Assessment of Rehabilitation Options for Environmental Impacts of Abandoned Mines

Kavirathne SR, Udayanga RI, Keerthi T, Gunawardana ADTJ, *Chaminda SP and Jayawardena CL

Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka

*Corresponding author – chaminda@uom.lk

Abstract

The quarries which are abandoned ceasing operations without a proper closure plan cause negative impacts on the environment and also risk for the health and safety of society and the economy. This research focused on the environmental aspects that are affected by abandoned quarries and a sustainable methodology to design future land use. The objective of this research is to introduce a quarry rehabilitation method that is effective and has a positive impact on the environment, and applicable for abandoned quarries in Sri Lanka. In this respect, the district of Colombo has been chosen due to its importance in social and economic aspects. The research was conducted by identifying abandoned quarries through remote sensing and geographic information system technique (RS & GIS) analysis of satellite images of the concerned area. Prioritised two quarries among identified quarries for further analysis and suggested possible rehabilitation options. According to the land use analysis around the two quarries, the better rehabilitation option is to transform the lands into a vegetation area.

Keywords: Colombo district, Land use, Quarry rehabilitation, RS & GIS, Sri Lanka

1. Introduction

Mining has become one of the major aspects that contribute to the economy of developing countries. Regardless of the scale of the mine, it causes so many adverse effects to the environment as well as to society during its operations [1]. Some of these effects may impact for decades. It happens due to improper waste management and also due to negligence of rehabilitation measures [2]. Each and every mine has a lifetime for it. With time mines need to shut down their operations on a temporary or permanent basis due to the run out of ore supply, drop in commodity price or the uneconomical nature of operating the mine. After mining, people tend to abandon the mine without any precautions because there is a lack of clearly assigned responsibilities for mine rehabilitation, and it is uneconomical to rehabilitate since there are no fund allocations for it [3].

The main intention of mine rehabilitation is to reduce the long-term effects of environmental contaminations and also the social effects that are caused by abandoned mines [4]. Due to continuous mine waste

disposal in mine abandoned areas, it leads to many environmental hazards as the destruction of wildlife and aquatic biodiversity, landscape degradation, dust pollution and water pollution due to siltation, heavy metals and other contaminants. Other than to the environment, abandoned mines cause harmful impacts on society and on the economy also [2]. From the view of society, it brings changes to the lifestyle of the people after abandoning a mine. So, it will lead to the value of nearby lands becoming inferior. The pollution caused by mines will lead to the spread of different diseases by providing grounds for vectors. Other than these, visual pollution may compel psychologically for people. Therefore, these factors are associated with improper mine abandonment.

Since there are a lot of abandoned mines without rehabilitation, prioritisation is important. The methodologies based on GIS, environmental and socio-economic factors, multi-criteria analysis and GIS, hazard maps compilation etc., are used to select the mines that need to be rehabilitated [5].

In the present world, due to the development in the GIS sector, it uses GIS in many circumstances. In mine rehabilitation, also it can be used in every step. For that, it needs satellite images of the particular area. With the use of satellite images, it can identify abandoned mines, their surrounding land uses, visual pollution interpretation etc. [6]. Other than these, it can be used for multi-criteria analysis and select the areas with needed requirements. The selection of practicable rehabilitation options also can be with the use of these. Afterwards, the monitoring and managing of the rehabilitation process can be done by the evaluation of satellite images. So, the usage of satellite images makes the process of rehabilitation effective and efficient.

Under rehabilitation, there are recommended practices for soil management, erosion control, slope stabilisation, species selection, seed collection, nursery establishment and maintenance, seeding and planting strategies and techniques, weed control, fauna attraction and other aspects of rehabilitation techniques.

A long-term sustainable approach should be taken when selecting rehabilitation options. So a mine site can be rehabilitated under the main two categories as a development project or an open space project [7]. When considering about a development project, the mine sites can be converted to industrial plants, residential buildings, cemeteries or infrastructures. As open space projects, particular land can be transferred into agricultural lands, waste disposal sites, leisurely places, and places to attract tourists or can be left for natural vegetation. Among all these options, it can select one of them depending on the nature of the site, requirements and the availability of resources.

