Received: 12 Nov 2023 | Revised: 28 May 2024 | Accepted: 07 June 2024 | Published: 30 June 2024
Volume 2(1) Pages 59-71
DOI: https://doi.org/ 10.56279/jicts.v2i1.60

JICTS
Journal of ICT Systems

Geospatial Assessment of Impacts of Sand Mining Activities in Zanzibar

Rahma Rashid Amour[1], Haji Ali Haji

Department of Computer Science and Information Technology, School of Computing, Communications, and Media Studies, State University of Zanzibar, Zanzibar, Tanzania

[1]Corresponding author
Email: amourashid@gmail.com

Funding Information

This work was self-sponsored.

Keywords

Sand mining
Geospatial technology
Geographic Information System (GIS)
Environmental degradation

Abstract

This study assessed the impacts of sand mining activities in Zanzibar by using geospatial technology, focusing on three villages in the North 'B' district of Unguja: Donge-Muwanda, Mchangani, and Misufini. Geospatial technology was employed, utilizing two distinct datasets to analyse the spatial extent of environmental degradation due to sand mining. The first dataset comprised of geographic coordinates of sampled mining sites, acquired through field survey by using the Global Positioning System (GPS). The second dataset involved satellite imagery obtained from the Google Earth application. These datasets were utilized to find the area, volume, and depth of mining sites and create three-dimensional (3D) models for each sand mining site by using ArcMap software and Surfer 19 software. The Google Earth images from 2020, 2021, 2022, and 2023 were utilized to determine changes in vegetation cover before and after the mining activities in the study area. The key finding of the study indicates that there is a high extent of environmental degradation caused by intensive sand mining activities, impacting both the community and environment in surrounding sand mining areas. The study suggests that the results should be used to emphasize the importance of existing policies, guidelines, and laws related to sand mining.

1. Introduction

Sand is a vital natural resource that is commonly found on Earth and is crucial for global economic development [1]. The formation of sand occurs through the process of erosion, where mountain rocks are transported by streams and rivers, resulting in the transportation of sediment that can eventually form sand [2]. The particle size and mineral composition of sand vary, with measurements ranging from 0.06 mm to 2 mm [2]. The availability of sand in certain areas has often led to sand mining activities.

According to Adedeji et al. [3], sand mining is a process that involves the extraction of sand from its natural habitat, which can be carried out in various locations, such as beaches, inland dunes, ocean beds, and riverbeds. This activity has been a source of livelihood for some communities and individuals [1]. Furthermore, sand has numerous applications, including its use in agriculture, as a habitat, in construction, as well as serving as a source of financial gain [4].

Sand mining is a global economic activity that has a significant impact on the economy, society, and environment. Sand mining has both positive and negative social and environmental impacts [5]. The mining process has created employment opportunities and wealth in the mining areas, but it has also resulted in widespread environmental degradation and the erosion of traditional values in society [6]. The mining process has led to the distortion of topography, creation of pools of water for breeding pests, deforestation of areas, and degradation of the ecosystem [6].

Sand mining has emerged as a significant issue globally with far-reaching social, political, economic, and environmental implications. The rapid advancement of science and technology has led to significant changes in the development of urban and rural areas [2]. The increased urbanization and construction of large-scale infrastructure projects have resulted in increased demand for sand resources [7]. It is estimated that between 32 and 50 billion tons of sand are mined globally each year, particularly in developing countries [1].

Tanzania has experienced a rise in public infrastructure investment in recent years, including the construction of roads, bridges, railways, and public buildings. To complete these large projects, sand has emerged as a crucial resource. As a result, there has been a sharp increase in sand mining in Tanzania [8].

Zanzibar Island, as a semi-autonomous part of Tanzania, is seriously affected by sand mining activities due to the increasing sand demand enhanced by rapid urbanization [9]. Sand demand has resulted into the increased number of sand mining sites. Due to inadequate monitoring of sand mining sites and post-management practices, several agricultural lands have been turned into wetlands or borrow pits. Land rehabilitation is required for the sustainability of natural resources and their associated environments [10].

Monitoring and managing the impacts of natural resources due to sand mining activities is of utmost importance to ensure their sustainability. Therefore, it is essential to adopt restoration and conservation measures and employ innovative, improved, and feasible techniques to assess and address these impacts of mining activities. Currently, geospatial techniques have been widely used in investigating the mining or urban environment as they provide a large amount of earth observation data at global, regional, and local scales [11]. Geospatial technology also enables the study of the impacts of mining practices on agricultural environments and suggests environmentally friendly practices [12, 13].

Geospatial technology plays a vital role in the decision-making process of resource utilization by using geographic information systems (GIS). Owing to its capability to handle geographical information, which is crucial for most processes in making decisions, it has significantly impacted the development of decision support systems, especially in the areas of environmental modeling and model development [12].

Numerous researchers have employed geospatial technology to evaluate the impacts of sand mining activities [1, 3, 4, 6, 11]. However, a noteworthy observation showed that the previous studies conducted in Zanzibar have paid limited attention in utilizing geospatial technology to asses the impacts of sand mining [9, 14]. The limited utilization of geospatial technology in Zanzibar may result from a lack of awareness among researchers and policymakers regarding its potential advantages. Furthermore, constrained access to essential tools and resources may act as a barrier to its widespread adoption. The effectiveness of geospatial technology is closely linked to the accessibility and quality of pertinent spatial data.

It is essential to assess the impacts of sand mining activities in Zanzibar using geospatial technology. This technology is potential and allows to acquire data that is referenced to earth easily. The collected data could be used for analysis and visualization of the impacts of sand mining activities, providing a suggestion to minimize social and environmental impacts concerning sand mining activities.

