Vol. 13(4), pp. 57-69, October-December, 2021
DOI: 10.5897/JGMR2021.0356
Article Number: BBCFE2368263
ISSN 2006-9766
Copyright©2021
Author(s) retain the copyright of this article
http://www.academicjournals.org/JGMR

Journal of Geology and Mining Research

*Full Length Research Paper*

# Use of computer softwares and geomatic techniques for reclamation study of environmentally degraded mined lands in Benin City, Nigeria

**Kalu Iroakazi Kalu[1*], Opeyemi Emmanuel Abiodun[2] and Clement Olanrewaju Alaba[2]**

[1]Department of Civil Engineering, Faculty of Engineering, University of Benin, Benin City, Nigeria.
[2]Department of Mining Engineering, School of Engineering and Engineering Technology, Federal University of Technology, Akure, Nigeria.

Received 13 January, 2021; Accepted 28 April, 2021

**Land degradation in the form of creation of massive pits, and deforestation of land are some adverse impacts associated with open pit mining activities. Benin City and its environs have witnessed a high proliferation of open pit sand and/ laterite mining activities popularly called borrow pits in recent times, with its associated environmental risk. This research is carried on five selected sand mines in Benin City to estimate the cumulative land area degraded as a result of sand mining operations, thus it determines the level of environmental damage done and quantity of material required for refilling and reclamation. The method involves the use of a GPS based geomatics technique to acquire GIS data of five selected open pit sand mines, as well as computer softwares for the analysis, and area and/volume studies. The result showed that sites A, B, C, D, and E deforested a land area of 17,923.125, 33,991.803, 36,038.761, 13,212.545, and 2,882.046 m2 respectively; while the volume of excavation created by the five sites are respectively 1,792,154.644, 4,992,730.898, 2,701,846.644, 9,878,111.857, and 134,258.932 m3. Thus, a cumulative area of 104,048 m² of land was deforested in the five sites while 19,499,102.98 m³ of excavation was cumulatively created which requires refilling and total reclamation.**

**Key words:** Reclamation, land degradation, sand mining activities, excavation, environmental damage, GIS data

## INTRODUCTION

Sand mining like any other type of mining activities is a destructive venture to the environment (Kondolf, 1997; Kim, 2005; Martín-Vide et al., 2010; Baena-Escudero et al., 2019). It can trigger erosion of all forms, sedimentation of rivers, air quality deterioration especially in dry seasons and total land degradation in general (Pitchaiah, 2017). But a very unique adverse impact of sand mining is creation of large borrow pits due to massive excavation of soil materials from the ground, and deforestation (Cao, 2007). These excavations when left unreclaimed could be a potential source of serious safety risks to both man and farm animals alike and to the environment at large. Also, deforestation of land has become a common occurrence associated with mining

*Corresponding author. E-mail: iroakazi.kalu@eng.uniben.edu.

and has serious negative impact including the much talked-about climate change. Of much serious concern is when the mining activity is taken place in a fast growing metropolitan town like Benin City. Ecological restoration is required to reverse the environmental degradation and mitigate human pressures on natural ecosystems (Benavas et al., 2009; Feng et al., 2013). For this reason, a study was carried on five selected sand mines located in the city to determine the volume of sand material removed that requires refilling and complete remediation as well as total area of land deforested. Also, most mine reclamation projects have laid emphasis on engineering design. A series of engineering measures can be adopted to restore damaged ecosystems in mining sites, including restructuring landforms, importing soil, and revegetation (Gao et al., 1998; Wang et al., 2001; Skleniˇcka and Lhota, 2002).

## Study area

The study area is Benin City and its environs. Benin City is the capital of Edo State, Nigeria. The study sites (Figure 1) are located within four contiguous local government councils that make up Benin City and environs. From the geological and Mineral resources map of the state (NGSA, 2006) on a scale of 1:500,000, the study area is located between latitudes 6°14'22" and 6°26'22" North and between longitudes 5°30'30" and 5°42'30" East and above the equator. It covers a landmass of about 10,956km² with a 2006 population figure of 1,208,631 persons (NPC, 2006). The native language spoken by the indigenous people is Edo. The area lies within the sub humid tropical region and because of its location; Benin City has a temperature of about 27°C and annual rainfall of over 2000 mm (Eseigbe et al., 2007). It has two seasons, the wet and dry seasons. The wet season lasts from March to October, while the dry season is from November to February with scanty rainfall and the seasons are controlled by the position of inter tropical discontinuities (ITD) whose movement is reflected in the corresponding shifts with the rain belt (Aziegbe, 2005). The tropical maritime air mass and the tropical continental air mass are the prevailing winds in the area with maritime air mass dominating the area through greater part of the year (Eseigbe and Magnus, 2012). Benin City is built on a nearly undulating low – lying surface with eastern edge of it tilted towards the Ikpoba River that drains the eastern portion of the City while the western edge slopes gently towards Ogba stream that drains the western portion of the City. Also, it is underlain by sedimentary formation of the Miocene-pleistocene in age with local relief in the City put at 91m above sea level (Eseigbe and Magnus, 2012). A topographical map of the City on a scale of 127,778 produced by Balasha-Jalon consultants shows that the City contained 15 local depressions which may have been formed during the arching in the Neogene of the lower tertiary beds (Odemerho, 1988).

## METHODOLOGY

A GPS-based survey of each pit was done using a Garmin hand-held GPS receiver to acquire X, Y and Z datasets corresponding to longitude, latitude and elevation respectively. This involves: selection of five strategic open pit sand mines from the study area; a detailed and systematic collection of representative point datasets from each of the selected sand mine using a GPS receiver; and generation of spot heights of top and bottom elevations of each site using the GPS receiver.

Each of the point datasets was described with a code to reflect the spot heights of top and bottom elevations of each site where it was collected. Points generated from the top elevation/perimeter of a pit were coded T, while those collected on the floor elevation were coded F. The points were acquired at scattered locations to give a good representation of the pits. The longitude and latitude data were converted from their geographic values (degrees, minutes and seconds) to their equivalent UTM values (meters) using INCA geomatrix software. The converted data with their corresponding elevation values were populated as X, Y, Z data in a Microsoft excel table and imported into ArcGIS 9.3 to generate attribute tables of the respective sand mines. A geodatabase was created in the Arc catalogue environment of the GIS to store the attribute datasets. From the database, attribute datasets were exported to the GIS's Arcmap environment and displayed as mass point features. Polygon shapefiles were created from the mass points by connecting the T coded point features of each pit through digitizing and/editing to produce a perimeter plot. The surface area of each perimeter plot was determined in the GIS software. The total value obtained from the five pits corresponds to the total area degraded through mining activity. That is, total area degraded is the algebraic sum of the area of respective sand mines, that is:

$$\alpha t = \sum \beta i \quad (1)$$

Where, $\alpha_t$, is the total land area deforested by the respective sites; β = area of land deforested by pit, i; i = A, B, C, D, E.