To minimise these impacts, it is necessary to follow a proper rehabilitation plan. The rehabilitation plan depends on the nature of the mine as well as on the surrounding nature [7]. Through mine rehabilitation, the productivity of disturbed land can be increased. Thus, by rehabilitating an abandoned mine it can prevent environmental pollution, harmful impacts on the environment and increase the health and safety of the area. Furthermore, it can make abandoned land into a useful, profitable and sustainable asset for the long run [8].

2. Methodology

Colombo district is the main administrative district of Sri Lanka with the highest population density of 20,192 person/km^2. But the land area of Colombo is 699 km^2 [9].

Initially, the abandoned quarries of the concerned area were identified through a classification of satellite images. Through an analysis of land use, rock exposure and topography it identified the possible

locations for the availability of abandoned quarries

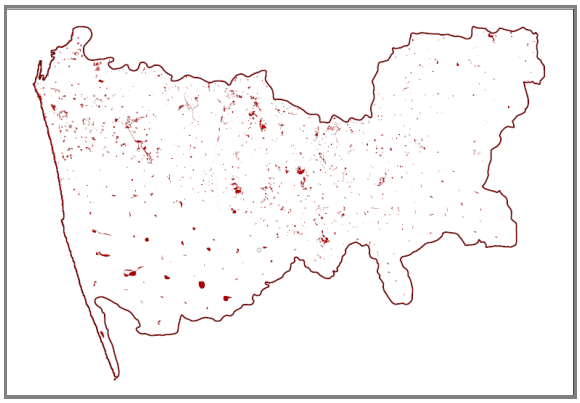

Figure 1: Possible locations for the presence of abandoned mines.

These locations were observed using Google Earth on different time scales and separate the quarries that did not operate for the past three years or more.

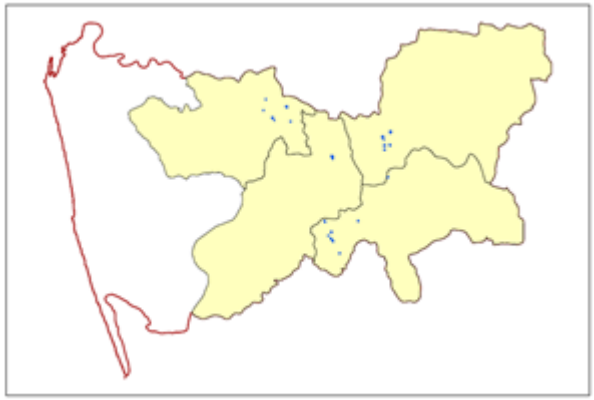

Figure 2: Identified abandoned quarry locations in the Colombo district.

Through the analysis, it identified 24 abandoned quarries that were available in the Colombo district. Among these quarries, it prioritised two quarries based on the population density and the presence of water resources around those quarry locations.

3. Results

3.1 Population Density Analysis

The population densities of the identified quarries are in Figure 3. Based on the population density, the quarry in Figure 4 can be identified.

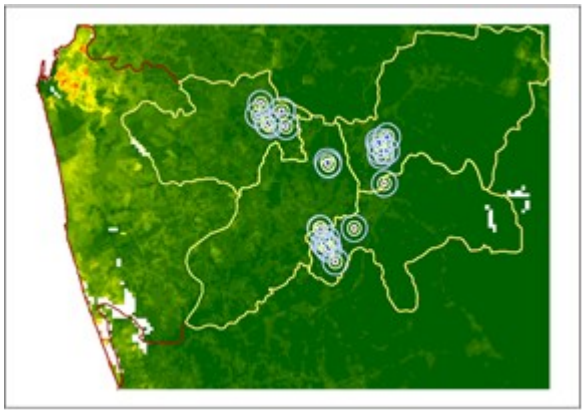

Figure 3: Population density of Colombo district.

Figure 4: Google Earth image of the quarry with the highest population density.

The operations of the quarry started before 2004 and ceased operations of this part at the end of 2016. This mine has an area of 13,057 m^2. The land use and the topography around the quarry are shown in Figure 5 and Figure 6, respectively. The surrounding area around the quarry was categorised into 100 m, 200 m, 500 m and 1 km buffer zones.