Many tools, including questionnaire and interview, have been adopted in the previous studies conducted in Zanzibar [9, 14], to assess and analyze the impacts of sand mining activities. Though the application of GIS in this study has easily aided in identifying and mapping locations for sand mining within the study area, it also helped to identify consequences associated with sand mining activities.

This study has involved the use of spatial-temporal analysis in examination and interpretation of both spatial and temporal (time-related) patterns and trends of mining areas in North ‘B’ district in Unguja. This type of analysis explores how phenomena change and interact in both geographical space and over different periods of time. The spatial-temporal analysis involved the use of Google Earth imagery that enabled researchers to leverage its rich dataset, historical imagery, and various tools for visualization. Spatial-temporal analysis in this study involved environmental monitoring that tracked changes in land cover and vegetation from 2020, 2021, 2022, and 2023 around mining areas.

1.1 Study Area

The study was conducted in North ‘B’ Unguja Island, Zanzibar, which is 1,666 square kilometers in size. Zanzibar is a semi-autonomous part of the United Republic of Tanzania; it is situated 40 kilometers off the coast of East Africa between latitudes 5° and 6° south and longitudes 39° and 40° east. Unguja covers over 85 kilometers from north to south, and its width varies from 9 kilometers in the north to nearly 35 kilometers in the south [15].

The study area was North 'B' District, which is located in the Northern Region of Unguja Island. This region is divided into two administrative districts, North ‘A’ and North ‘B’, both of which fall under the purview of the Local Governance in Zanzibar Legislative Regulation [16]. The North ‘B’ District covers an area of approximately 234 square kilometers. Figure 1 shows the location of the study area on a map of Unguja Island.

According to the Population and Housing Census of Tanzania of 2022, the total population of Zanzibar was 1,889,773 people, with a yearly growth rate of 3.7%. However, the population in the North Region of Unguja is approximately 257,290 people. The North 'B' District has a current population of 81,675 people, accounting for 6.2% of the total population of Zanzibar.

Zanzibar Island’s maximum temperature ranges from 28℃ to 33℃ per year. In the meantime, the low annual temperature ranges between 22℃ to 25℃. High temperatures and heavy rainfall are two of Zanzibar's defining characteristics throughout the year [18]. It is important to note that the short rainy season occurs in either September or October, while the long rainy season spans from March to May.

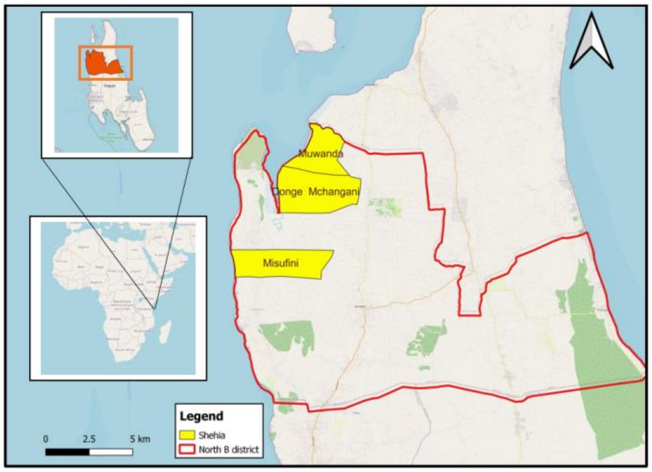

Figure 1. The map shows a location of the study area. *(Source: Open Street Map, 2023)*

2. Methodology

This study was conducted in the North 'B' district of Unguja Island, focusing on sand mining sites. The researchers selected villages based on the proximity of sand mining activities. The study was conducted in areas that are severely impacted by sand mining. The afflicted areas were chosen by using purposeful sampling because they meet the researchers' objectives. The study used primary and secondary data. The primary data was geographic coordinate and secondary data used was Google Earth imagery. For acquiring secondary data, convenience sampling was used to get the satellite data from the portal.

The study used current and past Google Earth imagery to find the spatial extent of environmental degradation as a result of sand mining activities in the North 'B' district. The researchers selected three (3) *Shehias* out of 31 *Shehia* in North 'B' for analyzing the impacts of sand mining, where sand mining is commonly carried out. The Shehias selected were Donge-Muwanda, Donge-Mchangani, and Misufini. One mining site significantly impacted by sand mining activities was chosen from each *Shehia*. In these areas, satellite imagery was obtained between the year 2020 to 2023. Though, prior to 2020, these areas exhibited no mining operations; instead, they were characterized by vegetation and trees.

The geographic coordinates of these mining sites were acquired through on-site surveys employing a GPS. For precise identification of sampled mined areas, approximately two random geographic coordinate points were documented at each site. The GPS tool used was Garmin GPSMAP 64sx. This handheld GPS device was used for the study due to its user-friendly features, higher reliability and accuracy. Garmin GPS devices offer real-time tracking capabilities and play a crucial role in enhancing the efficiency and effectiveness of spatial data collection and analysis. The coordinates obtained were later fed into the Google Earth desktop application software for precise identification of each of the mining sites in the satellite imagery (ground truthing).

After precise identification of mining site in Google Earth application, the 'add path' tool was used to generate coordinates points in the mined area. The researchers created many random points to ensure the mined area is covered. The rationale for generating many coordinate points was to facilitate a smooth surface. In simple terms, the higher the number of random points created, the smoother the surface. The random points generated saved in the computer database with the "kml" file format. The saved files of random points of three mining sites were then fed into the TCX Converter tool to generate the elevation value of each point and change the file extension from KML to CSV format. The TCX Converter tool is commonly used for converting GPS-related data formats. In this study, this tool helped to enhance compatibility between Google Earth, Surfer 19 software and ArcGIS software by ensuring the data are in suitable format for integration and analysis.

