Landscape Alteration Effects of Quarrying Operation and its Reclamation Prospect Using Drone

EYITAYO OLUWASEYI I. IFELOLA, University of Technology,
Mining Engineering Department,
The Federal Akure, Ondo State, Nigeria
MUHAMMED BABAGIDA A. ALHASSAN, University of Technology,
Mining Engineering Department,
The Federal Akure, Ondo State, Nigeria

Professional paper
UDC: 622.271:622.35
DOI: 10.5937/tehnika2404417I

Surface mining involving quarrying of rocks often causes significant landscape alteration, culminating in a range of environmental effects from aesthetics to ecosystem disturbances if not properly managed. This study focused on the assessment of the geo-spatial changes in landscape of a marble deposit occasioned by quarrying in Ikpesi, Akoko-Edo, Edo State, Nigeria with the aim of future reclamation. Aerial mapping of the quarry and its contiguous vegetated land was carried out using an unmanned vehicle (UAV) DJI Phantom 4 drone. Images captured were uploaded to the cloud and processed by DroneDeploy software to generate the digital surface models-orthomosaics of the quarry and its adjoining land as well as the elevation Heatmaps, the pits cut/fill of the quarry and the Plant health map. The results show that a significant landmass of the quarry has been affected due to excavation of materials. The total area of land worked by the Quarry was (40,400 m^2), the total cut (106,469.6 m^3) and fill of (124,708.5 m^3) with a net fill volume of (-18,238.84 m^3). In order to avoid material deficit for reclamation in the long run, critical planning for "quarry waste materials" management is needed to ensure ultimate reclamation to an acceptable topographical level.

Key Words: *Quarrying, Landscape Alteration, Mapping, Drone, Reclamation*

1. INTRODUCTION

Mining is an economic endeavor that entails extraction of natural minerals from the earth and sometimes comes with significant negative impact on the environment [1-6]. The surface mining method used to exploit outcropping to shallow-bearing minerals is synonymous with a number of environmental effects [4] including alteration of landscape aesthetic values and degradation of the ecosystem. In open pit rock quarrying where rocks are excavated to sizeable ground depths; massive volumes of rock and overburden materials are removed from their *in-situ* locations. The broken rock is usually hauled and stockpiled temporarily while the overburden is dumped as waste materials elsewhere in the quarry at the dump site. In the process, the topography of the quarry landscape and its immediate environment is affected. After the extraction of the reserve, the altered landscape (mined-out area) as a rule, is expected to be reclaimed in order to dampen the effects of the mining on the quarry landscape and its immediate environments [7-8].

Generally, most quarries in the Country, once through with the operations are left abandoned without any form of reclamation. Basically, due to lack of proper planning, sheer negligence by the quarry operators and at times, non - enforcement of the environmental sustainability provision enshrined in the National Minerals and Mining Act by the appropriate regulatory body. Landscape restoration is key to achieving a sustainable post-mining environment.

The reclamation of post-mining landscapes could be very challenging particularly when no proper or strategic plan for the reclamation is put in place at the onset (earlier stages) of the mine. This type of planning is site-specific and requires time-bound schemes that are geared towards achieving sustainable mine environment after cessation of mining operations. In

Author's address: Eyitayo Oluwaseyi Ifelola, University of Technology, Mining Engineering Department, The Federal Akure, Ondo State, Nigeria
e-mail: eoifelola@futa.edu.ng
Paper received: 16.05.2024.
Paper accepted: 24.06.2024.

order to address this technical challenge, it is pertinent to easily assess the area being affected [9] and quantify the volume and pattern of material displacement within the quarry.

One of the means to readily and effectively achieve this is to deploy a spatial mapping technique that is much faster, less laborious, comparatively safer and cheaper than the usual conventional survey methods [10-11].

Being able to have a comprehensive aerial view of various sections of the quarry where extraction of rock and earth/soil materials are removed or moved to is very important in planning and implementing a successful reclamation programme. Through the use of unmanned aerial vehicles (UAVs)(drones), sufficient and accurate survey data of these quarry sections can easily be obtained, images captured and data processed to develop an informed strategy for successful reclamation programme.