Triangulated Irregular Network (TIN) data model of each borrow pit was also generated from the attribute tables using the GIS arc toolbox's 3D analyst toolset. The TIN model of each site served as an input to the GIS for computing the volume of excavation created in each site. Total volume of materials removed that requires refilling is therefore the algebraic sum of the volume of respective mine sites. that is:

$$Vt = \sum Vi \quad (2)$$

Where, $V_t$ is total volume of excavation created by the respective sites: $V_i$ is volume of excavation created by pit i: i = A, B, C, D, and E.

Outputs generated from the study are perimeter/spot height map and TIN map of the respective pits. Others are area and volume computation result table, and charts showing area of land degraded, and volume of excavation created by the five mine sites.

## RESULTS

Table 1 shows the result of the area and volume computation of the respective site locations as well as the cumulative environmental degradation caused by the five open pit mine sites. Also shown in this table are the local government areas where each of these mine sites is

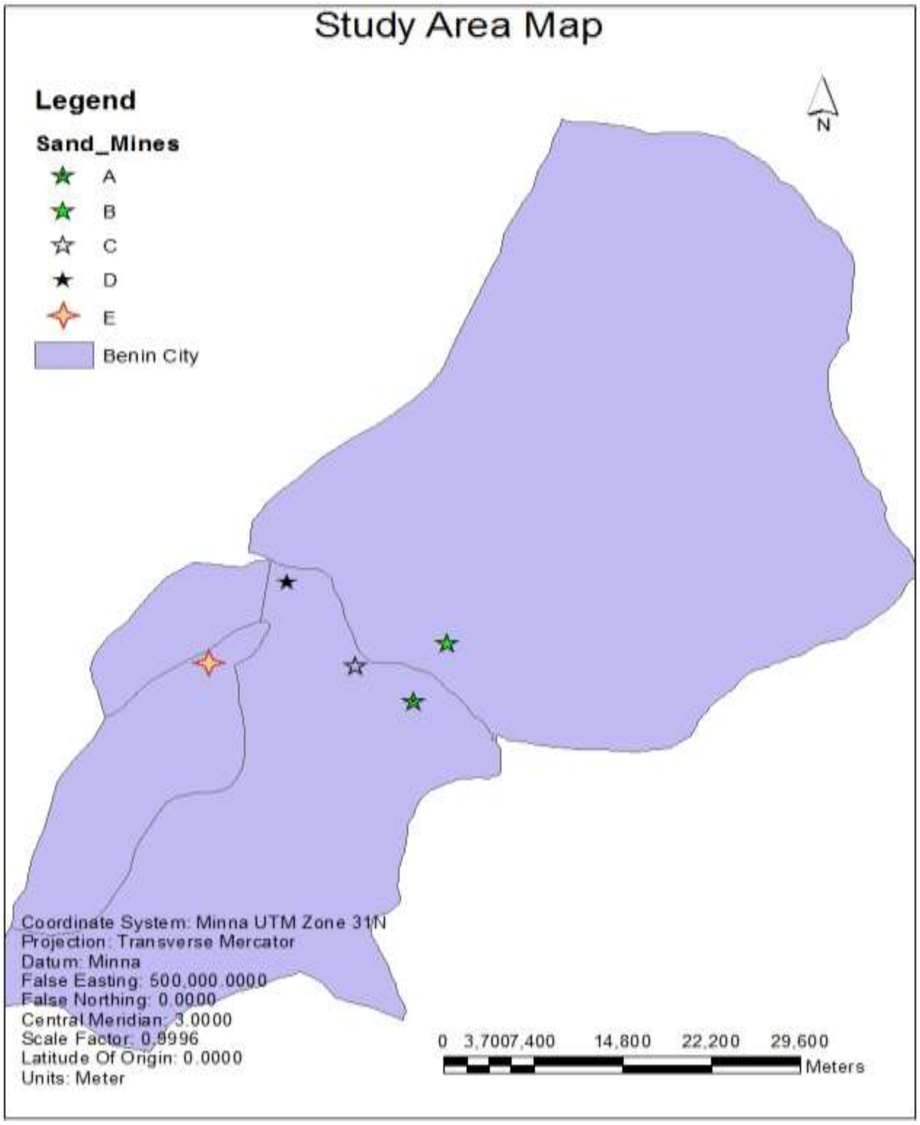



**Figure 1**. Map of Benin City Showing the Mine Locations.
Source: Adapted from Geological and Mineral Resources Map of Edo State (NGSA, 2006).

**Table 1.** Area and Volume Computation Result of the Five Open Pit Sand Mine Sites.

| Pits | UTM coordinates (m) | Area of land deforested (m²) | Volume of excavation created (m³) | L.G.A |
|---|---|---|---|---|
| A | N695251.4<br>E802454.874 | 17,923.125 | 1,792,154.644 | Ikpoba Okha |
| B | N700798.9<br>E805194.03 | 33,991.803 | 4,992,730.898 | Uhunmwonde |
| C | N698607.8<br>E797669.694 | 36,038.761 | 2,701,846.644 | Ikpoba Okha |
| D | N706805.2023<br>E791946.8621 | 13,212.545 | 9,878,111.857 | Egor |
| E | N698852.8<br>E785365.78 | 2,882.046 | 134,258.932 | Oredo |
| | **Total** | **104048** | **19499102.98** | |