The (x, y) coordinates and elevation database of all the sample mining sites created were exported to Surfer 19 Software, where they were converted to a grid using Inverse Distance to a Power gridding method. The 3D surface analyses were carried out using gridding values and 3D surface mapping tools. Minimum and maximum elevation values were obtained from Surfer 19 during analysis. This method of creating 3D mapping has also been implemented by Oluku and Asikhia [6] for easy visualization of the extent of degradation in the mined area.

Moreover, Google Earth application was used to generate the (x, y) coordinates points that were used to create polygon. The polygon used to find the values of area and volume of mined sand. The saved boundary values of three mined areas were then loaded into ArcMap 10.7. Initially, the coordinate points were converted from point to the path, then the path to the polygon. Furthermore, the ArcMap software was used to calculate the area of a polygon using the "Calculate Geometry" tool. In the "Calculate Geometry" dialog box, the "Area" field was selected as the property to calculate the area. This methodology helped the researchers to calculate and populate the value of area of each polygon.

Additionally, in calculating the volume of mined sand, similar procedures were adopted as in earlier steps in ArcMap 10.7. After adding a new field named 'Volume,' the 'Field Calculator' was selected by right-clicking on the new field in the attribute table. In the Field Calculator dialog, authors constructed an expression to calculate volume. The formula used for finding volume (V) was given by the product of area (A) and depth (D). After setting up the expression, ArcMap automatically computed the volume of sand excavated at each mining area.

The difference between the maximum and minimum pixel' elevation is referred to as the "depth" of the mining area. The results obtained, which were values of depth, area and volume of sand mined, were considered in assessing the spatial extent of environmental degradation as a result of sand mining activities in the North 'B' district. Figure 2 demonstrates the flow-diagram of the methodology employed in the present study.

3. Results and Discussion

The study findings show that the environmental degradation in the North 'B' district is more significant due to daily and yearly increases in sand mining activities. Figure 3 shows the activities of sand miners which contribute to land degradation in the area of Donge-Mchangani.

The organization of the results in this section is based on Google Earth imagery and 3D images of mined areas. The 3D images show the current situation of the mining areas and reveal the extent of land degradation. The Google Earth images depict the condition of the mined area before as well as after the end of mining operations. Additionally, Table 1 shows the spatial measurement of extent of environmental degradation of the mined area. These measurements were obtained by analyzing the Google Earth Images collected in the year 2023.

Table 1. GIS/Spatial Measurements of Mined Areas.

Mined Area	Coordinates		Elevation (m)		Approx. Area(m^2)	Depth (m)	Volume (m^3)
	Latitude	Longitude	Min	Max			
Donge-Mchangani	5°55'57.23"S	39°13'59.39"E	10	21	79,380	11	873,180
Donge-Muwanda	5°54'21.34"S	39°13'55.11"E	8	19.5	45,867	11.5	254,561.8
Misufini	5°58'37.79"S	39°12'23.67"E	13.5	21	27,411	7.5	205,582.5

