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Land Surface Topographic Change Detection Using Remote Sensing Techniques

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This study examines the use of remote sensing technology in the detection of changes on land surface topography which is usually caused by human activities such as mining, building, road constructions, farming, borrow pits and others. The study area is Pampi village in Chanchaga Local Government Area (LGA) of Minna, Niger State where gold mining is taking place. The study was carried out within a minimum of three and maximum interval of five years with effect from year 2000 to 2018. Satellite DEM of the different epochs considered were downloaded and sample data were acquired with DGPS from the study area. These coordinates were converted to shape file in ArcGIS 10.2 and used to extract the elevation from each of the DEM, comparison between the extracted elevations was made and an error matrix was generated. Annual percentage change in elevation was computed. The results showed that the topography of the study area has reduced in elevation by 13.55% as at June 2018 from what it used to be in the year 2000. The research work also predicted the situation in the topography for the next five years using excel forecast function and found out that the annual percentage change in elevation will be approximately 20% by June 2023. The extent and future consequences of mining activity is the ultimate issue this study had addressed and because it has exposed certain parts of the area to erosion and flooding, it is recommended that mining activity should be discouraged and the land reclaimed by the appropriate authority.

Keywords: Remote sensing, DEM, DGPS, Mining, Topography.

Introduction

Land surface topography changes every day, sometimes these changes or transformations are very small and they are extraordinary to the detriment of man. Most of these changes are brought about by natural forces and others are man-made. Change detection is a process of detecting differences with objects or phenomena which are observed at different time intervals (Jovanovic *et al*., 2015). Human efforts are sometimes employed to detect these changes using technological means, but this is limited when detail analysis is involved (Agone & Bhamare, 2011). Periodic and precise change detection of earth's surface features is extremely important for understanding relationships and interactions between human and natural phenomena in order to facilitate better decision making. Remote sensing data are primary sources extensively used for change detection in decades (Singh, 2007). In studying change detection, both traditional method and remote sensing technology can be adopted. Traditional methods which include field surveys, map interpretation, collateral and ancillary data analysis are not effective for proper change detection studies because these methods are time consuming, date-lagged, and often far less economical in large projects (Jwan *et al*., 2013).

Many change detection techniques have been developed over the years for the analysis of changes and to determine a very suitable method (Ako *et al*., 2014). Jovanovic *et al.* (2015) applied multi-temporal Remote Sensing information to analyse the historical effects of an occurrence quantitatively and thus helps in determining the changes associated with land cover and land use properties with

reference to the multi-temporal data sets. Due to anthropogenic activities, the earth's surface has been significantly altered and has resulted to an observable pattern in the land surface topography over time (Ali *et al*. 2010). In situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from earth sensing satellites has become vital in mapp
infrastructures, managing natural resources and studying environmental changes (Ako *et al*., 2014).

Remote Sensing is the only available technology that provides continuous acquisition and recording of these constant changes of the earth surface features (Musa & Jiya 2011). The satellite development improves the possibility of collecting remotely sensed data and it offers a good way for obtaining the information over a wide-open area (Nazan, 2015; Halit, 2011). Honda (2014) stated that the direct survey still provides the basic control points and framework for all topographic works, though remote sensing has greatly sped up the process of gathering information over a large scale. Changes are detected by the remote sensor and this enable the interpreter to extract useful information about the target. Also it provides classification of landscape with identified areas susceptible to erosion and can also be used to map stream and river courses (Musa & Jiya, 2011). Remote sensing in conjunction with Geographic Information System (GIS) allows for revision and update of maps at a small to medium scale. When it comes to data collection in a hostile area, disputed and inaccessible area, rugged terrain, water lodged or marshy terrain etc, remote sensing does it better than any other technology (Liilleskov *et al.*, 2015).

The topography of an area refers to the surface shapes and features themselves, or a description (especially their depiction in maps) (Honda, 2014). Garai and Narayana (2018) sees topography as the configuration of the earth's surface, including its relief and the positions of its natural and man-made features. The gold mining activity in the study area which has been active for several decades is a major contributing factor to the changing landscape too. This has left the land surface inhabitable for residential buildings, agricultural activities and recreation. As a result, this calls for a research to unveil the actual situation using satellite remote sensing technique.