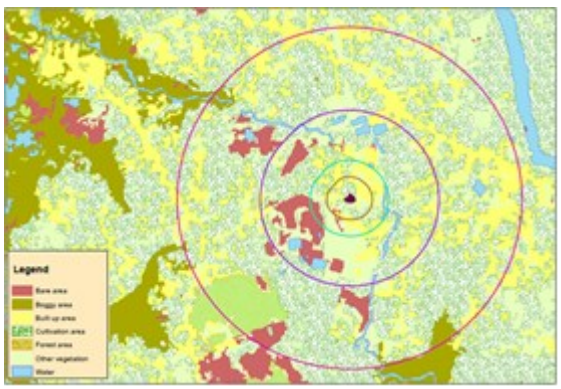

Figure. 5: Landuse around the quarry.

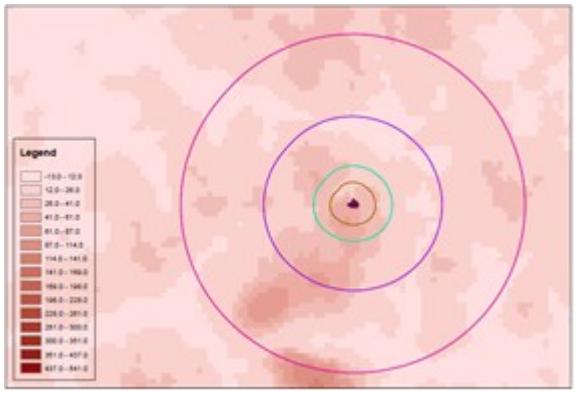

Figure 6: The topography around the quarry.

3.2 Water Resource Availability

The available water resources around the selected quarries are shown in Figure 7.

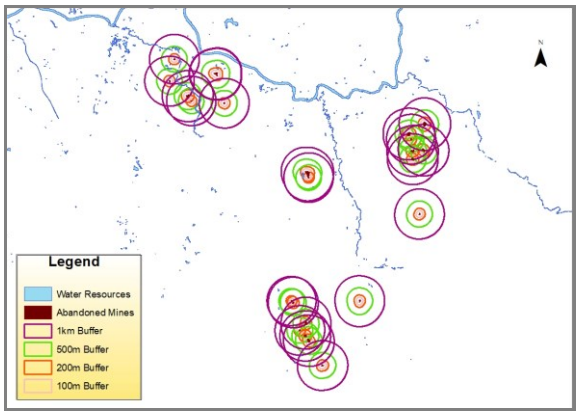

Figure 7: Available water resources around selected quarries.

Based on the presence of water resources closer to the quarry, the following quarry in Figure 8 can be identified.

The Kelani River flows within 1 km of this quarry. Therefore, this quarry mine was selected for the rehabilitation process.

Figure 8: Google Earth image of the quarry with nearby water resources.

This quarry started its operations before 2014 and ceased operations in 2017. It has an area of 17,091 m^2.

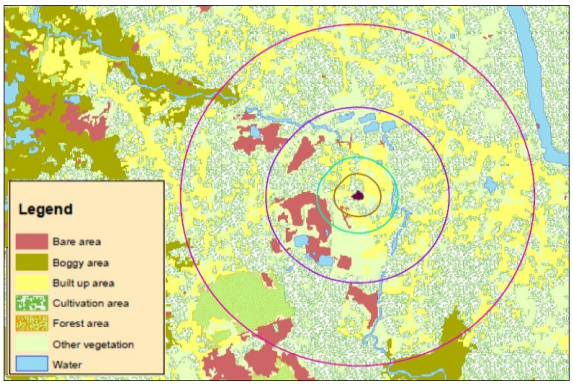

Figure 9: Landuse around the quarry.

The land use around the quarry and the topography of the quarry are demarcated in Figure 9 and Figure 10.

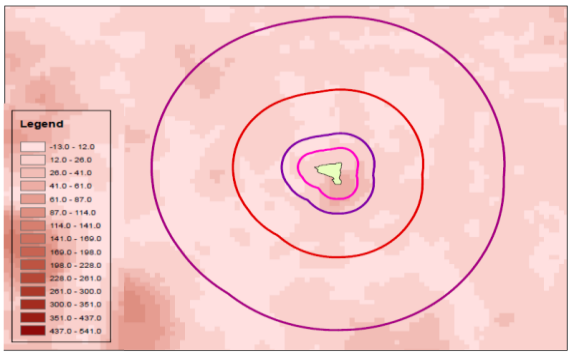

Figure 10: The topography around the quarry.