**Table 2.** Primary Data from GPS Reading for the Five Selected Sand Mines.

| S/N | Elevation (m) | | | | |
|---|---|---|---|---|---|
| | **PIT A** | **PIT B** | **PIT C** | **PIT D** | **PIT E** |
| 0 | 69.3 | 33 | 48.1 | 46 | 45.6 |
| 1 | 64 | 38 | 47.7 | 46.8 | 46.7 |
| 2 | 63.2 | 38.9 | 44.5 | 47.1 | 47.7 |
| 3 | 60.2 | 38 | 47 | 47.8 | 50.48 |
| 4 | 57.8 | 40 | 52.7 | 48.2 | 52.5 |
| 5 | 55 | 43 | 51.4 | 49 | 54.04 |
| 6 | 50.5 | 43.3 | 51.9 | 49.6 | 55.22 |
| 7 | 45.4 | 43.3 | 58.7 | 50 | 54.9 |
| 8 | 43.2 | 46.6 | 59.9 | 52.1 | 53.05 |
| 9 | 42.3 | 48.8 | 60 | 55.3 | 52.08 |
| 10 | 42.7 | 49 | 55 | 60.2 | 50.41 |
| 11 | 43.4 | 55 | 72.1 | 55.2 | 49.15 |
| 12 | 45.3 | 60.2 | 36 | 63.4 | 47.4 |
| 13 | 48.4 | 60 | 37.7 | 65 | 45.94 |
| 14 | 52.3 | 63 | 35 | 68.4 | 44.41 |
| 15 | 54.8 | 66.5 | 33.4 | 71.2 | 43.22 |
| 16 | 57.4 | 68.5 | 28 | 72.4 | 42.09 |
| 17 | 59.8 | 70 | 55.6 | 74.6 | 41.23 |
| 18 | 60.1 | 71 | 60.5 | 75.2 | 40.24 |
| 19 | 62.3 | 70 | 63.3 | 76.4 | 40.07 |
| 20 | 64.7 | 70 | 67.2 | 75.5 | 39.89 |
| 21 | 65.8 | 73 | 71 | 0 | 39.98 |
| 22 | 68 | 70 | 27.5 | 71.4 | 39.98 |
| 23 | 65.6 | 62 | 27 | 68.3 | 39.98 |
| 24 | 69.1 | 56 | 27.2 | 64.3 | 39.99 |
| 25 | 20.1 | 45 | 27.8 | 63.4 | 39.98 |
| 26 | 19.8 | 43 | 27.9 | 62.7 | 39.98 |
| 27 | 19.1 | 26.4 | 28 | 61.2 | 40.08 |
| 28 | 21.1 | 27.5 | 28.4 | 59.8 | 40.3 |
| 29 | 22 | 28.6 | 28.7 | 59 | 40.43 |
| 30 | 23 | 27 | 28 | 60.4 | 40.35 |
| 31 | 22.2 | 29 | 35 | 62 | 40.35 |
| 32 | 22.6 | 29.2 | 32 | 62.8 | 41.1 |
| 33 | 21.5 | 20 | 33 | 63.5 | 41.43 |
| 34 | 23.5 | 19.5 | 33 | 64.1 | 41.6 |
| 35 | 23 | 20.1 | 35 | 64.1 | 41.95 |
| 36 | 25 | 22 | 27.5 | 64 | 41.97 |
| 37 | 25.8 | 28.9 | 27.3 | 63.5 | 42.3 |
| 38 | 27.1 | 28 | 31.15 | 61.8 | 42.94 |
| 39 | 24 | 30 | 28.83 | 60.6 | 43.14 |
| 40 | 22 | 37.6 | 27.44 | 59.6 | 43.94 |
| 41 | 22.4 | 40.7 | 35.46 | 60.8 | 43 |
| 42 | 21.3 | 40 | 27.45 | 60.8 | 42.6 |
| 43 | 21 | 41.8 | | 60.2 | 43 |
| 44 | 32 | 20 | | 58 | 42.7 |
| 45 | 32 | 19.3 | | 57 | 43.1 |
| 46 | 27 | 19.7 | | 56.8 | 42.1 |
| 47 | 40 | 19.6 | | 55 | 42 |
| 48 | 35.6 | 19 | | 53.6 | 42 |
| 49 | 38 | 19.8 | | 50.9 | 42.6 |

**Table 2.** Cont'd

| | | | | |
|---|---|---|---|---|
| 50 | 35 | 20 | 49.9 | 42 |
| 51 | 40 | 23 | 49.9 | 41.9 |
| 52 | 39 | 22.1 | 49.7 | 42.8 |
| 53 | 34 | 22 | 49.5 | 41.4 |
| 54 | 33.4 | 28.5 | 48.9 | 41.8 |
| 55 | 38 | 28.7 | 48 | 42.8 |
| 56 | 35 | 20 | 47.5 | 39 |
| 57 | 38.6 | 28 | 46.7 | 38.7 |
| 58 | 20 | 20 | 45.4 | 40.1 |
| 59 | 64.2 | 26 | 44.5 | 40 |
| 60 | | 27 | 46.2 | 39 |
| 61 | | 22.5 | 44.3 | 38.8 |
| 62 | | 22 | 43.6 | 39.2 |
| 63 | | 22.4 | 43.4 | 38.5 |
| 64 | | | 43.4 | 39 |
| 65 | | | 43.3 | 39 |
| 66 | | | 43.4 | 37.8 |
| 67 | | | 43.7 | 38.6 |
| 68 | | | 44.3 | 37.5 |
| 69 | | | 44.7 | 36.6 |
| 70 | | | 45.2 | 37 |
| 71 | | | 45.4 | 38 |
| 72 | | | 45.5 | 39 |
| 73 | | | 45.6 | 38.8 |
| 74 | | | 45.4 | 39.2 |
| 75 | | | 45.3 | 37.4 |
| 76 | | | 45.5 | 36.2 |
| 77 | | | 47 | 38.2 |
| 78 | | | 46 | 39 |
| 79 | | | 46 | 39.5 |
| 80 | | | 46.5 | 38.4 |
| 81 | | | 45.7 | 38.3 |
| 82 | | | 45.4 | 39 |
| 83 | | | 44.3 | 43.2 |
| 84 | | | 44.2 | 42.3 |
| 85 | | | 45.2 | 43.5 |
| 86 | | | 44.1 | |
| 87 | | | 43.4 | |
| 88 | | | 43 | |
| 89 | | | 43.5 | |
| 90 | | | 42.7 | |
| 91 | | | 43.3 | |
| 92 | | | 43 | |
| 93 | | | 41.2 | |
| 94 | | | 49.2 | |
| 95 | | | 48.9 | |
| 96 | | | 48.7 | |
| 97 | | | 47.8 | |
| 98 | | | 48 | |
| 99 | | | 47.5 | |
| 100 | | | 48 | |
| 101 | | | 47 | |