Study area

Pampi village is located along the Eastern bypass in Chanchaga LGA of Minna, Niger State. It lies between latitude 9∘ 34’ 35’’ and 9∘ 24’ 33’ and longitude 6∘ 38’ 33’ and 6∘ 24’ 54’. The open cast mining of gold deposit in the study area covers an area of 17.2225 hectares (Musa & Jiya, 2011).

Digital Elevation Model (DEM)

DEM as defined by United State Geological Surveys (USGS) is a digital file consisting of terrain elevations for ground positions at regularly spaced horizontal intervals (Jain, 2008). Land surface is commonly modelled either using vector (triangulated irregular network or TIN) or gridded (Raster image) mathematical models (Patrick, 2002). DEMs may be derived from existing paper maps and survey data, or they may be generated from new satellite or other remotely sensed radar or sonar data (Sumit, 2018). A reliable and accurate DEM brings the possibility of extracting a number of land-surface parameters, which are useful to accurately delineate and quantify landslides and other similar features using geomorphometrics criteria (Bhatt *et al*., 2009). DEMs data have gained so much relevance in research/applications where quality topographic data are needed for the analysis of terrain. Having sufficient ground control points (GCPs), we can have DEM of absolute horizontal and vertical accuracy of 7m and 10m. But this same principle is applicable when other satellite imagery (DEM source) is used (Wolfdersdorfer, 2018). Several remote sensing technologies such as LiDAR, ASTER, SRTM exist

(Liilleskov *et al.,* 2015) which calculates land elevation data.

Open Cast Mining

Wolfdersdorfer (2018) defined open pit/cast mine as "an excavation or cut made at the surface of the ground for the purpose of extracting ore and which is open to the surface for the duration of the mine's life". Nazan (2015) noted that one of the human footprints that cause drastic changes on the environment is mining despite its significant contribution to the economy and a notable influence on the life of the community. Signh (200**7)** also provides the chance to mine selectively to meet requirements for certain grades of ore and complete extraction of the ore inside the pit limits. Also, Nazan, (2015) stated that large open-pit operations involve heavy capital outlay for equipment, and where the amount of overburden to be removed is extensive, correspondingly high capital expenditure is required for stripping. During mining activities huge amount of waste materials are excavated and removed from one place to other places causing big holes on the land surface (Pratik *et al*., 2002). Musa and Jiya, (2011) is particular about the fast depreciation of the ecosystem due to man activities. Garai and Narayana (2018) discovered that mining activities result in topographic change and principal environmental impact come out as a physical disturbance such as landscape change and degradation. Hence, it is imperative to examine the effects of mining on land surface in order to minimize its impact on the environment as well as to proffer solutions to land management in order to improve decision making. To achieve this objective, remote sensing data and GIS Technology are useful tools to observe and analyse the periodical change of the topography in the study area. Opencast mining operations in the study area remain one of the main contributing factors to short- and long-term environmental damage, as it has a direct and cumulative impact on the ecosystem.