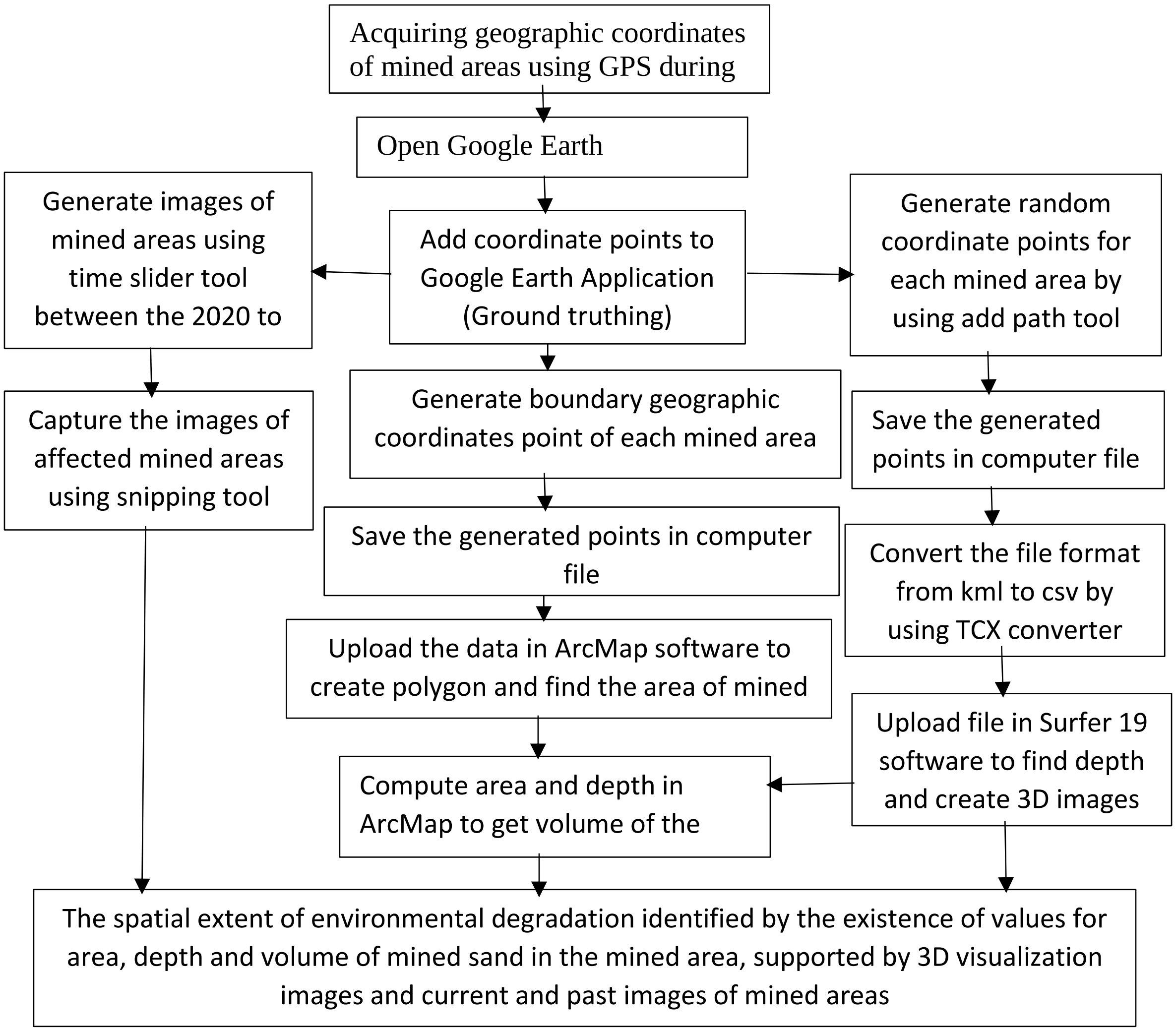

Figure 2. Methodology employed in the study.

Figure 3. Activities of Sand Miners Showing the Extent of Land Degradation.

From Table 1, the results show that, the elevation of the mined area at Donge-Mchangani was 11 m above the sea, covering an area of 79,380 m^2 and the volume of sand excavated was 873,180 m^3. On the other hand, at Donge-Muwanda the elevation was 11.5 m with an area of 45, 867 m^2 and 254,561.8 m^3 is the volume of sand that had been excavated. In Misufini, the elevation is 7.5 m, covering an area of 27,411 m^2, and 205,582.5 m^3 is the volume of sand that had been excavated from the area.

Figure 4, Figure 5, and Figure 6 show the spatial extent of environmental degradation causes by sand mining activities in the area of Donge-Muwanda, Donge Mchangani and Misufini respectively. They also show the depth of degraded land. Figure 4a and Figure 4b show the Google Earth imagery and 3D image of Donge-Muwanda, respectively. The results show that the spatial extent of environmental degradation in this area is very high. During 2020, the area was covered with vegetation, and villagers used this area for agricultural activities. In the year 2021, the area was also covered with vegetation. However, in the year 2022 and 2023, the results show that the area is degraded since the top layer has been removed due to sand mining activities that made the bare land. The results show that the land is no longer useful for agricultural purposes due to the extensive degradation.

Figure 5a and Figure 5b show the Google Earth imagery and 3D image of Donge-Mchangani, respectively. During 2020 and 2021, this area was covered with trees. However, in the year 2022, mining activities were carried out and continued to the year 2023, resulting a degraded land. The results show that mining activities in this area have caused deforestation and damaged the ecosystem. Before mining started, there was a road crossing the area, but when mining activities started, the local road was not spared from destruction either.

Figures 6a and 6b depict the Google Earth imagery and 3D representation of the Misufini area, respectively. In 2020, the area was densely vegetated with trees. However, mining activities in 2021 led to extensive deforestation, leaving the terrain strewn with tree roots. Additionally, during the same year, the imagery indicates water accumulation on the left side of the area, impacting local fauna, flora, and human inhabitants. Despite these changes, the environmental degradation in the area was relatively limited, as the mining pit's depth was shallow. Typically, deeper mining operations result in greater loss of fertile soil. Presently, the area is no longer operational and shows signs of natural recovery, characterized by the emergence of small bushes and grasses, which is a positive indication of ecological restoration.

The findings of the study indicate that the impact of sand mining on both the environment and local communities is inevitable, particularly due to the close proximity of mining sites to residential areas. The resulting environmental repercussions are significant, affecting both the natural surroundings and social dynamics. Furthermore, the outcomes derived from this research are transferable to similar regions across Unguja and Pemba Islands, given the comparable environmental characteristics and lifestyle patterns prevalent in these areas.

Land degradation resulting from sand mining activities exerts a detrimental effect on both the environment and nearby communities. Through the examination of current and historical satellite imagery in mining areas, this study has found substantial land degradation caused by sand mining operations. This corroborates the findings of previous studies [3, 4, 6], which similarly highlighted the adverse environmental effects of sand mining activities.