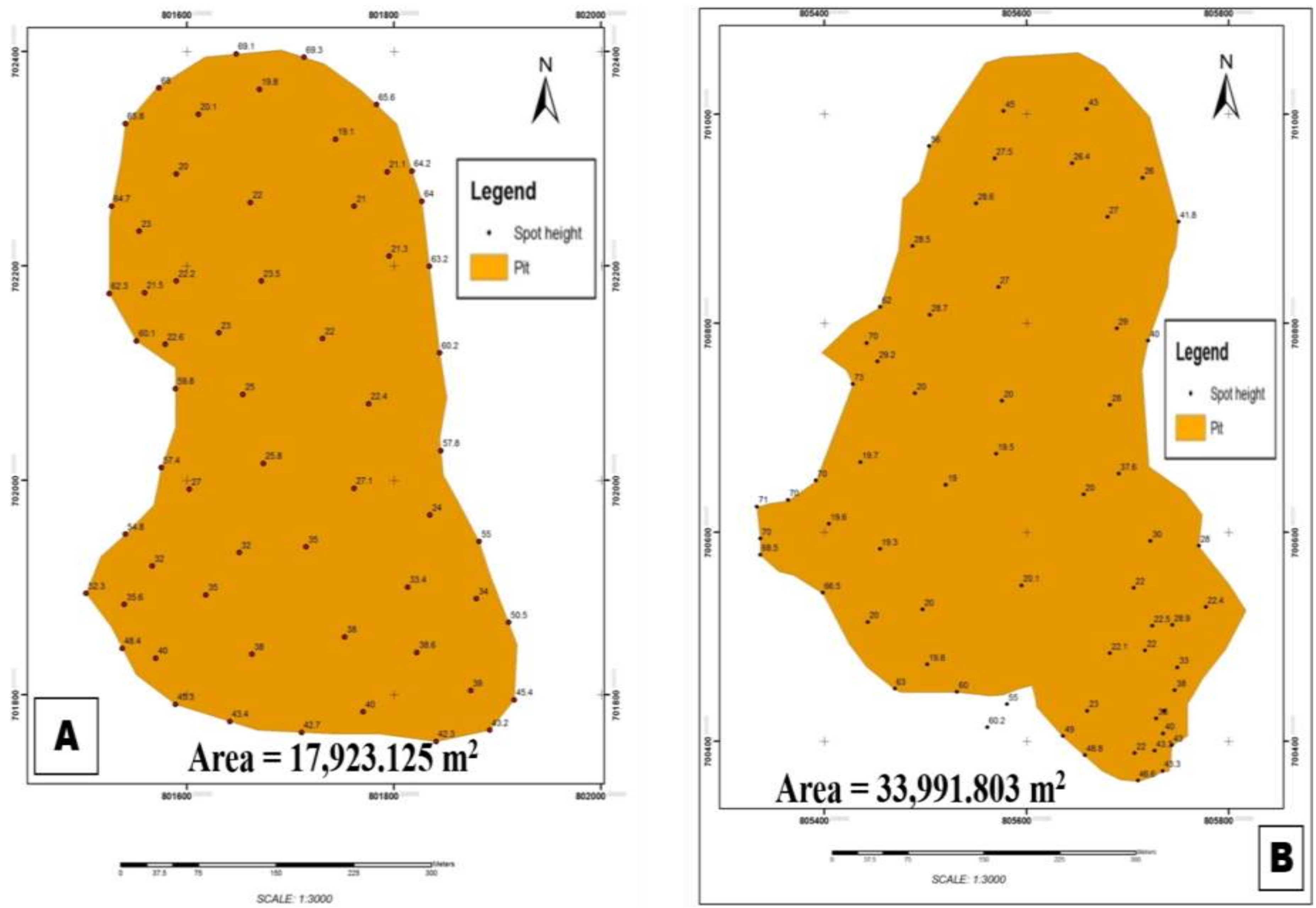
**Table 2.** Cont'd

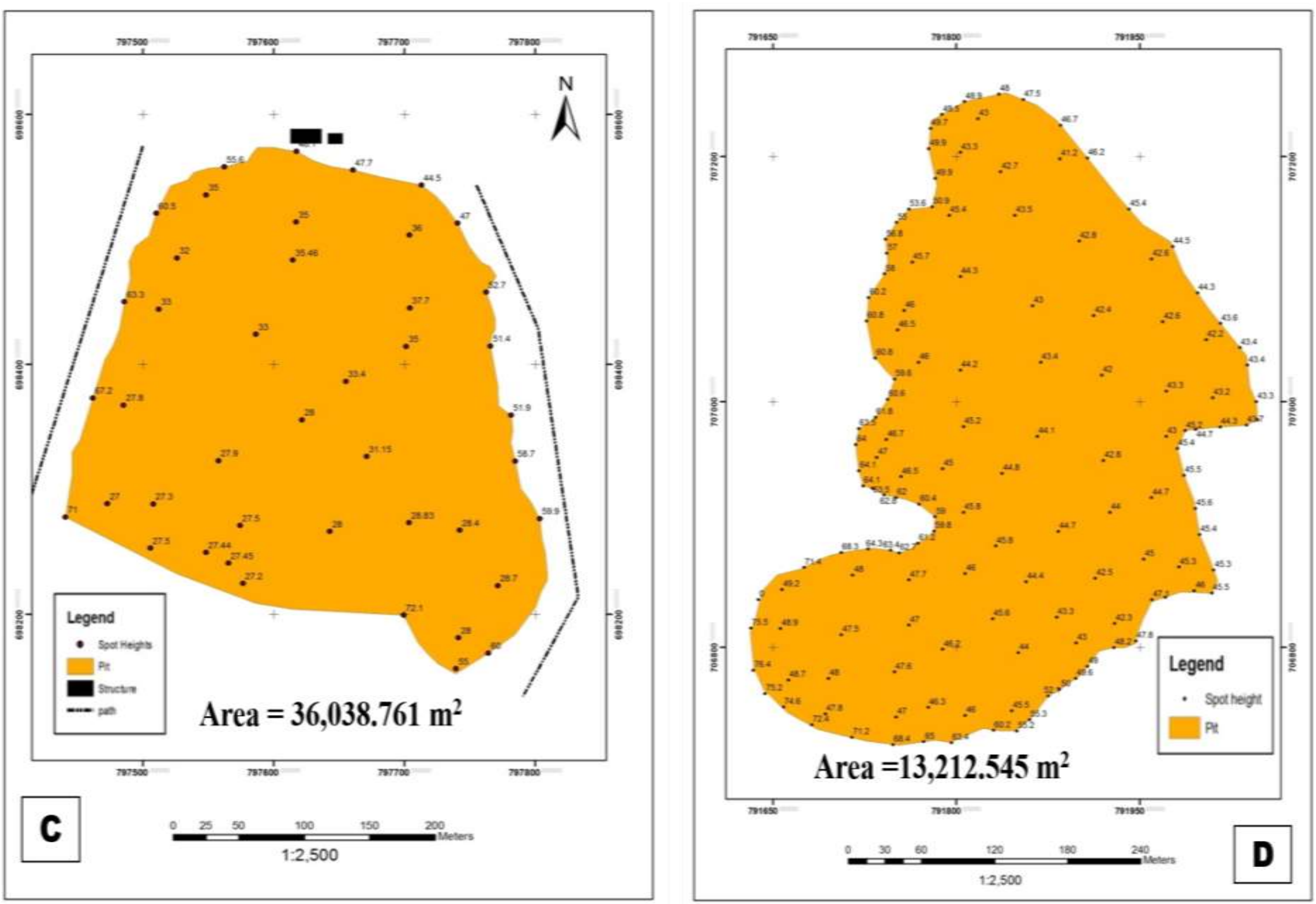
| | |
|---|---|
| 102 | 47.6 |
| 103 | 47.7 |
| 104 | 47 |
| 105 | 45.6 |
| 106 | 46 |
| 107 | 46.2 |
| 108 | 46.3 |
| 109 | 46 |
| 110 | 44 |
| 111 | 45.5 |
| 112 | 43.3 |
| 113 | 43 |
| 114 | 42.3 |
| 115 | 43.2 |
| 116 | 42.2 |
| 117 | 43 |
| 118 | 43.3 |
| 119 | 42.6 |
| 120 | 42.6 |
| 121 | 42.8 |
| 122 | 42 |
| 123 | 42.4 |
| 124 | 42.8 |
| 125 | 42.5 |
| 126 | 44.4 |
| 127 | 45.8 |
| 128 | 45.8 |
| 129 | 45 |
| 130 | 45.3 |
| 131 | 44.7 |
| 132 | 44 |
| 133 | 44.7 |
| 134 | 44.8 |
| 135 | 45 |
| 136 | 46.5 |
| 137 | 46.7 |

located. Table 1 also shows the area of land deforested in the respective mine sites that require reclamation and the respective volumes computed from the respective mine sites. It shows the volume of excavation created in the respective mine sites that require refilling and total reclamation Table 2 shows the primary data from GPS reading for the five selected sand mines. Figure 2 shows the perimeter and/spot height maps of pits A, B, C, D, E respectively. This figure shows the various spot heights and perimeters from where the surface areas deforested by open pit sand/laterite mining activities in the sites were computed. Also, Figure 3 are the Triangulated Irregular Network (TIN) maps of pits A, B, C, D, and E respectively. The figure shows the surface volumes of the five mine sites from where the volume of excavation created by open pit sand mining activities in the sites were estimated.