Drones, equipped with high-resolution cameras have been effectively deployed in mining to gather accurate and detailed data for different operations including aerial data collection for field assessments, building of models for field developments, conduct of aerial inspections and volumetric measurements, monitor of systems for potential threats and environmental footprints amongst others.

Deploying drone technology in conjunction with the appropriate photogrammetry - based software offers tremendous advantage [11-14] and opportunity to rapidly access a mine spatially and map the locations of interest to carry out necessary decisions. This study is therefore aimed at assessing the extent of alteration to the natural landscape of the Golden Girl quarry with the purpose of aiding the processes of the quarry reclamation and restoration.

2. MATERIALS AND METHODS

2.1. The study area

Golden Girl quarry is located in Ikpeshi town in Akoko Edo Local Government area of Edo State, South Western Nigeria between latitude: 07˚10.218 N - 07˚10.433N and longitude 06˚11.079E- 06˚11.263E. It is among the three major marble quarries located at the outskirts of Ikpeshi town. Operations at the quarry is semi-mechanized due to low level of equipment and machinery involved. It is approximately 10 km east of Auchi township, and 15 km north of Igarra town. Annual rainfall ranges between 3–207 mm per year and average temperatures range from 21.2˚C to 32.2˚C.

There are two major seasons in the study area which are wet and dry seasons. The wet or rainy season lasts an average of 9 months often starting from early March to November with short break in August; while the dry season starts in November and ends in March.

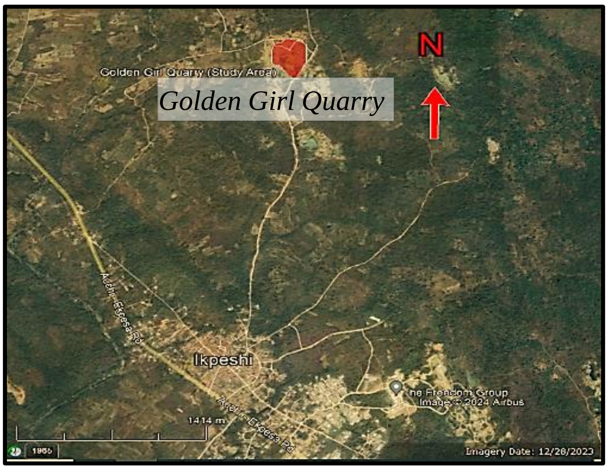

Figure 1 - Geographical location Map of the Quarry (in red) the Study Area near Ikpeshi town

2.2. Flight planning and mapping

The area under study was aerially mapped using a DJI Phantom 4 (GPS-enabled, multispectral) drone to survey the quarry and its contiguous vegetation area. Prior to the flights, a pre-defined flying path was programmed into the drone's flight module [10-12] via the interactive visual display unit installed into the phone device attached to the flight controller. The drone was set to auto flight at an altitude of 100 m along the specified paths and with a high camera resolution with an accuracy of Ground Sample Distance (GSD), (that is distance between two consecutive pixel centers measured on the ground) of 9-10 cm, multiple real-time georeferenced images were taken with image to image overlapping ratio greater than 70% (image: front side).

Two sets of flights were taken, first one was for the Golden Girl quarry and the second was for the adjoining area covered by natural vegetation and farm plantation. In the first flight, 290 images were taken while the second flight captured 295 orthophoto images.

2.3. Data Processing

All data of captured images were saved and then uploaded to cloud for processing with the aid of DroneDeploy application software [14]. The software algorithm is programmed to execute a series of operations. In this study, the captured georeferenced images were assembled, matched and stitched together to generate 3D point cloud from which digital surface models (DSMs), orthomosaic of the Golden Girl quarry and that of the adjoining area covered with vegetation were developed as described by Liba and Berg-Jürgens [12]. The plant health of the study area based on the multispectral camera images captured by the Phantom 4 drone was estimated by the DroneDeploy software using inbuilt Normalized Difference Vegetation Index (NDVI) algorithm. Also, elevation Heatmap, volumetric estimation of the various pits excavated within the quarry and the cut and fill of the pit depressions were automatically calculated based on site specific selection variables integrated into the software application.