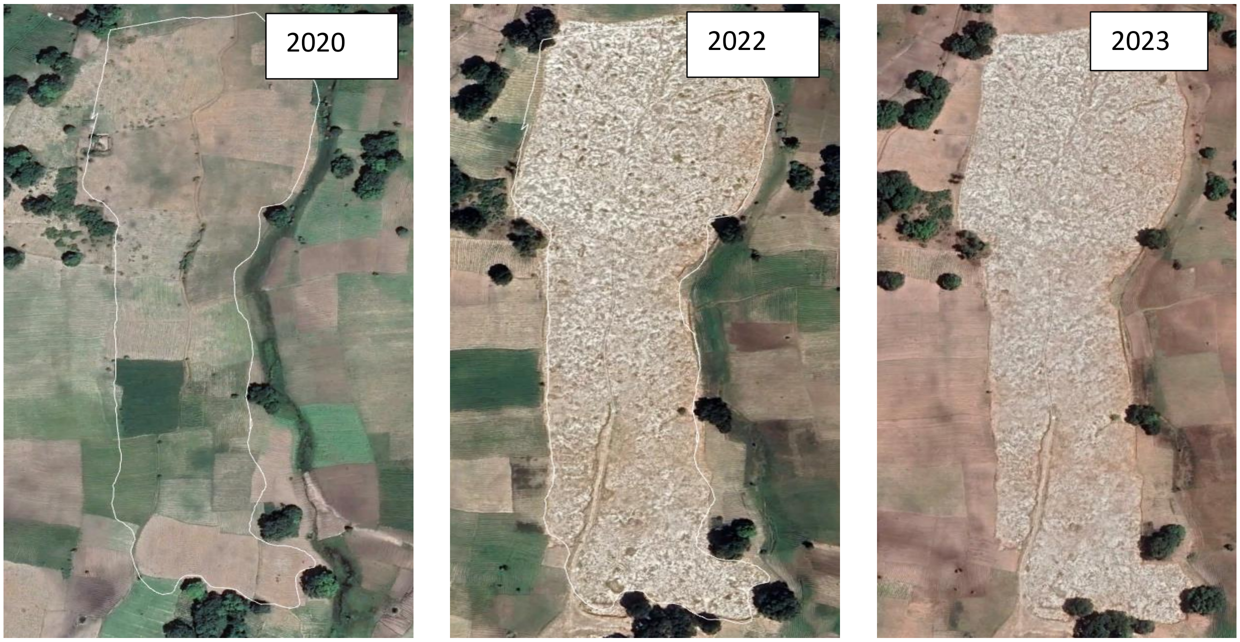

Figure 4a. Satellite Imagery. *(Source: Google Earth, 2023)*

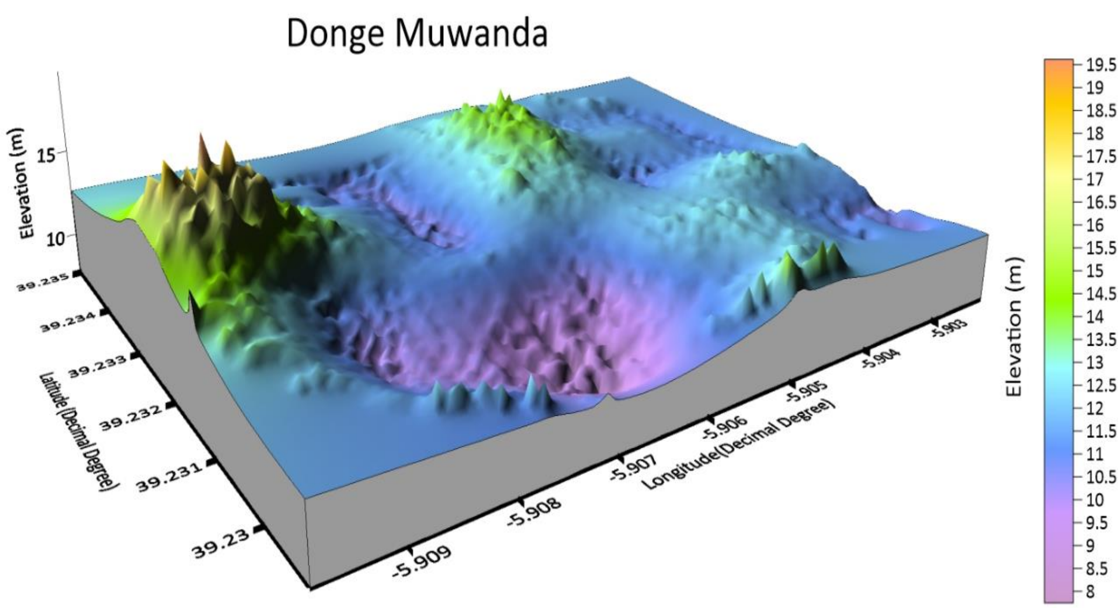

Figure 4b. 3D Image.

