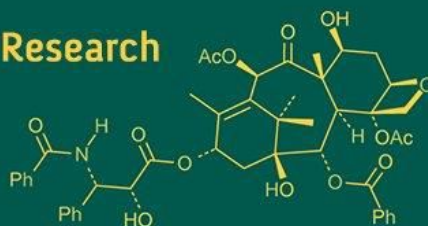


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Innovative volumetric assessment of red ochre mining: AI-driven drone surveys and underwater volume calculations using DGPS and bamboo stick methodology

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Abstract

This research presents an in-depth case study of volumetric assessment conducted on a Red Ochre mining lease located in Jalodiya Kelukheda, Tehsil Choti Sadri, District Pratapgarh, Rajasthan, India. The study's primary objective was to accurately estimate the volume of excavated material using an innovative integration of advanced AI-driven drone technology and Differential Global Positioning System (DGPS) techniques, combined with a unique approach to calculating submerged volumes. To tackle the challenge of measuring the underwater portions of the excavation, the study introduced a bamboo stick rover equipped with a DGPS rover to capture precise underwater depth measurements. This method represents a novel, low-cost solution for calculating submerged volumes in mining operations, ensuring both high accuracy and practicality in challenging conditions.

The study utilized drone technology to capture high-resolution aerial imagery and generate detailed Digital Elevation Models (DEMs), Digital Terrain Models (DTMs), and Digital Surface Models (DSMs), enabling precise volumetric calculations for the dry portions of the mining area. In addition, traditional techniques for underwater volume assessment, enhanced by DGPS-equipped bamboo sticks, allowed for the calculation of submerged excavation areas that would otherwise remain unmeasured by aerial methods alone. The integration of these two methods provided a comprehensive volumetric assessment covering both dry land and water-filled pits.

By bridging the gap between modern AI-based drone technologies and traditional volume measurement techniques, this study establishes a new framework for mining operations where both surface and underwater excavations are prevalent. The results demonstrate the effectiveness of combining cutting-edge aerial survey methods with practical in-field measurements, offering significant improvements in accuracy and efficiency over traditional volume estimation methods. This comprehensive approach not only improves the precision of mining volume estimations but also holds substantial potential for future applications, especially in areas where water-filled pits present a challenge for volumetric assessments. Furthermore, this case study sets a precedent for utilizing low-cost, locally sourced tools in conjunction with advanced technology, paving the way for more sustainable and accessible methodologies in mining volume estimation.

Keywords: Volumetric assessment, red ochre mining, drone technology, differential global positioning system, bamboo stick rover, submerged volume calculation

Introduction

The integration of unmanned aerial vehicles (UAVs), commonly known as drones, into mining operations has significantly transformed how volumetric assessments, topographic surveys, and environmental monitoring are conducted. Traditionally, mining operations relied on manual surveying methods or satellite imagery, which often lacked the precision, efficiency, and adaptability required for complex terrains. However, with the advent of drone technology, particularly those equipped with advanced artificial intelligence (AI) algorithms, mining companies now have access to highly accurate and cost-effective solutions for mapping, monitoring, and assessing large-scale mining areas.

In this case study, we harness the power of AI-driven drones to perform high-precision surface mapping over an extensive Red Ochre mining lease area in Jalodiya Kelukhera, Tehsil Choti Sadri, District Pratapgarh, Rajasthan, India. This approach allows for the rapid generation of detailed Digital Elevation Models (DEMs), Digital Terrain Models (DTMs),

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and Digital Surface Models (DSMs), which form the basis of volumetric calculations. These digital models provide invaluable insights into the current state of the mining site, offering a clear understanding of excavation progress, terrain changes, and resource depletion.

However, this study goes beyond standard surface volumetric calculations by addressing a critical challenge often faced in open-pit mining operations—accurately measuring the volume of excavations that are submerged beneath water. Water accumulation in mining pits is a common issue, particularly in regions where rainfall or groundwater infiltration occurs. Traditional drone-based methods, while highly effective for surface measurements, cannot accurately assess volumes below the water surface. To solve this problem, we introduce an innovative method involving a bamboo stick rover equipped with Differential Global Positioning System (DGPS) technology, designed to measure submerged sections of the excavation. This low-cost yet highly effective tool offers a practical solution for mining operations that face the challenge of calculating underwater volumes.