Volumetric estimation of excavated materials (Marble rock) from the Quarry was extracted from the real-time image of the quarry with the drone deploy software. The entire quarry was sectioned into six visible pits tagged Pits A – F according to the mined-out pit geometry. Each pit was identified by different color code. The total volume of material moved was calculated by summation of the total cut and fill of the pits, the net volume of material moved was calculated by subtracting the total cut from the total fill of pit.

3. RESULTS AND DISCUSSION

The results of the drone mapping revealed a significant detail of the real-time spatial features of the Golden Girl quarry as captured by the DJI Phantom 4 drone and processed by the DroneDeploy photogrammetry software (Figure 2). From the final orthomosaic (Figure 3), the access roads, the mining pits, the disjointed natural vegetation, and waste dump, all could be seen clearly at once.

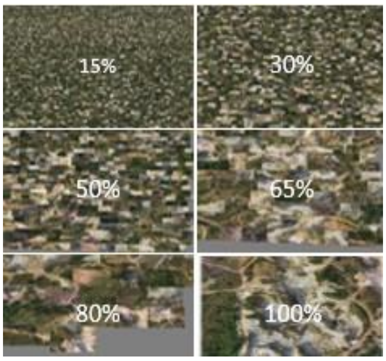

Figure 2 - Matching and stitching stages of the quarry drone-captured images (from 15% very rough to 100% very smooth real-time imagery

Figure 3 - Real-time Imagery (Orthomosaic) of Golden Girl Quarry

The revealed features show how the disturbances to the natural landscape as a result of the quarrying operations.

The examination of the real time image of the bordering environment of the quarry showed the forest vegetation to be the dominant land cover in the study area. By implication, the natural landscape in the study area is covered with vegetation with no bare ground surface. The variations in the green-texture landcover in the adjoining area (Figure 4) from that of variegated shades of light brown- coloured quarry area (Figure 3) stems from the differences in the vegetation cover due to absence of anthropogenic activities in one and the presence of major quarrying activities in the other.

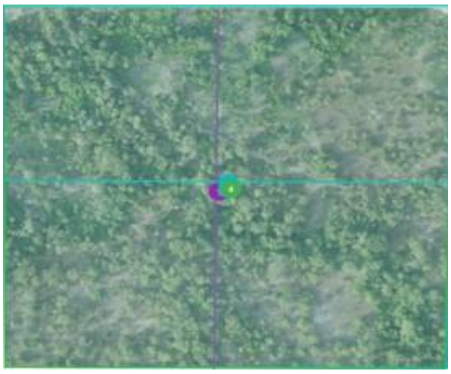

Figure 4 - Real-Time Aerial Imagery (Orthomosaic) of Golden Girl Quarry Adjoining Vegetation

3.1. Plant health of the study area

The NDVI plant health maps generated from the captured images show that only few scattered vegetation was left within the marble pits as indicated by the extent and spread of red pigmentation in RGB colour coding (Figure 5). According to the DroneDeploy processed map, the green coloration signifies presence of trees and grasses indicating a healthy plant region while the thick dark red colour signifies absence or sparse vegetation.

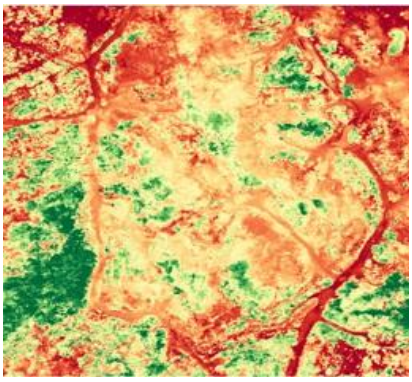

Figure 5 - NDVI Map of Plant Health of the Quarry

In Figure 6, the mapped image of the plant health of the adjoining environment shows that a bit of contrast exists between that of the quarry pit area and the neighboring side. The area covered by the green pigmentation, that is the forested and/or grassy land indicate unperturbed healthy soil area and this could serve as a template or reference site to deduce and ideal plan for the reclamation programme for the quarry. The flourishing growth of plants in this area imply that the soil structure and composition can readily support growth and self-sustenance of the species of vegetation found in the place. Therefore, a well-structured plan to replicate this soil pattern in the mined-out area when backfilling the excavated/dug-out pits in the quarry with the overburden waste rock and soil would be an ideal plan towards re-establishment of functional eco-system in the area.