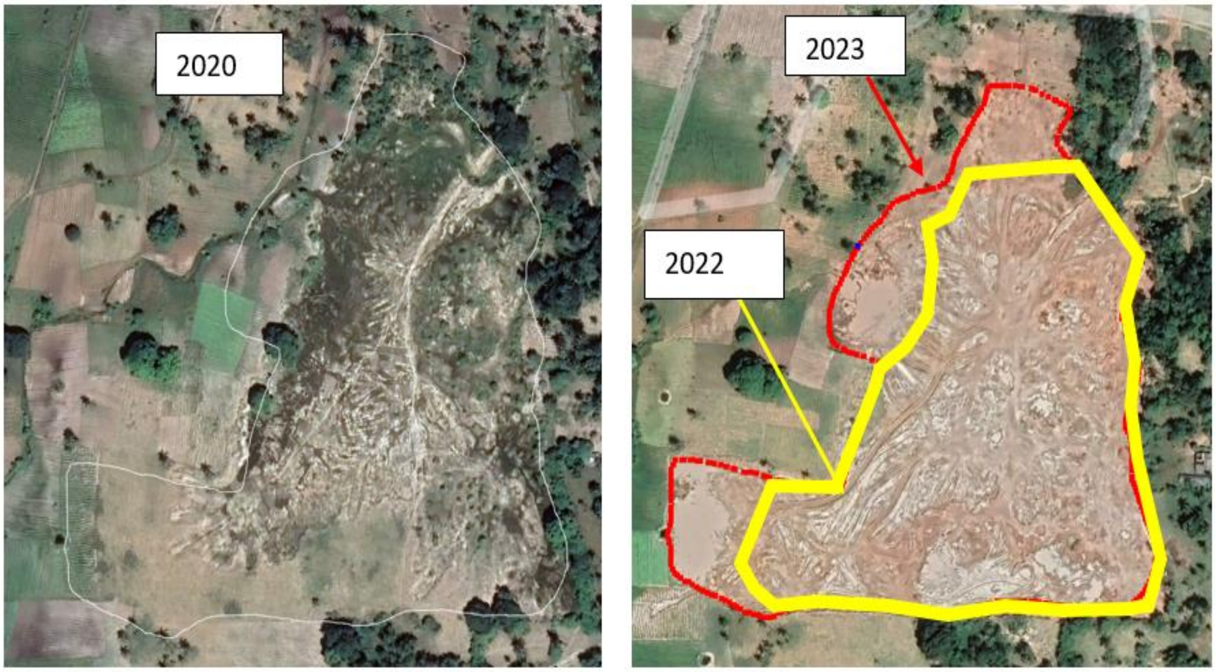

Figure 5a. Satellite Image. *(Source: Google Earth, 2023)*

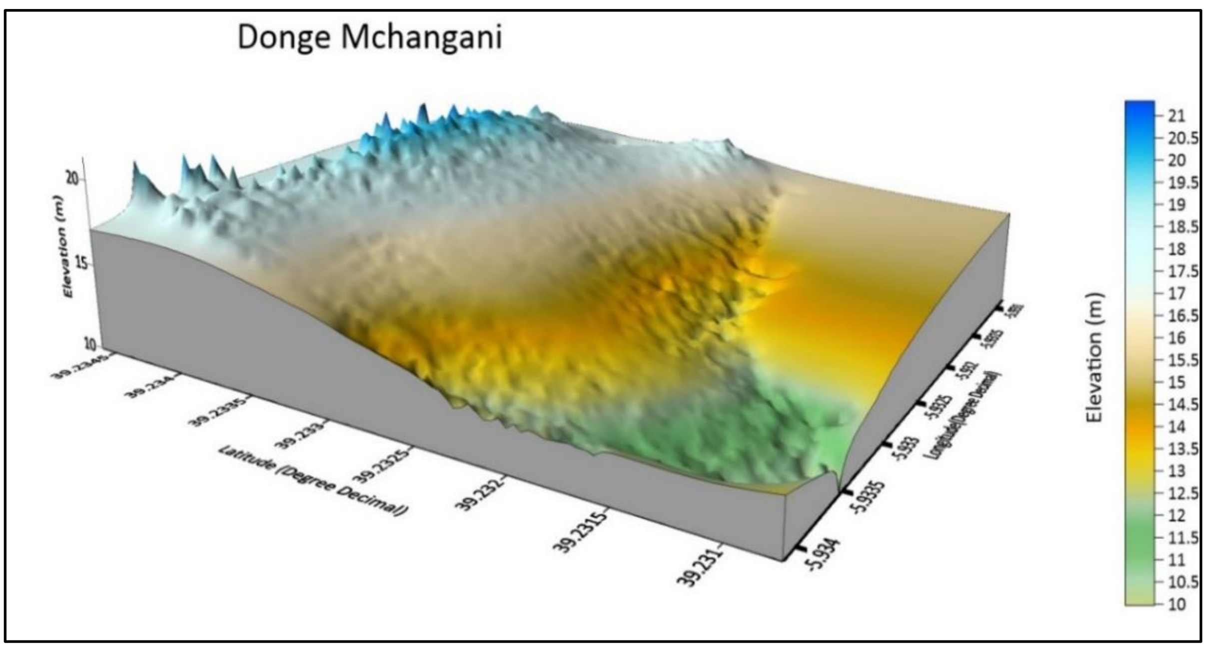

Figure 5b. 3D Image of donge-Mchangani.

