from different ends of the quarry and was a major source of foul smell in and around the dumping spots thus a major source of air pollution. Other activities within the site included small-scale urban agriculture, occasional picking of stones during dry periods. The quarry land was abandoned and was a source of decay and degradation. On-site presence of street urchins was a source of theft to the residential houses on the boundary of the quarry. Activities within Migosi post-mine site included dumping of both household and human wastes.

Urban agriculture in terms of planting of nursery seedlings was also carried out on small scale. Abandonment of the site was a major source of negative social effects in terms of presence of street urchins who visited the dumping areas to ravage through the wastes. Wathorego post-mine site had activities that included dumping of household wastes on the shallow ends of the quarry and human wastes at some parts next to the nearby access roads. Occasional artisanal quarrying was carried out at the deepest end of the quarry. Occasional artisanal quarrying for stones and murram was the only activity carried out within the Kanyawegi post-mine site.

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Plate 7: Dumping of wastes on one end of Migosi post-mine site.
Source: Author, 2017

Plate 8: Dumping of household wastes from the nearby residential houses at Wathorego post-mine site. Source: Author, 2017

Views within the site

Views within Nyawita post-mine site included high rugged quarry stone walls, dumped wastes, waterlogging next to the entry point at the lowest end. The regular dumping was a major source of bad views into the quarry from various view points and as such negatively affected the aesthetic value of the neighborhood within the quarry vicinity. All the other three post-mine sites exhibited similar views as those of Nyawita post-mine with only exception at Kanyawegi post-mine site that lacked dumping of wastes during the period of the study.

Plate 9: Part of the Kanyawegi site showing the exposed rugged walls.
Source: Author, 2017

Plate 10: Rugged high stone walls at Wathorego post-mine site and waterlogging within the deepest end of the pit.

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DISCUSSION

The study established that each brownfield had unique spatial attributes. All the reviewed literature in this paper Novasak et al., (2013); Kuter (2013); Siebelec (2012); Frantal et al., (2012); Hagiou & Konstantpoulou (2010); Hersch et al., (2010); CLARINET (2007); Ferber at al., (2006) and Harris and Dines (1998) all stress the importance of the spatial attributes to a given post-mine site as the first step in planning reuses during rehabilitation. The authors in this paper posit that adequate information on the spatial attributes through inventorying is an important first step towards planning for the rehabilitation of these abandoned landscapes that pose a lot of problems within their locations. In terms of location, the study revealed that the four post-mine brownfields were within the peri-urban areas and not within the city centre. The reuse options for each therefore should be compatible with the existing land uses zoned for the different areas i.e. residential use for Migosi, Nyawita and Wathorego. A study by Hagiou & Konstatntpoulou (2010) analyzed the adequacy of abandoned quarry sites for communal facilities in terms of the area of the quarry, distance and accessibility from the neighbouring settlement and the population size that could be serviced by the proposed facilities in case of rehabilitation.

Land ownership revealed that all the abandoned quarry lands were on private land either under freehold or leasehold. The land owners must be included in the planning process for the reclamation of the four post-mine sites into beneficial land uses. Ownership of a mining site according to the U.S. Environmental Protection Agency (2011) can be a significant stumbling block to a site's redevelopment if the site is not wholly owned by one entity or if site ownership is unknown or unclear. If parts of the site are held by different parties with different interest, this can present problems in terms of common interests, decision making delays, and limited forward progress throughout the project. Nyawita post-mine is owned by two different individuals with different sections with different acreage of land within the quarry. According to the director of environment at the County Government of Kisumu the proposed use of the abandoned quarries within Kisumu City during reclamation is likely to be affected partly by issues of land tenure and ownership structure as these abandoned quarries belong to private individuals and not the County Government of Kisumu. The main objective may not be realized in case the viable options evaluated for the different sites is not supported by the quarry land owners as they are owned privately and not by the public in terms of the County Government of Kisumu. Different opinions held by the different quarry land owners in case of joint ownership may also affect realization of implementation of the viable options during rehabilitation. Viable options for example in the Nyawita post-mine site should be able to get support of the two different quarry land owners who have different ideas on the reuse options to implement during reclamation/rehabilitation.

The cost of acquisition for each of the sites is relatively within the public means in case of acquisition from the private owners for reclamation into public facilities. The location of brownfields as stated by Novasak et al. (2013), close to highway network may be an important development factor for relatively large brownfields and hence Nyawita being the nearest to City

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centre can benefit from this important factor and being the largest in land area. If the site is too small and irregular shaped or has topographical challenges traditional reuse options like residential are limited as similar studies by Hersch et al., (2010), have proved. Similar studies have also proved that reuse option like production of solar energy are only feasible when the land area is a minimum of 40 acres and this means none of the four sites under study can have this as an effective reclamation reuse due to the small land areas they possess.