## DISCUSSION

From Table 1 and Figure 2, surface area of land deforested by the five respective mine sites are 17,923.125, 33,991.803, 36,038.761, 13,212.545 and 2,882.046 $m^2$. Thus, a total of 104,048 $m^2$ of land was deforested with pits B and C recording the highest of 33,991.803 and 36,038.761 $m^2$ respectively; while pit E was least with 2,882.046 $m^2$. Deforestation portends


801600
801800
802000
702400
702200
702000
701800
N
Legend
Spot height
Pit
A
Area = 17,923.125 m²
SCALE: 1:3000
805400
805600
805800
701000
700800
700600
700400
N
Legend
Spot height
Pit
Area = 33,991.803 m²
B
SCALE: 1:3000


N
Legend
Spot Heights
Pit
Structure
path
Area = 36,038.761 m²
C
0 25 50 100 150 200 Meters
1:2,500
Legend
Spot height
Pit
Area =13,212.545 m²
D
0 30 60 120 180 240 Meters
1:2,500

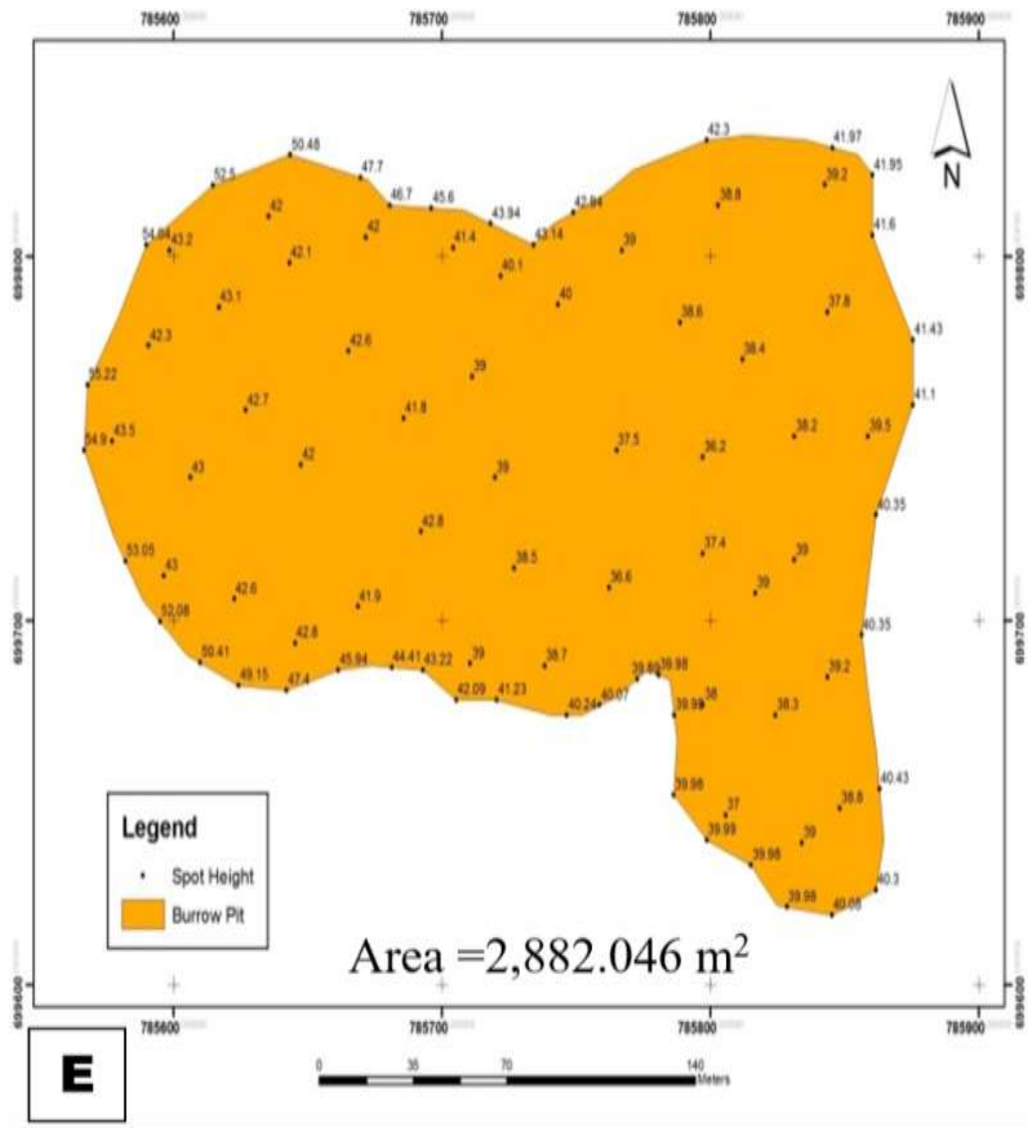



**Figure 2.** Spot Heights/Perimeter plots showing the surface areas deforested by open pit sand/laterite mining activities in the sites.

great danger to the environment as it can lead to soil erosion (Rogge, 2007), climate change and deterioration in air quality (Sahney et al., 2010), biodiversity loss (Nilsson, 2014), etc. Also, the result showed that a total of 19,499,102.98 $m^3$ of material was cumulatively removed from the five mine sites leaving these +areas as open excavations. Table 1 and Figure 3 show that the respective volumes are 1,792,154.644, 4,992,730.898, 701,846.644, 9,878,111.857 and 134,258.932 $m^3$. No attempt has been made to reduce the dangers posed by these open pits to both men and animals and to the environment as at the time of this research. Pit D records the highest volume, 9,878,111.857 $m^3$, while pit E recorded the least volume at 134,258.932 $m^3$. Dangers associated with open excavations have been widely reported in Akeredolu (2009a, b), Ajibade (2009), etc.