Figure 6a. Satellite Image. *(Source: Google Earth, 2023)*

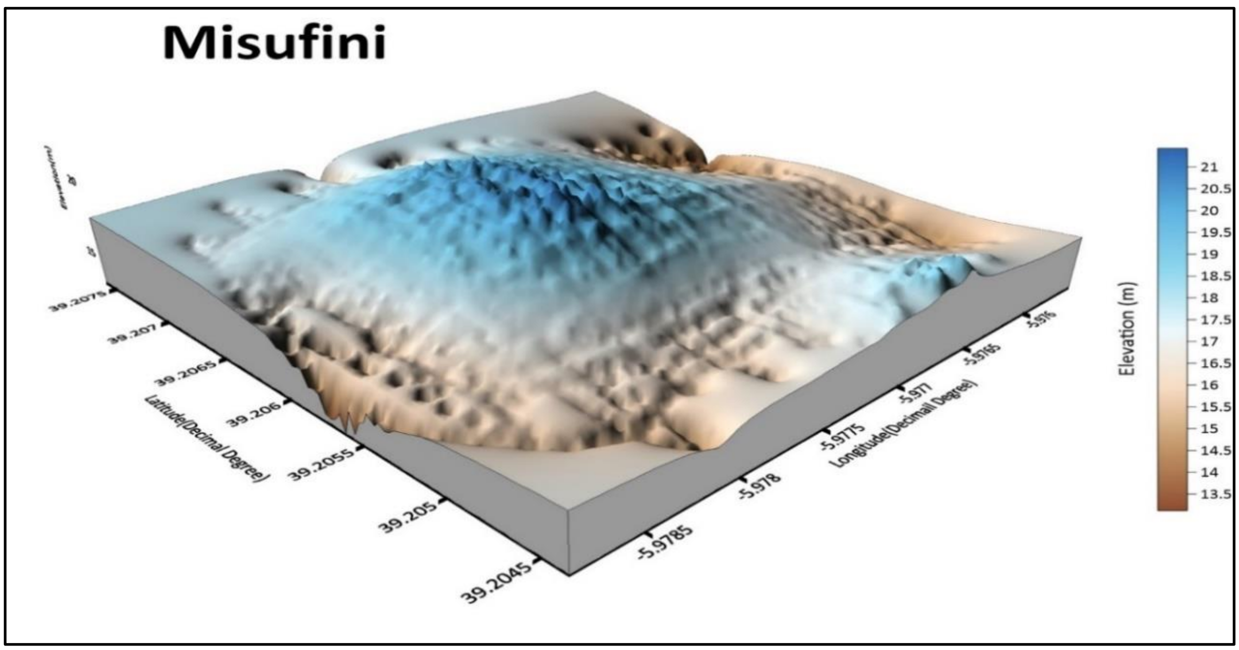

Figure 6b. 3D Image of donge-Misufini.

Oluku and Asikhia [6] employed geospatial technology to analyze the spatial extent of environmental degradation, a methodology closely aligned with the approach undertaken in this study. Despite minor variances in methodology, such as the utilization of DEM data by Oluku and Asikhia [6] versus satellite imagery in this study, both investigations sought to delineate and visualize the extent of land degradation. The methodology proposed in this study has been shown to be useful for detecting forest disturbance, degradation, and environmental damage.

Similarly, Odeyemi and Atejioye [4] analysed the impacts of sand mining by using GIS technology. Their study's findings aligned with the findings of this study, since sand mining is the source of land degradation in mining areas. Land degradation was measured by three parameters including the depth, volume, and areas of the mined pits. However, the methodology adopted in their study was different compared with the one used in this study. Odeyemi and Atejioye [4] used Triangulated Irregular Network (TIN) analysis to find the volume of mined sand. This study used the Field Calculator tool to compute the parameter of depth and area that resulted in the parameter of the volume of sand that has been extracted. Both methods involved the use of ArcGIS software in the analysis.

Furthermore, the findings of the present study were obtained by analyzing the Google Earth Data. These data are very significant for assessing the impacts of sand mining activities, investigating and identifying sand mining areas for sustainable development, and environmental monitoring. Prasad et al. [11] has also used this technology in mapping and analyzing sand mining activities.

Moreover, the present study found that sand mining has caused serious environmental problems, including land degradation, in mining areas. The study by Adedeji et al. [3] show the impacts of sand mining on the environment, which include water quantity, and air pollution, which are also found in this study. Both studies used GIS technology to assess the impacts of sand mining activities.

The findings of this study also revealed that villagers have lost their farmland and vegetation due to massive environmental degradation caused by sand mining activities. This finding looks similar to what was said by previous scholars [9, 16, 17], who mentioned that sand mining has caused the removal of vegetation and destruction of the soil's top layer. They also claimed that sand mining has been alleged to result in the degradation and decline of farmland as well as agricultural productivity.

Furthermore, the findings of this study show that sand mining has resulted a deforestation and damage the ecosystem. This finding also align to the results mentioned by precious scholars [7, 13], who noted that deforestation is primarily caused by sand mining activities in mining areas. Additionally, the findings of this study indicated that deforestation has negative effects on animals, plants and people living near mining areas.

With regard to the findings, this study aimed to provide the following contributions: firstly, to enhance the public's awareness of the current impacts associated with sand mining activities in the North 'B' district of Unguja. Secondly, the study aimed to contribute knowledge on the methods and tools used to assess the impacts of sand mining.

Our study faced methodological limitations due to the use of Google Earth imagery from 2020, 2021, 2022, and 2023. The imagery was used to analyze mining areas and assess the impacts associated with sand mining activities. Another limiting issue was the time-limit for data collection. The researchers required to collect coordinate points from the affected areas. These data were used for ground truthing. However, mining sites are in dangerous bushy areas and very far from towns, thus researchers had to wait to be accompanied by government officials when they were free from their other commitments. This has led the researchers to spend much time in the process of data collection. Additionally, due to time constraints, the study was also limited to use only three Shehias out of thirty-one Shehias, and only one mining site from each *Shehia*.

4. Conclusion and Recommendation

This study investigated the impacts of sand mining activities in Zanzibar by using geospatial technology. The study was conducted in Zanzibar, specifically in the North 'B' district located in the Unguja Islands, which is where the majority of sand mining activities take place.

The study has demonstrated that sand mining activities have negative effects on the environment and local communities living near the mining areas. Based on the results, the study shows that sand mining has caused massive effects, including land degradation, deforestation, loss of vegetation, loss of farmland, and general damage to the ecosystems.

This study suggests that the results should be utilized to underscore the importance of current policies, guidelines, and laws related to sand mining. For example, in August 2022, an Expression of Interest (EOI) was lodged to formulate the Zanzibar Mining Policy, Guidelines, and Laws. This was aimed to promote sustainable management and minimize the overuse of sand resources that can results environmental degradation.

Moreover, the study suggests that the Government of Zanzibar should commence a high-level decision-making session if one does not already exist, with participation from all stakeholders to discuss the issue of sand mining. The objective is to collaboratively address the negative impacts of sand mining activities and formulate prompt solutions. This should be done through the appropriate Ministry and Department of Minerals since the villagers in the North 'B' district are at high risk of losing their life and farmland due to continuing sand mining activities.