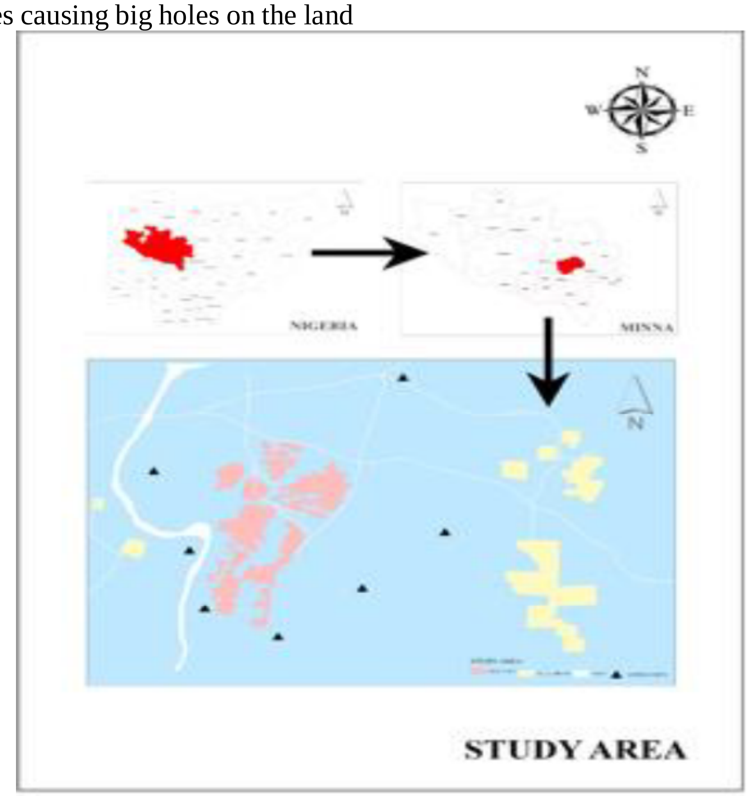

Figure 1: The study area

Materials and Methods

Data Acquisition

In this study, supervised methods of analysing satellite images is presented, with the aim to identify changes in land surface over specific time frame using the procedures adopted by Sumitha and Suresh (2015).

Data and Source

Two main source of data acquisition was adopted in this research these include:

1. Field survey using Differential Global Positioning System (DGPS)
2. Satellite imagery downloaded from USGS site (United State Geological Surveys), SRTM (Shuttle Radar Topographic Mission) website and LPDAAC (Land Processes Distribution Active Archive Centre).

The field survey procedures

Control extension was carried out from the Nigerian National Datum popularly known as L40 located in Minna, to FUT/SVG184 and FUT/SVG185 along the city gate – Bosso Road. After field observation, the DGPS data were downloaded onto the computer system. The high-target geomatics office (HGO) processing software was used to process the acquired data.

Satellite Data Acquisition

The UC web browser was accessed through http//:earthexplorer.usgs.gov. Coordinate of the required area was used to download the satellite imagery. This same procedure was repeated to download all the images used for the study.