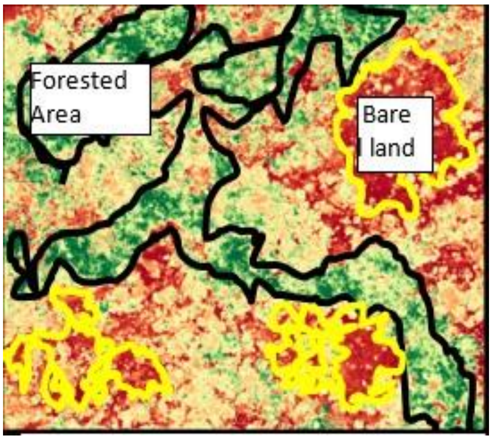

Figure 6 - NDVI Map of Plant Health of the Adjoining Undisturbed Area

Results of Volumetric Estimation of Materials (Marble rock) Excavated from the Quarry

The volume estimation of marble rock excavated from the Quarry via pit created as summarized in Table 1 shows that Pit E covered the largest area of land 10,800 m^2 and has the highest cut of 31,409.73 m^{3}and fills of 17,526.66 m^3 respectively. Pit D has the smallest area of land (1,700 m^2) and lowest cut of 2,064.09 m^3 and fill of 11,312.01 m^3.

The total area of land covered by the Quarry is 40,400 m^2, the total cut is 106,469.6 m^3 and the fill 124,708.5 m^3 with a total net volume of -18,238.4 m^3 as shown in Table 1.

This, technically implies that the earth material left for fill is at the present not sufficient to cover up the volume of fill required. Figures 7, 8 and Table 1, show the images of the different quarry pits and their respective calculated cut and fill.

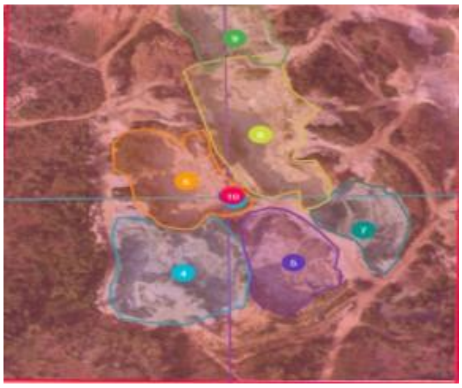

Figure 7 - Total Land Area of the Quarry with the different Mining Pits

Table 1. Estimated Volume of Materials Moved from the Mine

S/No	Pit Symbol	Area (m^2)	Cut (m^3)	Fill (m^3)	Net (m^3)	Tolerance (cm)
1	Pit A	10200	21366.35	31583.10	-10216.75	0
2	Pit B	6200	24525.44	8310.90	16214.54	0
3	Pit C	7400	5275.60	55799.76	-50524.16	0
4	Pit D	1700	2064.09	11312.01	-9247.93	0
5	Pit E	10800	31409.73	17526.66	13883.08	0
6	Pit F	4100	21828.40	176.02	21652.38	0
	Total	40400	106469.6	124708.5	-18238.84	0

In Figure 8, the orthomosaic generated from the drone captured images is shown revealing the configuration and volumetric sizes of different pits mined-out in the quarry.