Depths and widths vary across the four sites with Nyawita being the widest and Migosi with the least width. The main activity within most of the post-mine sites was dumping of wastes. There is need to provide alternative dumping site if rehabilitation is to be undertaken within the sites. Drainage was a problem in all the four sites hence water logging within some parts of the abandoned quarry pits. The four sites had common negative attributes like water logging and there is need for the preferred reuse options to plan for this and change it to be a positive aspect. The untamed vegetation provided good hideouts that can aid crime and hence the reuse option during rehabilitation should address the possible hideouts that lead to insecurity. Dangers posed by the deep depths due to lack of physical barriers should be addressed by the chosen reuse options during rehabilitation to ensure this negative attribute is addressed. These negative attributes affect the perceived attractiveness of the abandoned quarry lands. Baczynska et al. (2017) investigated whether attractiveness of abandoned quarries existed. They posit that the level of attractiveness was defined by quarries uniqueness, differentiation in addition to the interest and curiosity they evoked among the locals and visitors. Survey findings among residents of these post-mine brownfields by K'oyoo et al. (2022b) revealed that the negative spatial attributes of uncontrolled dumping, waterlogging, rugged landscape and untamed vegetation was negatively perceived by most of the respondents. The respondents believed these negatively affected the visual aesthetic quality of their immediate surroundings.

A study by Hagiou & Konstantpoulou (2010) on environmental planning of abandoned quarry lands first gave prominence to detailed examination of quarry sites in terms of their legal status, ownership status, topography, geotechnical characteristics, access and orientation, soil, climate, flora and fauna, land uses in the direct and wider environment of the quarry. They also considered the population in terms of size, economic activities as well as the deficiencies in communal facilities. They posit that this forms the database of crucial information that then becomes a useful tool in making decisions regarding selection and determination of the most suitable rehabilitation solutions for the abandoned quarry lands. We concur with Hagiou & Konstantpoulou (2010) on the priority that should be placed on detailed examination and analysis of each abandoned quarry land in the process of planning for holistic restoration, rehabilitation to accommodate beneficial reuse options. These authors further point out the extent of environmental pollution caused by abandoned quarries in terms of ground water pollution/health hazard due to dumping of wastes secondly safety hazard due to slope and face stability and accessibility of the site in terms of presence or lack of protective fencing, distance from roads and populated areas and lastly the visual

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disturbance in terms of the extent of visibility (Hagiou & Konstantpoulou, 2010). We concur with these authors that negative spatial attributes of abandoned quarry lands pose several environmental challenges to their immediate neighborhoods (pollution from dumping of various wastes leading to possible contamination, possible hideouts to aid crime and other social evils, visible landscape scars leading to unpleasant visual quality) and this has led to growing interest and concerns for rehabilitation in many areas (K'oyoo et al., 2022a; 2022b).

Brownfields according to Frantal et al. (2013) are placed and rooted in a certain geographical space with unique spatial characteristics. Every brownfield site therefore should be seen as quite unique and should be perceived in their local spatial context. When assessing them the site-specific attributes should be clearly understood and analyzed in order to recommend and implement appropriate rehabilitation reuses. According to National Environment Management Authority (NEMA) director and Ministry of Mining official the only known spatial attributes for the four post-mines sites under study was their location however other details on their acreage, depths among other spatial attributes was not within their records. This study aimed to fill the gap in knowledge regarding the spatial attributes of these post-mine sites that were the first quarries within Kisumu as gathered from the land owners and other key informants. The authors in this study confirm that all the four sites revealed different spatial attributes across the aspects that were used to study them.

CONCLUSIONS

The study established that each brownfield had unique spatial attributes and as such each needs to be planned for differently if successful rehabilitation for alternative reuse options is to be achieved. All the four sites are within the peri-urban areas of Kisumu City in areas with good access and they vary in size and all under private ownership. All the sites occupy large areas that are currently abandoned and neglected and are considered as problem spaces. These spaces can be planned into beneficial and productive land uses through rehabilitation to eliminate the negative concerns they pose. The study confirms earlier findings by other studies that each post-mine site has its unique spatial attributes and as such there is no specific rehabilitation reuse option that is a fit it all. Each site has to be analyzed in its unique way depending on its spatial attributes and appropriate reuse option recommended for implementation. The first step in effective planning for rehabilitation of post-mine sites to reverse the problems they pose is through examination of their spatial attributes and coming up with inventories to aid in holistic planning for their rehabilitation reuse options..

The four sites have various negative effects that they pose to the residents living within their neighborhoods. All the negative spatial attributes like water logging, deep depths, untamed vegetation etc. for the four post-mine sites should be addressed to convert them into positive attributes that are beneficial for the preferred reuse options when planning for rehabilitation. Addressing these negative spatial attributes leads to elimination of the negative effects they pose

to the ecological and social environment within these neighborhoods. The study recommends that any viable options on how to reverse the negative effects and integrate the brownfields to be in harmony with other urban land uses must proceed from a careful analysis of each individual site.

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