3.3 Quarry Surrounding Analysis within 200 m Buffer zone

Within the 200 m buffer zone around the abandoned quarry area, the land uses are categorised into four main areas: abandoned quarry area, operating quarry area, residential area and vegetation area.

Figure 11: Google Earth image of quarry 1.

When considering the land use around quarry 1 within 200 m, the major amount is covered by the currently operating quarry

(nearly 40% of the area). The rest of the area is for residences and vegetation.

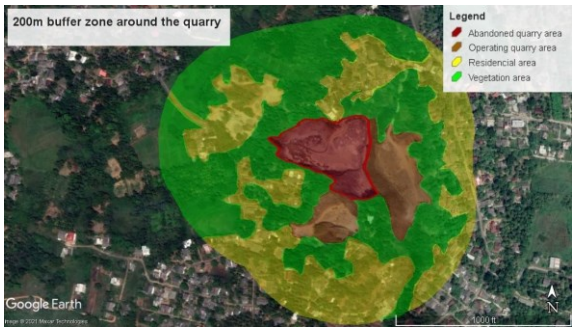

Figure 12: Google Earth image of quarry 2.

Within 200 m around quarry 2, half of the area is covered by vegetation, including farmlands. The operating quarry, which is closer to the abandoned quarry, has approximately similar areas. The human habitats also spread in a considerable area (nearly 36%) within the concerned 200m buffer zone.

4. Discussion

Mining is a crucial source of income for the economy of a developing country like Sri Lanka. As same as the necessity for mining, the impact from it is also higher. Hence, as in the research process, it can identify the abandoned quarry mines in the country and monitor the drawbacks in the mine closure process and make awareness among the relevant stakeholders and authorities.

Identifying abandoned quarries that have been neglected for the past three years or more, without a proper closure plan in Colombo district through a classification of satellite images (Figure 2) and using them to prioritise the quarries according to the selected two criteria (Figure 4 and Figure 8). Based on the topography (Figure 6 and Figure 10) and the land use (Figure 5 and Figure 9) of the surrounding, two quarries are selected and, using the literature review study, sustainable and appropriate rehabilitation methods can be suggested for Sri Lankan quarries.

The method of rehabilitation was selected based on the population and the land use of the surrounding environment. But it can use other factors as soil properties, underlay rock properties, the geography of the area and also the perspective of the community and their standards could also be considered to select the most appropriate rehabilitation method.

Quarry 1 has the highest population density around its location (According to Figure 3). Thus, when rehabilitating this quarry, prioritisation should be given to the community standards, their preferences and their requirements. Therefore, a quarry site in an urban area is better to be rehabilitated into residential areas, infrastructure buildings, park or any other project that support the socio-economic development of the community.

Quarry 2 has the highest impact on water resources (according to Figure 7) than the other selected quarries since it is located closer to the main river of the country, the Kelani River. According to the literature review studies, when there is a water resource closer to the quarry that is to be rehabilitated, it is appropriate to rehabilitate in a manner that manages that water resource to take the optimum use from it. Other than the availability of water resources, the quarry is located in an area with a considerable population. So, it can be recommended to transform this quarry into a farming land or agricultural land with the comfort of accessing water that is required.

Quarry 1 is located on uneven ground when compared with quarry 2, as in Figure 6 and Figure 10.

In further analysis, land uses within 200 m of the quarries are considered as in Figure 11 and Figure 12.

Though there is a high population around quarry 1 than quarry 2, when considering the 200 m buffer zone, the settlements are mostly located around quarry 2 than quarry 1. Furthermore, in the case of considering the size quarry 2 is spread in over a larger area than quarry 1. Therefore, the impact on the community is higher from quarry 2 than from quarry 1. Other than these factors, the common characteristics of these two quarries

(Figure 11 and Figure 12) are that the presence of a currently operating quarry mine closer to these both quarries.