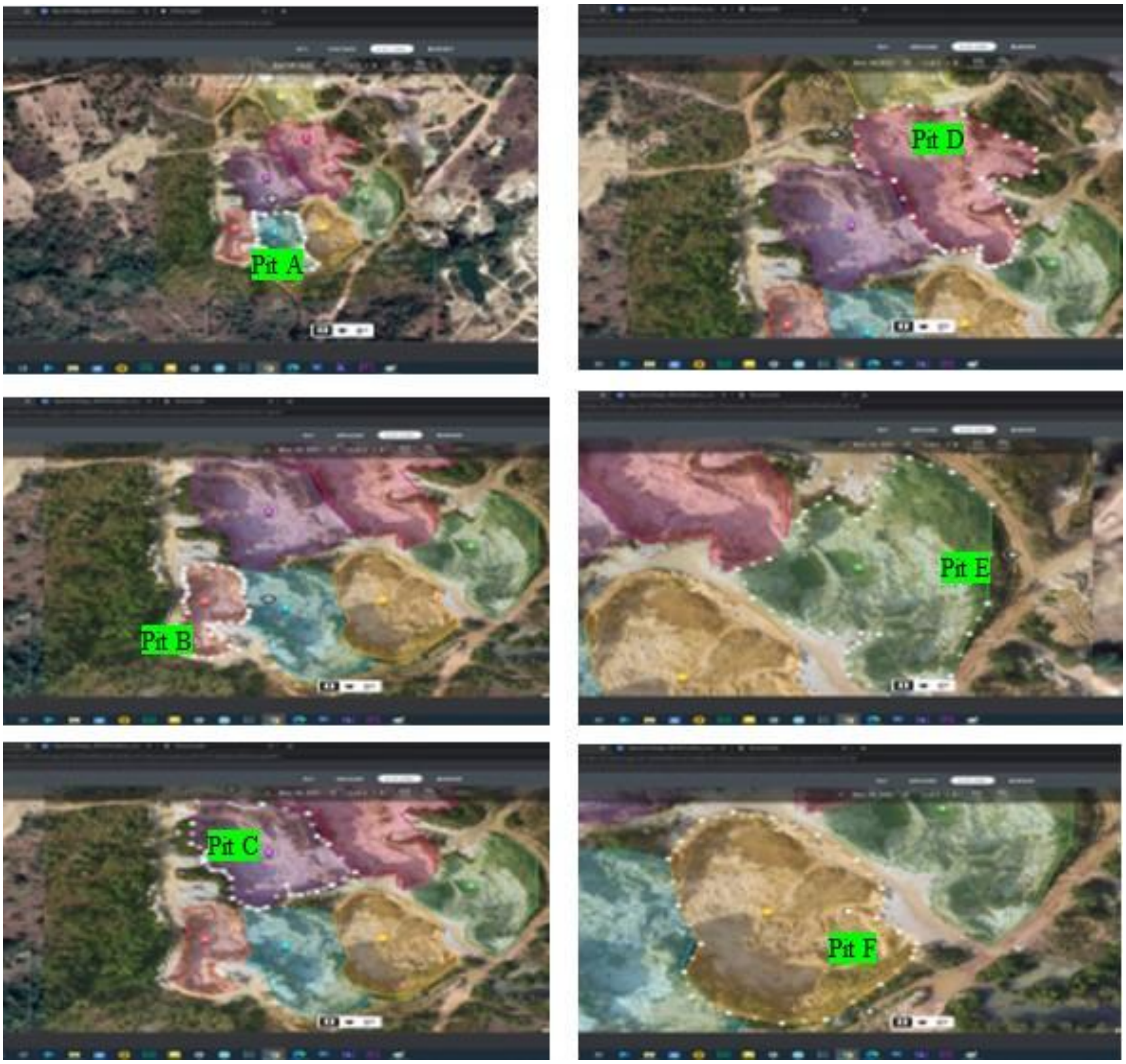

Figure 8 - Quarry Pits highlighted according to their sizes and spatial geometry

The topography of the study area shows the heights and depths of various locations in the quarry relative to the mean ground level in the area as indicated by the colour gradients in Figure 9.

The dark blue color represents the topography of -11.24 meter from the surface, the light orange color represents the height of 0.3 meter from the surface and the dark red color represent 12.46 meters above the ground surface. While the digital elevation model is displaying the relative heights of natural features in the quarry, the digital terrain model simply displayed those details that naturally conform to the earth or ground surface in Figure 10. However, in both Figures 9 and 10, it is clearly shown that at the centre of the quarry lies the deepest voids created by the excavation of the marble rock.

Figure 11 shows a stack of multiple geospatial models of the quarry generated by the droneDeploy and exported to google earth environment.