The primary objective of this paper is to comprehensively evaluate the total excavated volume of the mining site, including both dry land and submerged sections, by integrating traditional volumetric measurement techniques with modern AI-powered drone technology. This dual-method approach provides a more holistic and accurate assessment of mining activities, which is essential for operational planning, environmental monitoring, and regulatory compliance. Furthermore, this methodology offers a replicable framework for other mining sites facing similar challenges, particularly those in regions where water accumulation significantly impacts mining operations and volumetric estimations.

Location of the Area

The mining lease area is located near village - village Jalodiya Kelukheda, tehsil- Choti Sadri, district- Pratapgarh Rajasthan. On survey of India GT sheet 45/L-15. It is approached from Udaipur to Choti Sadri 126 km and from Choti Sadri to Jalodiya Kelukheda 19 km and from Jalodiya Kelukheda to mine site is 2 km.

Latitude and Longitude of Boundary Pillars is as under

FRP- Longitude 74°47'27.32664"E

Latitude 24°22'47.95234"N

Table 1: Showing Latitude and Longitude of the Area

Pillar No.	Longitude	Latitude
A	74° 47'38.8867"E	24°21'22.0040"N
B	74° 47'44.4826"E	24°21'21.4459"N
C	74° 47'44.1729"E	24°21'19.3682"N
D	74° 47'46.2870"E	24°21'18.9384"N
E	74° 47'45.5450"E	24°21'16.3256"N
F	74° 47'43.5375"E	24°21'16.6313"N
G	74° 47'43.6019"E	24°21'17.0856"N
H	74° 47'37.9696"E	24°21'18.5237"N

Methodology

A comprehensive drone-based survey was conducted over a 2.4920-hectare area to perform a high-precision topographical analysis for volumetric assessment of mining excavations. This survey forms part of a larger assessment, totaling 4.769 hectares, encompassing both the mining lease

and adjacent non-lease areas. The survey aimed to evaluate the excavated volume in order to support mining operations, compliance, and environmental monitoring. The data collected, including georeferenced images, models, and associated volumetric analysis files, is attached herewith for further review.

The application of UAVs (Unmanned Aerial Vehicles) equipped with high-resolution cameras and advanced AI-based processing systems for surface mapping offers a distinct advantage over traditional methods due to their ability to capture high-resolution, geo-referenced imagery over large spatial extents. By maintaining a low-altitude flight path, the UAV captured detailed surface data essential for accurate volumetric measurements. Furthermore, the integration of multiple strategically positioned Ground Control Points (GCPs) ensured that the drone achieved centimeter-level positional accuracy, thereby enhancing the reliability of the orthomosaic, DEM (Digital Elevation Model), and DSM (Digital Surface Model) outputs.

This methodology allows for rapid, accurate volumetric calculations when integrated with Differential Global Positioning System (DGPS) technology. The high accuracy of data acquired from both UAV and DGPS instruments facilitates precise volume estimates, a critical factor in excavation monitoring, ensuring both operational efficiency and regulatory compliance.

Methodology Adopted

DGPS Survey

- Geodetic Equipment:** A singular XYZ DGPS system was utilized for precise geodetic positioning of ground control points (GCPs), offering sub-centimeter accuracy.
- Control Points Setup:** Three strategically placed GCPs were established within the mining lease to define the area's spatial boundaries and elevation references. These control points were meticulously placed using rover receivers, with corrections applied via Real-Time Kinematic (RTK) GPS, ensuring optimal accuracy in positioning.
- Pillar Demarcation:** Lease pillars, key reference points for delineating the mining boundary, were precisely surveyed and marked with DGPS coordinates. The GCPs ensured positional accuracy during the integration of UAV data.

UAV Drone Mapping

- Flight Planning and Ground Control Point Setup:** Prior to flight, GCPs were marked at strategic locations, ensuring even distribution across the area for precise georeferencing. GCP coordinates (N, E, and Z) were obtained using DGPS for accurate ground elevation and positioning.
- Drone Flight and Image Capture:** The UAV was deployed to execute pre-programmed flight patterns using an east-west trajectory. By flying at a low altitude, the UAV captured high-resolution aerial imagery across the entire project area. The drone utilized a fixed-camera orientation and consistent overlap (80% front and 60% side) to ensure comprehensive coverage of the survey area.
- Image Upload and Georeferencing:** Post-flight, the captured images were uploaded to specialized Drone Data Processing Software. The North, East, and Zenith

(altitude) coordinates from the GCPs were simultaneously uploaded to the processing platform to facilitate precise georeferencing of the aerial imagery, correcting any positional errors.