In the case of quarry 1 (Figure 11), the impact from the operating quarry is higher because a major amount of the area within the concerned buffer zone is covered by the operating quarry. And also, the vegetation around that quarry is considerably lesser.

The condition around quarry 2 within 200 m (Figure 12) is different because that area is mainly covered by vegetation and other agricultural lands, and though there is an operating quarry, it is spread over a small area. But it is located near to an abandoned quarry. So, the impact from the operating quarry should also be considered.

Therefore, when introducing a proper rehabilitation method, it needs to take into account mainly the environmental pollution that happens due to these operating quarries. Because, when they are rehabilitated according to the previous recommendations, then those projects may be disturbed by quarries in operation. So, it would be more applicable to transform these two quarry areas into lands with vegetation.

So, according to the study, if the abandoned land is subjected to vegetation, it will act as a green belt and will minimise the environmental pollution from the operating quarries to a certain extent.

Through that, it can achieve three main benefits: minimising the impacts from the abandoned quarry, minimising the impacts from the operating quarry as well as increasing the green cover of the country.

5. Conclusions

By comparing the land use, topography and the population density of the area surrounded by quarries 1 and 2, it can suggest a rehabilitation procedure that is suitable for the abandoned land area. But irrespective of population density, topography and availability of nearby water resources, these two selected quarries have a common feature as both of them are located closer to an operating quarry site. If it uses another rehabilitation method, that may be interrupted by the impacts of the operating quarry.

So, according to the study, it can be recommended to rehabilitate these two abandoned quarry areas by transforming these lands into vegetation areas. Through that, it can allow the vegetation region to act as a green belt that minimises the environmental pollution from the nearby operating quarries while minimising the negative impacts from the abandoned quarry.

Acknowledgements

The authors are grateful for the immense support from the University of Moratuwa. Online availability of resources as satellite images and SRTM images free of charge. The authors also acknowledge the anonymous reviewers for their helpful and constructive comments.

References

[1] A Kumarasinghe *et al.*, "An attempt to reduce impacts of limestone quarries through biodiversity assessment and translocation : A case study at the Holcim Limestone Quarry Site in Puttalam, Sri Lanka," *Asian J. Conserv. Biol.*, vol. 2, no. 1, pp. 3–20, 2013.

[2] A. G. N. Kitula, "The environmental and socio-economic impacts of mining on local livelihoods in Tanzania: A case study of Geita District," *J. Clean. Prod.*, vol. 14, no. 3–4, pp. 405–414, 2006, DOI: 10.1016/j.jclepro.2004.01.012.

[3] E. Mavrommatis and M. Menegaki, "Setting rehabilitation priorities for abandoned mines of similar characteristics according to their visual impact: The case of Milos Island, Greece," *J. Sustain. Min.*, vol. 16, no. 3, pp. 104–113, 2017, doi: 10.1016/j.jsm.2017.10.003.

[4] E. T. Asr, R. Kakaie, M. Ataei, and M. R. Tavakoli Mohammadi, "A review of studies on sustainable development in mining life cycle," *J. Clean. Prod.*, vol. 229, pp. 213–231, 2019, DOI: 10.1016/j.jclepro.2019.05.029.

[5] O. E. Kubit, C. J. Pluhar, and J. V. De Graff, "A model for prioritising sites and reclamation methods at abandoned mines," *Environ. Earth Sci.*, vol. 73, no. 12, pp. 7915–7931, 2015, DOI: 10.1007/s12665-014-3949-3.

[6] S. Merugu and K. Jain, "Change Detection and Estimation of Illegal Mining using Satellite Images," no. August 2013, 2014.

[7] T. Milgrom, "Environmental aspects of rehabilitating abandoned quarries: Israel as a case study," *Landsc. Urban Plan.*, vol. 87, no. 3, pp. 172–179, 2008, doi: 10.1016/j.landurbplan.2008.06.007.

[8] C. Mccandless, "The Adaptive Re-Use of Resource Depleted Quarries," pp. 1–19, 2013.

[9] Colombo Municipal Council. 2021. Colombo Municipal Council. [ONLINE]. Available: https://www.colombo.mc.gov.lk/admin-districts.php. [Accessed: 27-Feb- 2021]