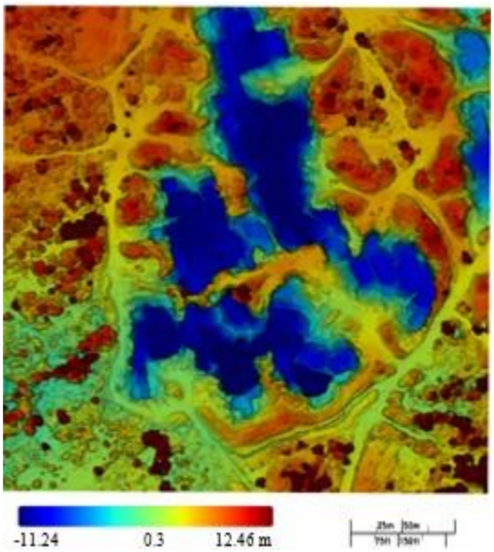

Figure 9 - Digital elevation model (DEM) of Golden Girl quarry

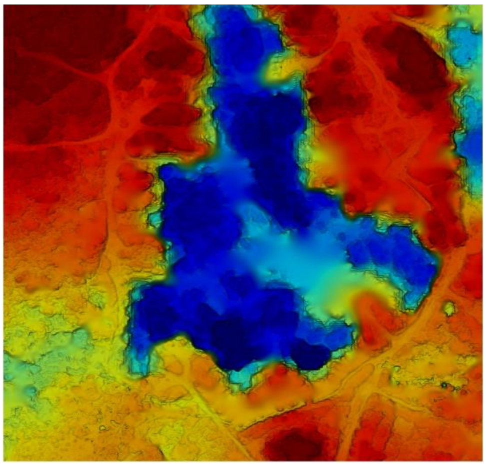

Figure 10 - Digital terrain model (DTM) of Golden Girl quarry

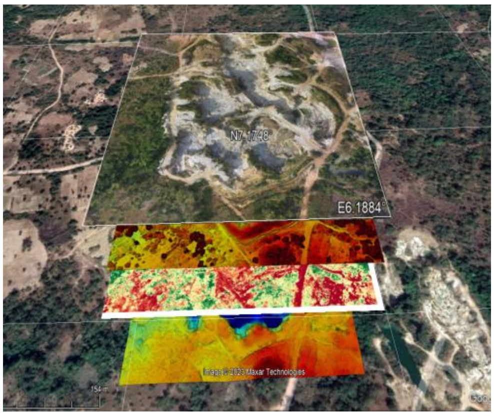

Figure 11 - Stacked layers of different geospatial models of Golden Girl quarry from the drone captured images and exported to google earth environment.

4. CONCLUSION

The study has shown the importance and advantage of spatial mapping using a combination of drone and cloud-based photogrammetry software in assessing the landscape pattern of the study area. Observations from the various maps generated shows that significant land alteration has taken place by the quarrying operation. This potential threat could pose some serious environmental challenges in the near to distant future if unattended to. By taking proactive steps and carefully utilizing the information in the knowledge domain including that of this research findings, good and positive future use could be devised for the study area while preventing unpleasant consequences.

5. ACKNOWLEDGEMENT

The authors wish to acknowledge the management of Golden Girl quarry for granting permission to carry out this research in their company.

REFERENCES

[1] Kuter N, Reclamation of Degraded Landscape due to Opencast mining, Advances in Landscape Architecture, intech, pp 823-858, 2013.

[2] Jovanovly B. B , Polaver S .M, Prastalo Z. M, Sarac R. U, Reclamation of “Garajevac Istok” surface mine near Novi Becej, *Technology-mining, Geology and metallurgy*, Vol. 74, No. 5, 2023

[3] Raviti K, Mining and quarrying environmental impacts https://www.linkedin.com/pulse/mining-quarrying-environmental-impacts-revati-k, 2022

[4] Osanloo M, Hekma, A, Aghajani A. *Reclamation of Granite Stone Quarry -A case study in Jostan Granite Mine*, Tehran, Iran, A conference proceeding on strategic versus tactical approaches in mining, 2006.

[5] Balcha D, Oyda S, Assessing the impact of stone quarrying on the landscape, crop and grazing land degradation in Loma Bosa District, Dawuro Zone, Southern Ethiopia, *International Journal of Scientific Research in Civil Engineering* Vol.5, No 2, pp 79-91, 2021.