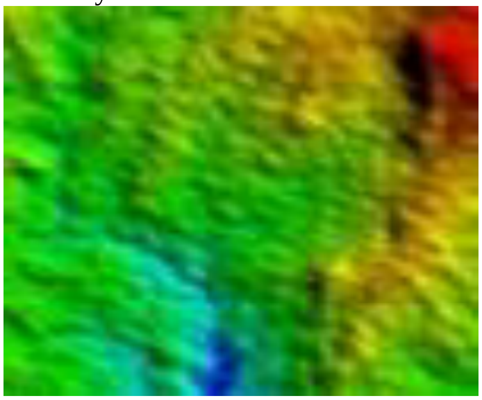

Figure 2.1 SRTM 3arsec with 90m resolution 2000

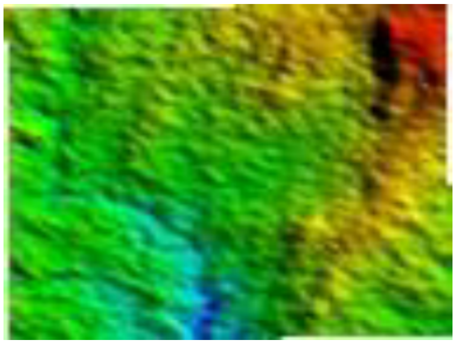

Figure 2.2: SRTM 1arcsec with 30m resolution 2005

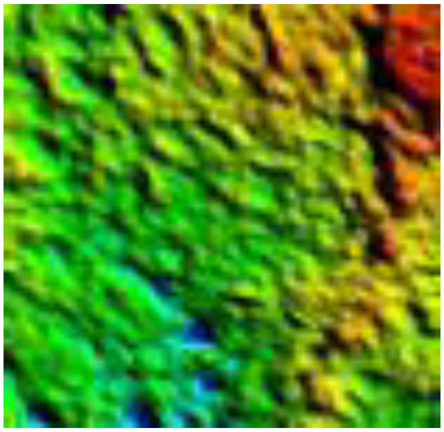

Figure 2.3: SRTM 1arcs with 30m resolution 2010

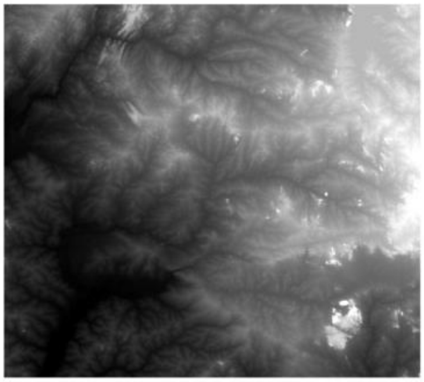

Figure 2.4: ASTERDEM 1arcsec with 30m resolution 2015

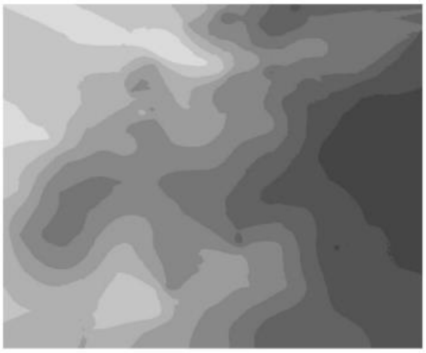

Figure 2.5: Field generated DEM with 30m resolution 2018

Change Detection Process.

A simple arithmetic algorithm was written in Microsoft Excel to detect changes that have taken place over the years since mining activities started in the study area.
The change detected was calculated as:

$$obs\ change = DEM_1 - DEM_0 \_\_\_\_\_\_\_\_\_\_ eqn\ (1)$$

Where:
Obs change = change detected per sample point
DEM_1= elevation for the first year
DEM_0= base map elevation
The result of this was used to generate error matrix in Table 4.1

The comparison of the elevation values of the sample size helped in identifying the percentage change, change rate and trend of change over the years selected, in achieving this, the first task was to tabulate the elevation values in Excel file due to multiple points involved and then calculate the percentage of change or trend per sample point as follow:

$$\%\ change = \frac{obs\ change}{base\ map\ height} \times 100 \quad - eqn\ (2)$$

Percentage Annual change caused by excavating activity is thus calculated using the following formula

$$\%A.C = \frac{\sum(obs\ change)}{100} \times total\ no\ of\ years\ considered(N) - -eqn(3)$$

Where %AC= Annual change percentage, N= 18 years
$\sum(obs\ change)$ = total sum of the change per sampled point.

The result from above calculation was used to depict the rate of change in percentage against each year.

Results and Discussion

This chapter presents the result and analysis of the findings. The results of the findings are presented in statistical tables, charts and maps.

Error Matrix

This is the change that occur between the two phenomena being compared, (i.e. their difference in elevations) as caused by mining operation. From equation (1) the matrix table below was generated for some of the selected points.

Table 2: Difference in elevation or error matrix

SAMPLED POINTS	2005	2010	2015	2018
1	-4.535	-9.554	-8.623	-8.444
2	-3.386	-2.625	-1.145	-6.857
3	-5.351	-6.489	-5.640	-7.252
4	-3.353	-3.157	-4.662	-6.052
5	-2.710	-1.848	-2.949	-4.504

From the table above, it is obvious that each year being considered, there was always an excavation activity and movement of earth material from one particular point to the other since the year the mineral ore was discovered in the area. The usefulness of this error matrix is that it can be used to determine the volume of earth material that has been excavated and the required volume for reclamation or filling of the dug pits.

Variation in Heights

Ten points were selected from the sampled data from which the graph of variation in height was plotted in Microsoft Excel.