- d. **Data Processing and 3D Modeling:** Following image and GCP data upload, the processing software initiated a detailed photogrammetric analysis to generate several outputs, including an orthomosaic image, DSM, and DTM. The processing duration was approximately 24 hours, given the high-resolution data input and GCP alignment.
- e. **Output Generation:** Upon completion, several critical outputs were produced: an orthomosaic image with a Ground Sample Distance (GSD) of 2.29 cm/px, a DSM with a GSD of 9.15 cm/px, a DTM, and a Digital Elevation Model in contour file format (.DXF). These models and images provide the foundational data required for accurate volumetric calculations.

Table 2: Data processing of Drone Survey

Project Name	Ochre Mining Lease
Total Area Processed	4.769 Hectare(s) (Including Mining Lease area)
GSD – Orthomosaic	2.29 cm/px
GSD-DSM/DTM	9.15 cm/px
Total Photos	101
Camera Model	Hero 10 Black
Photos Resolution	5568 X 4176 Px
Position Reference	GPS/ GCP



Fig 1: Orthomosaic image obtained from drone processing, displaying the excavated portion of the mining lease and the water-filled areas.

The estimation of Volume was conducted by leveraging data obtained through a comprehensive drone survey in the field. Subsequently, the software was employed, integrating both field and processing data, for the meticulous estimation of Excavated volume.

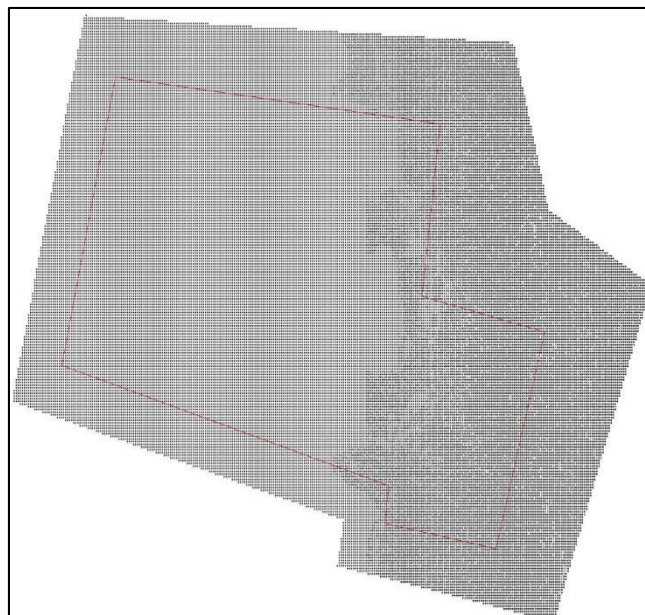


Fig 2: Point Cloud plan for volumetric calculation Drone processing software

Volumetric Calculations generated by Drone Survey up to water logged surface area

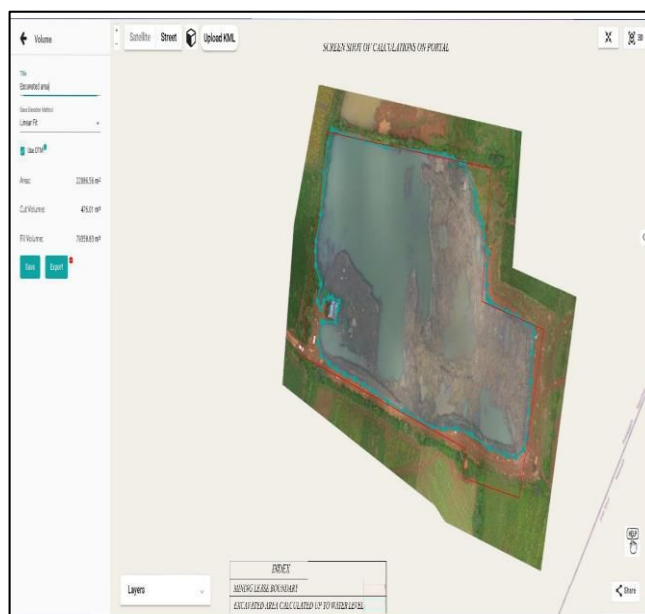


Fig 3: Calculations generated by Drone up to water logged Surface area = 79358.83 in cubic meters

Volumetric Calculations Calculated under the water level

The depth from the water surface to the bottom was measured using a 10-meter-long bamboo stick, which had markings at 1-meter intervals. This method ensured accurate measurement of the water level and depth.