[6] Ozcan O, Musaoglu N. Seker D. Z, Environmental impact analysis of quarrying activities established on and near a river bed by using remotely sensed data, *Fresenius Eenvironmental Bulletin* PSP Vol. 21, No 11. 2012.

[7] Legwaila I. A, Lange E, Cripps J, Quarry reclamation in England: A review of techniques, *Journal American Society of Mining and Reclamation*, Vol. 4, No. 2 pp 55-79, 2015. DOI:http://doi.org/10.21000/-JASMR15020055

[8] Chudzik W, The process of mined land reclamation in natural aggregate quarries exemplified by the sand and gravel quarry Debina Letowska, *AGH Journal of mining and geoengineering*, Vol. 36, No. 1, 2012

[9] Smith M. D, Knapp A. K and Collins S. L, A framework for assessing ecosystem dynamics in response to chronic resource alterations induced by global change, *Ecology*, Vol.90, No.12, pp. 3279–3289, 2009

[10] Kumar R, Agrawal A. K, Drone GPS data analysis for flight path reconstruction: A study on DJI Parrot& Yuneec make drones, *Forensic science international: Digital investigation* 38, 2021

[11] Barnawi A, Kumar K, Kumar N, Thakur N, Alzahrani B, Almansour A, Unmanned Aerial Vehicle (UAV) Path Planning for Area Segmentation in Intelligent Landmine Detection Systems. *Sensors*, 23, 7264. 2023.

[12] Liba N, Berg-Jürgens J, Accuracy of orthomosaic generated by different methods in example of UAV platform MUST Q, *2nd International Conference on Innovative materials, structures and technologies,*

IOP Conference Series: materials science and engineering 96, 2015. 012041 doi:10.1088/1757-899X/96/1/012041

[13] Nikolić R. R, Brodić N. D, Božić B. S, Examining the impact of ground control point quantity on the geometric Accuracy of UAV photogrammetric products formed using structure-from-Motion approach, *Tehnika*, Vol. 77 No. **5,** pp 535-544, 2023.

[14] Barna R, Solymosi K, Stettner E, Mathematical analysis of drone flight path, *Journal of Agricultural Informatics*. Vol. 10, No. 2:15-27, doi: 10.17700/jai.-2019.10.2.533, 2019

REZIME

KORIŠĆENJE DRONA RADI UTVRĐIVANJA EFEKATA PROMENE PEJZAŽA USLED EKSPLOATACIJE KAMENOLOMA I IZGLEDI ZA REKULTIVACIJU

Površinsko eksploatacija, koje uključuje vađenje kamena često uzrokuje značajne promene pejzaža, što kulminira nizom ekoloških efekata od estetskih do poremećaja ekosistema kada se ne upravlja pravilno. Ovaj rad je fokusiran na procenu geo-prostornih promena u pejzažu ležišta mermera, koje su izazvane eksploatacijom u Ikpesi, Akoko-Edo, država Edo, Nigerija, sa ciljem buduće rekultivacije. Vazdušno mapiranje kamenoloma i njemu susednog poljoprivrednog zemljišta izvršeno je korišćenjem bespilotnog vozila (UAV) DJI Phantom 4 drona. Snimljene slike su obrađene pomoću softvera DroneDeploi da bi se generisali digitalni modeli površine-ortomozaika kamenoloma i susednog zemljišta, kao i karte nadmorske visine, otkopane/ispunjene jame kamenoloma i mapa zdravlja biljaka. Rezultati pokazuju da je značajna površina kamenoloma zahvaćena iskopavanjem materijala. Ukupna površina zemljišta koje je obuhvatio kamenolom iznosila je 40.400 m^2, ukupno otkopano 106.469,6 m^3 i popunjeno materijalom 124.708,5 m^3 sa neto zapreminom nasutog dela od -18.238,84 m^3. Da bi se izbegao materijalni deficit za rekultivaciju na dugi rok, potrebno je kritičko planiranje upravljanja „otpadnim materijalom iz kamenoloma“ kako bi se obezbedila konačna rekultivacija do prihvatljivog topografskog nivoa.

Ključne reči: *vađenje kamena, promena pejzaža, mapiranje, dron, rekultivacija*