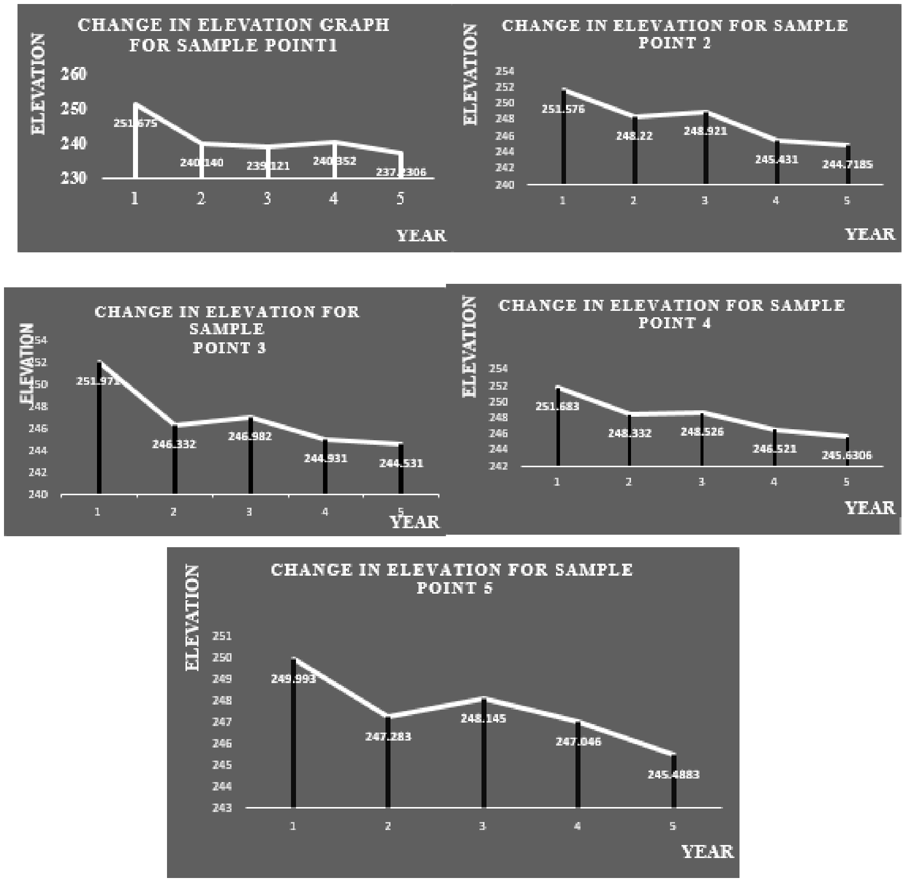

Figure 3: Selected points showing change in elevation

From the above graphs and for every given sample point for all the years considered, it is clearly seen that excavation is being carried out and the ground surface is decreasing except for year 2010 that there was no serious excavation. Also the graph shows that it is obvious there was serious disturbance on the ground surface for year 2005 and 2018.

Annual Percentage Excavation

According to the bar chart in year 2000 there appeared to be no excavation going on in the study area. But in 2005, excavation of this surface has taken a new dimension from 100% to 86.450%. These trend of change continued for year 2010 and 2015 with excavation percentage of 87.645% and 87.606% respectively. Currently as of June 2018 the earth surface material within the study area has been reduced by 86.064%.

Contour Plot

For the present situation as depicted in the contour plot above the area depicted in blue represent low land where farming activities or any form of construction cannot longer take place. This area is also more prone to erosion or flooding. The area depicted in yellow and red colour are considered relatively fit for agricultural activity currently.

Forecast

The forecast function module in Microsoft Excel 2016 was used for forecasting based on the previous data. The extracted height for the various years were copied into this sheet and the time interval was set to be June 30 2023 (next five years). The forecast result shows that the annual percentage change will be 80% and the forecasted elevation for each sampled point was used to plot Figure 5. Looking at the contour plot below the low land which is shaded in blue has increased and the area in yellow and red has decreased drastically, this implies that farm lands will be worst hit if this trend continues. In the past 18years the topography of this area has been altered as a result of this mining activity. Then a forecast made for the next five years using Excel 2016 forecast sheet which revealed that if the excavation activity continues for the next five years, this area will turn to a U-shaped valley having a very steep slope in its surrounding. And effect of this U-SHAPED valley are stated in Ako *et al*. (2014). They are: erosion, low soil fertility in the area that surrounds the valley, effect on ground water table and constructions such as building and other structures will be somewhat difficult due to high cost of reclamation and compaction of the soil.