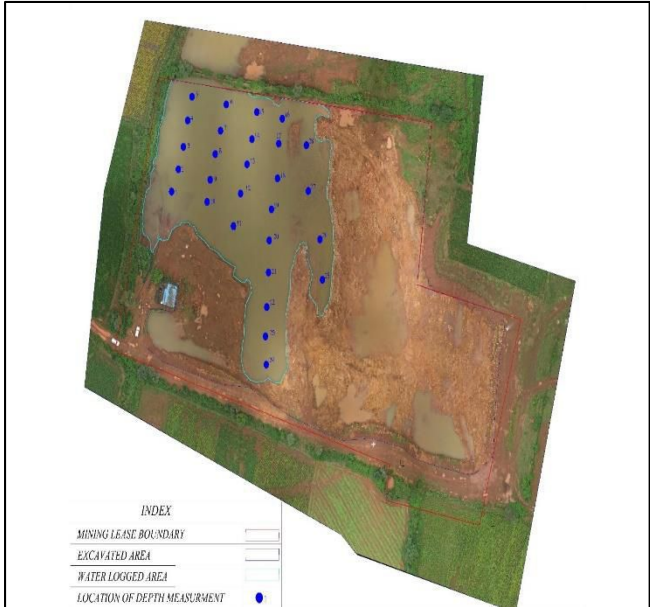


Fig 4: Points where the depth of water is calculated and coordinates are marked through DGPS

Table 3: Showing DGPS Location of Bamboo Stick, DGPS mounted

Volume Calculations and Water Level Depth Coordinates			
Point No	Northing	Easting	Depth (In Meters)
1	2693625.1	479119.445	3
2	2693633.785	479123.314	4
3	2693642.561	479126.237	4
4	2693652.847	479128.737	6
5	2693662.122	479131.233	6
6	2693659.076	479147.728	7
7	2693648.832	479147.728	8
8	2693639.696	479144.678	9
9	2693629.716	479141.748	9
10	2693621.095	479139.963	7
11	2693611.45	479455.186	9
12	2693624.327	479159.325	7
13	2693635.735	479163.038	8
14	2693645.573	479165.893	7
15	2693656.124	479168.749	4
16	2693653.532	479183.473	9
17	2693643.852	479181.415	3
18	2693630.249	479180.691	4
19	2693618.188	479177.217	6
20	2693606.033	479175.913	5
21	2693593.521	479175.469	3
22	2693580.021	479474.454	2
23	2693568.589	479173.73	2
24	2693557.6	479174.175	2
25	2693590.674	479206.667	1
26	2693606.43	479205.216	1
27	2693625.324	479198.505	1
28	2693643.205	479197.387	1
Total			138m
Average Depth Calculations			
Total depth divided with total number of points		138/28	4.93m
Total Water filled surface Area			7622m ²
Total Volume considering average depth and total water filled surface area		7622 X 4.93	37576.46m ³

Conclusion

This study represents a unique integration of traditional and advanced technological approaches in the field of volumetric assessment for mining operations. By combining drone-based surface mapping with a bamboo stick rover and DGPS for measuring underwater volumes, the study has achieved a level of precision rarely seen in such assessments. The survey not only provided accurate measurements of the excavated areas but also accounted for submerged sections, offering a more comprehensive analysis of the mining activities in the Jalodiya Kelukhera lease area.

The results from this innovative methodology are noteworthy:

- 1. Volume generated by the drone survey up to the water level: 79,358.83 cubic meters
- 2. Volume calculated from the water level to the bottom: 37,576.46 cubic meters
- 3. Total excavation volume: 116,924.4 cubic meters

This hybrid approach sets a precedent in mining volumetric studies, particularly in the accurate assessment of submerged volumes, which are often overlooked in traditional surveys. The integration of bamboo stick depth measurements with drone data processing and DGPS technology allowed for an exceptional level of detail, ensuring reliable results that are crucial for operational planning, regulatory compliance, and environmental monitoring.

The combination of these methods makes this case study one of its kind, providing a valuable framework for future volumetric assessments, especially in regions where mining operations involve water accumulation. It demonstrates that the integration of traditional techniques with cutting-edge technologies can significantly improve the accuracy of mining volume calculations, offering broader implications for the industry and environmental impact analysis in similar settings.

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