Additionally, the study recommends that the Department of mines and Minerals in Zanzibar use public media, including television, radio, newspapers, and social media to provide knowledge of effects of sand mining. This approach aims to raise awareness among community members, especially miners, about the environmental degradation caused by ongoing sand mining activities. The Department should also enforce the miners to invest in and repair the degraded mined areas, to minimize the possibility risk of landslides and accidents. The community members should play a crucial role in minimizing environmental degradation. This can be achieved by adopting various sustainable practices and actively participating in conservation efforts, such as involvement in tree-planting initiatives to enhance green spaces and combat deforestation. Additionally, staying informed about environmental issues and solutions through educational programs and workshops is essential.

This study involved the use of Geospatial Technology to assess sand mining impacts. However, there is a large knowledge gap in assessing more impacts of sand mining activities, which include rise in land surface temperature and loose of vegetation and farms. These impacts also identified by previous researches [3, 4]. There are many reasons besides sand mining that lead to rising in land surface temperature and loss of vegetation and farmland, including urbanization. Therefore, further research is needed to find out the contribution of sand mining activities to the rise of land surface temperature, and the contribution of sand mining activities in the loss of vegetation and farm land. Further research could also be done to determine the significance of sand mining activities to the national economic development of developing nations like Tanzania at large

Additionally, the future perspective of study is to apply a Machine Learning or Artificial Intelligence to monitor and predict the current and the future condition of degraded land, using historical data.

CONTRIBUTIONS OF CO-AUTHORS

Rahma Rashid Amour	Developed the concept, carried out data collection, performed data analysis, and compiled the paper.
Haji Ali Haji	Reviewed the paper and provided technical support on procedures and resources

REFERENCES

[1] Nwobodo TN., Ogbuene BE., Nzeadibe TC., *Effects of sand mining on land use/land cover on river environment in developing countries: a case study of ava river in Enugu state, Nigeria*, Ikenga, **22**(3): p.1–25, 2021.

[2] Rukmana D., Salman D., Alimuddin I., Arsyad. *Economic and environmental impacts of sand mining activities at Sadang river Pinrang Regency, South Sulawesi*, IOP Conf Ser Earth Environ Sci., **575**(1): p. 012043, 2020.

[3] Adedeji OH., Adebayo HO., Sotayo EI., *Assessing environmental impacts of inland sand mining in parts of Ogun State, Nigeria*, Ethiopian Journal of Environmental Studies and Management, **7**(5): p. 478–487, 2014.

[4] Odeyemi C., Atejioye A., *Analysing impact of sand mining in Ekiti State*, World J Res Rev, **6**(2): p. 26–31, 2018;

[5] Mngeni A., Musampa CM., Nakin MDV., The *effects of sand mining on rural communities*, Sustain Dev Plan VIII, **210**: p. 443–453, 2017.

[6] Oluku S., Asikhia MO., *Geospatial assessment of the impacts of sand mining activities in Benin City, Edo State Nigeria*, J Geogr Environ Earth Sci Int., **25**(1): p. 46–57, 2021.

[7] Koehnken L., *Impacts of sand mining on ecosystem structure*, process & biodiversity in rivers, 2018. link: https://d2ouvy59p0dg6k.cloudfront.net/downloads/sand_mining_impacts_on_world_rivers__final_.pdf.

[8] Christina S., Suykens B., *River Sand commodity chains in Tanzania*, 2022. Link: www.gicnetwork.be.

[9] Ladlow C., *An assessment of the impact of sand mining: Unguja, Zanzibar*, ISP Collection, p 1–41, 2015.

[10] Abraham CM., Essien K., Umoh EU., Umoh EC., Ehiremem LE., et al., *Towards effective monitoring of sand mining sites and post management techniques in sand dredged environment of Akwa Ibom State, Nigeria*, Glob J Ecol., **6**(1): p. 092–099, 2021.

[11] Prasad M., Reddy MR., Sunitha V., *Mapping of River Sand Mining Zones Using Remote Sensing and GIS: A Case Study in Parts of Papagni and Pennar River Beds, YSR district Andhra Pradesh*, Asian Academic Research Journal of Multidisciplinary, **3**(7): p. 45–55, 2016.

[12] Prasad, M., Reddy, YS., Balaji, E., Sunitha, V., Ramakrishna, MR., *Application of geospatial technology in evaluating the impact of mining associated urbanization on agricultural lands*, Nat. Environ. Pollut. Technol., **18**(3): p. 1041–1044, 2019.

[13] Ahmad, F., Prasad, RC., Goparaju L., *Geospatial technology perspectives for mining vis-a-vis sustainable forest ecosystems*. Present Environ Sustain Dev., **11**(1): p. 219–238, 2017.

[14] Mohammed Z., *Sand mining management systems and their effects on social and environmental aspects in Unguja, Zanzibar*, Int J Sci Environ Technol., **9**(6): p. 885–888, 2020.

[15] FAO, Evaluation of land resources in Zanzibar: phase 1 & 2, 1990. link: https://www.fao.org/4/as019e/as019e.pdf.

[16] Tidemand, Mukandala, Makaramba, Othman, *Local governance in Zanzibar*, UNDP report, 2003. link: https://www.dege.biz/Zanzibar.pdf.

[17] Jaeger W., *The hidden costs of relocating sand and gravel mines*, Resources policy, **31**(3): p.146–164, 2006.

[18] Pitchaiah S., *Impacts of sand mining on environment-a review*, International Journal of Geoinformatics and Geological Science, 4(1): p. 1–5, 2017.