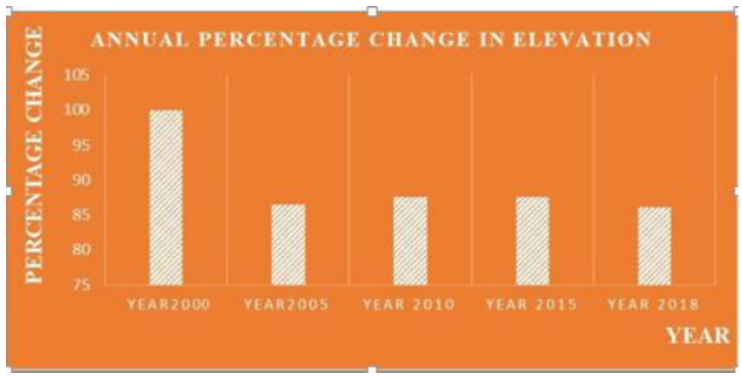

Figure 4: Annual percentage change in elevation

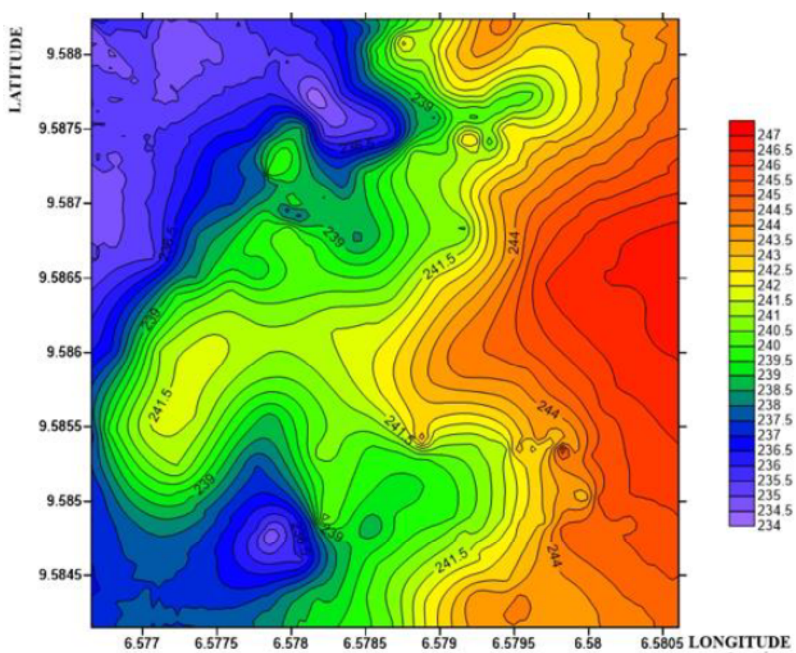

Figure 5: 2018 contour plot of the study area

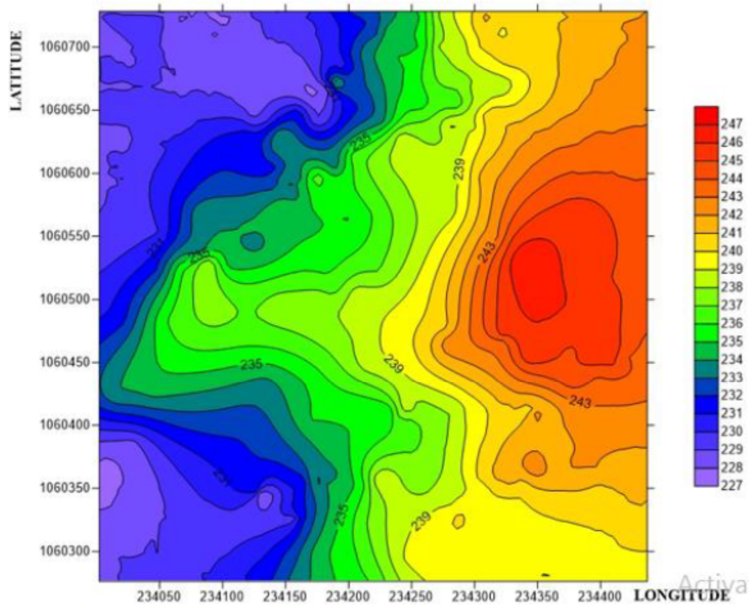

Figure 6: Contour plot of 2023 forecasted elevation

Conclusion

It was discovered that the elevation has decreased by 13.976% in year 2018 from what it used to be in year 2000. There is now relatively steep slope in the surrounding of the excavation site. Some parts of the area has been rendered useless for any useful activity. Thereby making it liable to flooding. The study presented the role remote sensing and GIS technologies play in change detection and monitoring of the ecosystem. Exponential trend function was also used to determine the rate of change. Since this takes into account every irregularity presents in the data. Based on the findings of the study, it is recommended that the excavation activity should stopped with immediate effect and this particular area should be reclaimed by the appropriate authority.

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