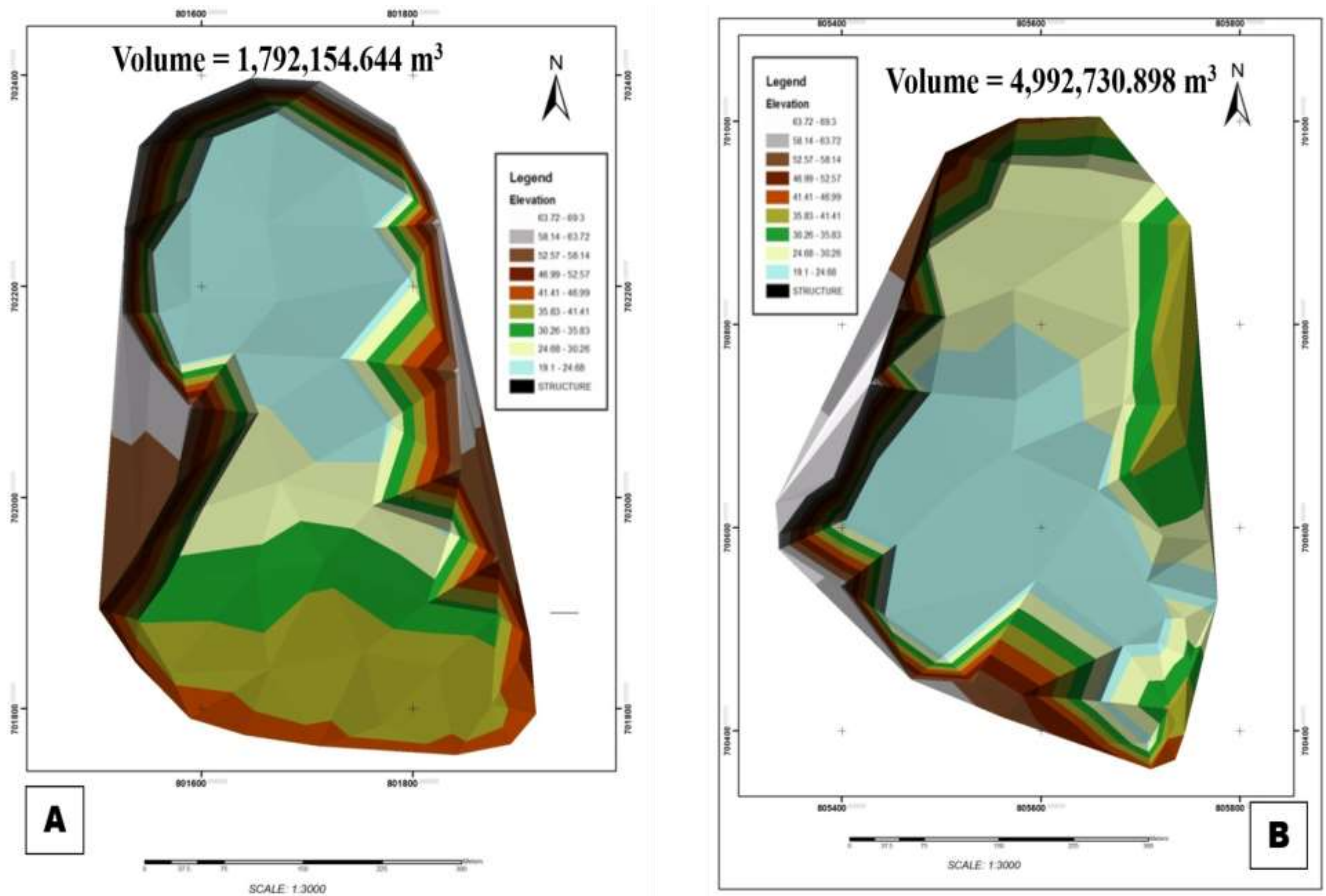
## Conclusion

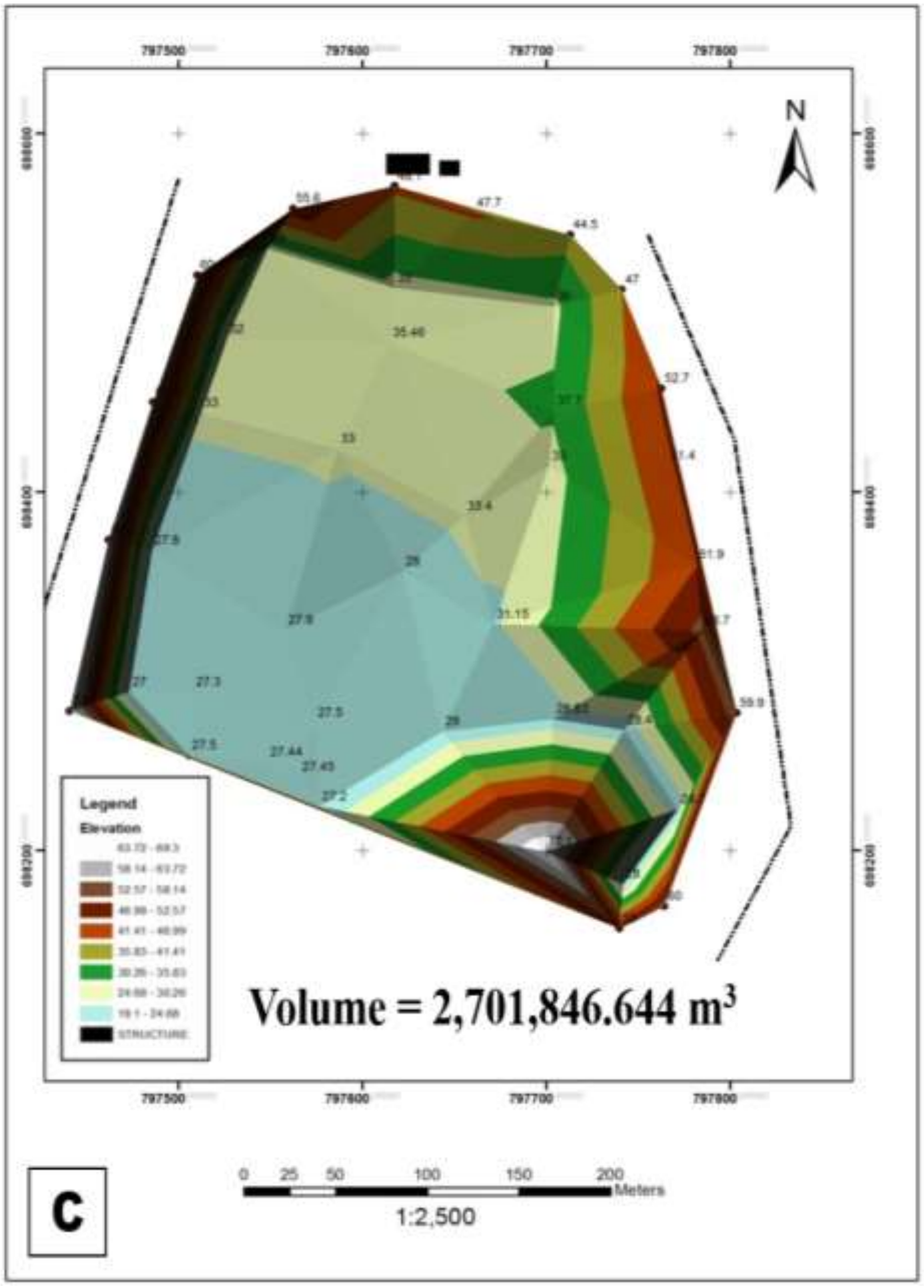
This study revealed that:

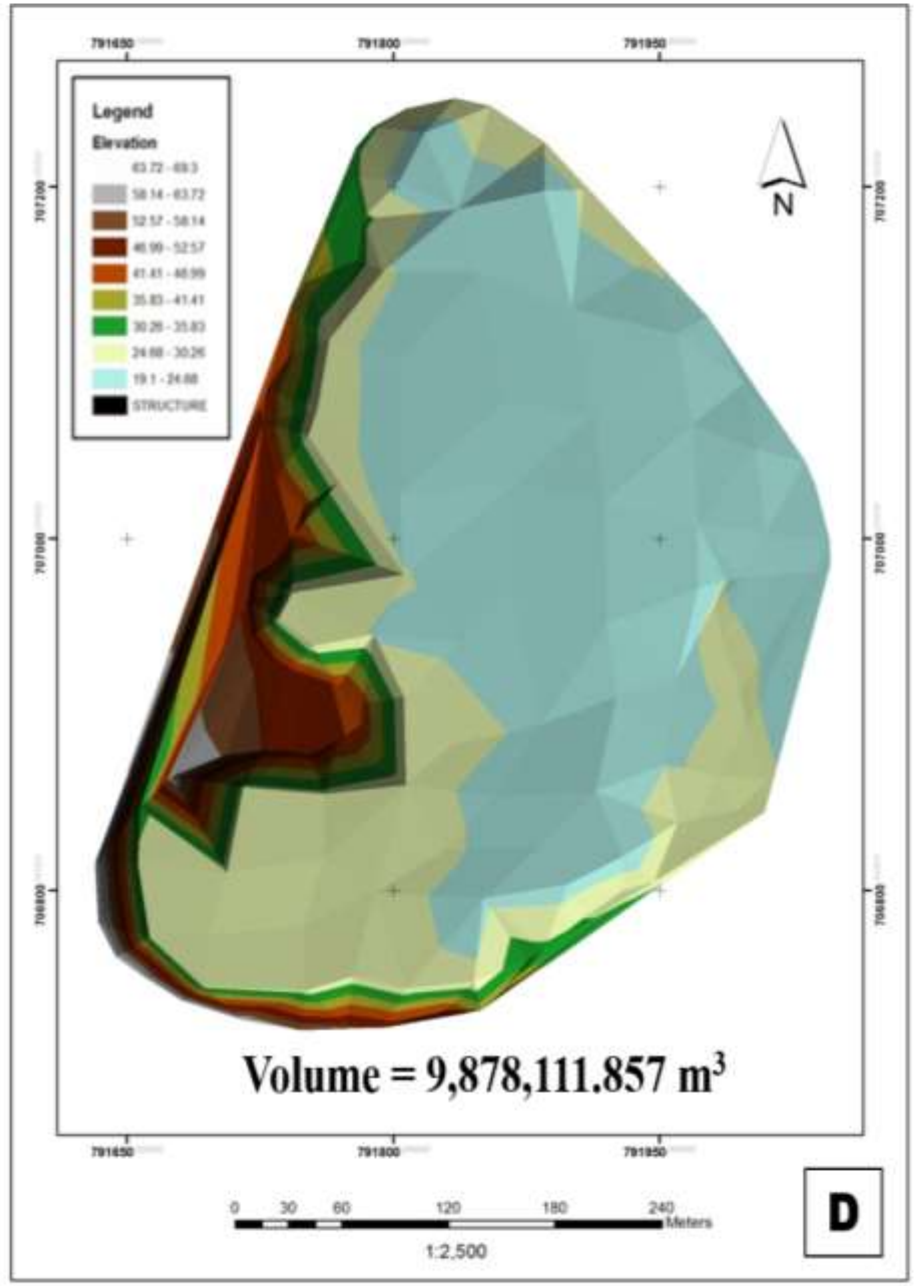
1) Sand Mining operations in Nigeria Constitutes land degradation problems.
2) Computer programs and softwares, and geomatic techniques are useful and effective tools in mine reclamation studies.
3) About 104,048 $m^2$ of land area is deforested and19,499,102.98 $m^3$ of material is required for refilling and reclamation of the selected sand mines

## Recommendations

(i) Environmental Audit should be done often (at least


Volume = 1,792,154.644 m³
N
Legend
Elevation
63.72 - 69.3
58.14 - 63.72
52.57 - 58.14
46.99 - 52.57
41.41 - 46.99
35.83 - 41.41
30.26 - 35.83
24.68 - 30.26
19.1 - 24.68
STRUCTURE
801600
801800
702400
702200
702000
701800
A
SCALE: 1:3000
Volume = 4,992,730.898 m³
805400
805600
805800
B
SCALE: 1:3000


Legend
Elevation
STRUCTURE
N
Volume = 2,701,846.644 m³
0 25 50 100 150 200
Meters
1:2,500
C


Legend
Elevation
63.72 - 69.3
58.14 - 63.72
52.57 - 58.14
46.99 - 52.57
41.41 - 46.99
35.83 - 41.41
30.26 - 35.83
24.68 - 30.26
19.1 - 24.68
STRUCTURE
N
Volume = 9,878,111.857 m³
0 30 60 120 180 240
Meters
1:2,500
D

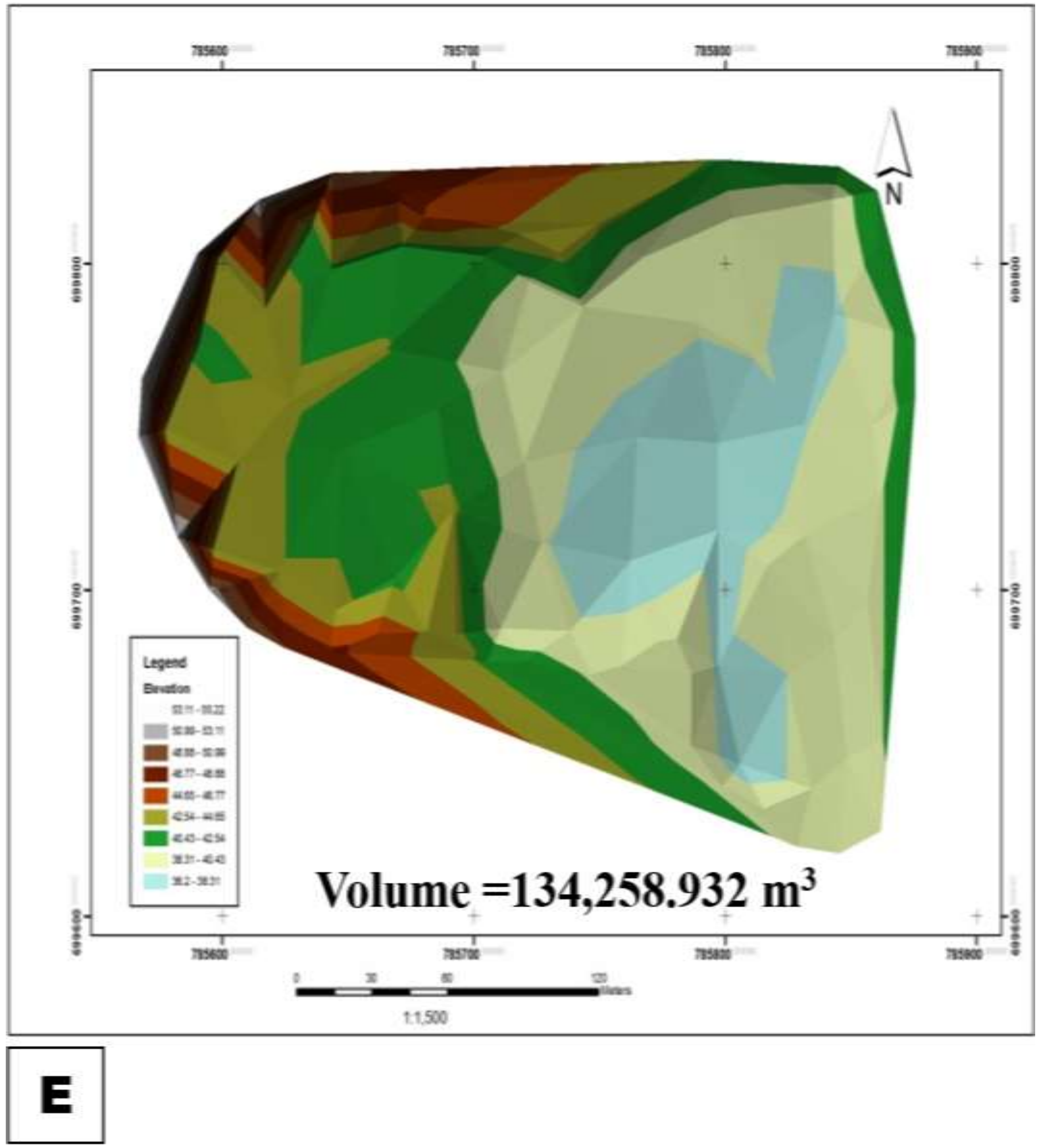



**Figure 3.** Triangulated Irregular Network (TIN) Model Plots showing the volume of excavation created by open pit sand mining activities in the sites.

once in three years), while environmental impact assessment should be encouraged for new mining projects.
(ii) For the massive area degraded, aggressive replantation of trees (reforestation) should be incorporated in the closure plan of these sites and adequately implemented, monitored by all stakeholders.
(iii) There is the need for a comprehensive study of all the borrow pits in Benin City with a view to reclaiming them for other meaningful/useful purposes.
(iv) Proper funding of government agencies is highly recommended to boost enforcement of laws.
(v) The sites should be temporarily fenced round as an interim measure pending further studies and reclamation so as to reduce casualties.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.
Ans: There is no conflict of interest here because reclamation of mine sites is an industry best practice which must be vigorously pursued.

## REFERENCES


Ajibade LSA (2009). Mining and its Environmental Impact. Paper Presented at the Environmental Capacity Building Programme for the Nigerian Mining Sector: Training Session 1. Abuja, Nigeria.

Akeredolu F (2009a). Environmental Mitigation Measures for the Nigerian Mining Sector. Paper Presented at the Environmental Management Capacity Building Programme for the Nigerian Mining Sector: Training Session 3. Enugu, Nigeria.

Akeredolu F (2009b). Guidelines for the Closure of Mines. Paper Presented at the Environmental Management Capacity Building Programme for the Nigerian Mining Sector: Training Session 3. Enugu, Nigeria.

Aziegbe FI (2005). Aspect of the Soils of Ekpoma Region, Their Implication for Agriculturally Planning and Development. Occasional Publication 1(1):34-41.

Baena-Escudero R, Rinaldi M, García-Martínez B, Guerrero-Amador IC, Nardi L (2019). Sediment mining in alluvial channels: Physical effects and management perspective. Geomorphology, 337:15-30.

Benavas JMR, Newton AC, Diaz A, Bullock JM (2009). Enhancement of biodiversity and ecosystem services by ecological restoration: A meta-analysis. Science. 325:1121-1124.

Cao X (2007). Regulating mine land reclamation in developing countries: The case of China. Land Use Policy 24:472-483.

Eseigbe JO, Magnus OO (2012). Aspect of Gully Erosion in Benin City, Edo State, Nigeria. Research on Humanities and Social Sciences 2(7):21-26.

Eseigbe JO, Omonfonmwan SI, Kadiri MA (2007). Solid Waste Generation and Management in Benin Metropolis. Confluence Journal of Environmental Studies 2(2):34-44.

Feng X, Fu B, Lu N, Zeng Y, Wu B (2013). How ecological restoration alters ecosystem services: An analysis of carbon sequestration in China's Loess Plateau. Scientific Reports 3:2846.

Gao L, Miao Z, Bai Z, Zhou X, Zhao J, Zhu YA (1998). Case study of ecological restoration at the Xiaoyi Bauxite mine, Shanxi Province, China. Ecological Engineering 11(1-4):221-229.

Kim C (2005). Impact Analysis of River Aggregate Mining on River Environment. KSCE Journal of Civil Engineering 9(1):45-48.

Kondolf GM (1997). Hungry water: effects of dams and gravel mining on river channels. Environmental management 24(4):533-551.

Martín-Vide JP, Ferrer-Boix C, Ollero A (2010). Incision due to Gravel Mining: Modeling a Case Study from the Gallegoriver, Spain. Geomorphology 117:261-271.

National Population Commission (NPC) (2006). PHC Priority Tables. population.gov.ng. Archived from the original on 10 October 2006. Retrieved 10 October 2006.

Nigeria Geological Survey Agency (NGSA) (2006). The Geological Map of Nigeria. A Publication of Nigeria Geological Survey Agency, Abuja, Nigeria.

Nilsson S (2014). Do We Have Enough Forests? American Institute of Biological Sciences, Accessed 22nd June, 2014.

Odemerho FO (1988). The Problem of Gully Erosion in Nigeria: Environmental Issue and Management in Nigeria Development. In Odemerho F. O. and Sada, P. O. (cds) Ibadan, Evans Brothers Publishers.

Pitchaiah PS (2017). Impacts of Sand Mining on Environment – A Review. Department of Geology, Nagarjuna University, Guntur, Andhra Pradesh, India, SSRG International Journal of Geo informatics and Geological Science (SSRG-IJGGS), 4(1):1-5.

Sahney S, Benton MJ, Falcon-Lang HJ (2010). Rainforest Collapse Triggered Pensylvanian Diversification in Euramerica. Geology 38(12): 1079-1082.

Skleniˇcka P, Lhota T (2002). Landscape Heterogeneity—A Quantitative Criterion for Landscape Reconstruction. Landsc. Urban Plan 58:147-156.

Wang Y, Dawson R, Han D, Peng J, Liu Z, Ding Y (2001). Landscape ecological planning and design of degraded mining land. Land Degradation and Development 12(5):449-459.