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Preliminary assessment of groundwater in crystalline basement in Mozambique through integration of remotely sensed data

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1. Introduction

One of the major geological challenges in the Precambrian basements of Mozambique is the development of water supply for the growing communities. Generally, the groundwater occurrence in crystalline rocks is limited within shallow weathered zones of limited extent typically with low yields. Their productivity is mainly dependent on the thickness of the weathered bedrock.

Fracture zones are lines of weakness and are foci for weathering, they may induce formation of vegetation of the same type and produce various soil types by strong weathering processes (Wang et al., 2013), as the presence and passage of water through fractures favors the lateral and vertical expansion of weathering.

Based on that background, this study aims to develop an integration technique from remotely sensed data and geophysics for regional groundwater exploration in areas over crystalline basement in Mozambique. The study area covers the entire districts of Angonia and Tsangano located NE of Tete province in Mozambique. Accordingly, the technique will contribute to accessing areas with highly fractured and deeply weathered overburdens.

2. Methods

2.1 Remotely Sensed Data Processing

The use of remote sensing images for groundwater investigation has the advantage of providing a spatially distributed measurements on a temporal basis over a large areas and sometimes inaccessible for ground survey or where the coverage of detailed geological maps and field data is insufficient. From remotely sensed images, physical features of the landscape such as lineaments provide valuable information for groundwater investigations (Sikakwe et al., 2015; Shaban et al., 2006).

To track the vegetation changes during different seasons, four scenes of Landsat-8 operational land imager (OLI) data sets (rows 70 and 71/path 168 of L1T) acquired on 27 April and 18 September 2015 were used. The processing of the images was performed using ENVI software. First, the digital numbers were converted into radiance data, and then atmospheric and radiometric corrections of the original images were considered using the fast line-of-sight atmospheric analysis of hypercubes (FLAASH), which transforms the radiance of each pixel into reflectance value. The parameter model in the FLAASH module was based on a tropical atmosphere and rural aerosol conditions with 2-band (K-T) aerosol retrieval. Next, the topographic normalization to correct the brightness distortions due to the irregular shape of terrain was performed using the C Correction method (Teillet et al., 1982).

Available water borehole data, supplied by the local Directorate of Water and Sanitation, comprising depth and flow rate were used as ground-truth data after digitalization and conversion of coordinate system.

2.2 Lineament Extraction

Extraction of lineaments were performed using the automatic and non-filtering approach, Segment Tracing Algorithm (STA) (Koike et al. 1995). The technique has been widely used for auto-detection of lineaments combined with the estimation of fracture planes (Koike et al., 1998; Wang et al., 2013; Masoud and Koike, 2011a) for geology, hydrogeology and geo-environmental studies. Masoud and Koike (2011a) refined the method of shading the gridded data to maximize the detection of maximum shading intensity with a technique called adaptive-tilt multi-direction shading (ATMDS). Connection of extracted segments to form long lineaments is performed by applying the B-spline. For more detailed explanation of the algorithm and estimation of fracture planes, please refer to Masoud and Koike (2011a and 2011b). Flowchart of the overall methodology applied in this study is presented in Fig. 1.

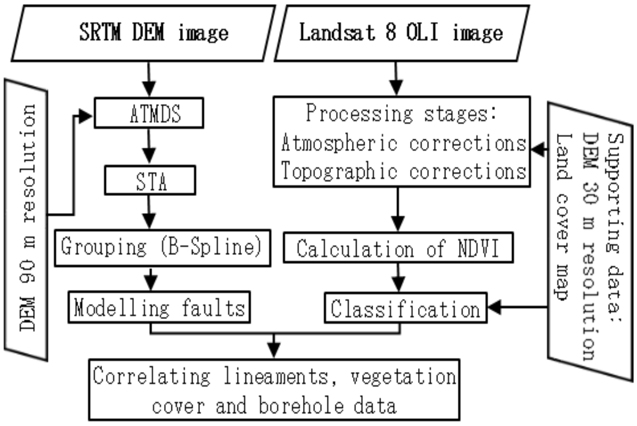

Fig. 1. Flowchart showing the overall methodology.

3. Results and Discussion

The derived lineaments indicate that the study area seats in highly faulted zone, with lineaments forming three main predominant trends along NW, NNE and NE (Fig. 2). Modelled faults are greater in number compared to those inferred from geological map scale 1: 250,000. The fault system is dominated by strike-slip (mixed) faults, over 58%, followed by reverse and last by normal faults. These trends have been formed by different tectonic cycles in the study area. The river regime, flowing along NE-SW, NW-SE is also controlled by the fault system. Although some borehole setting was done with no preliminary geophysical studies, they indicated proximity to faults or geological contacts. Deeper boreholes with low flow rate are likely to occur far from the fault zone. Conversely, shallow boreholes located along the faults indicate moderate to high flow rate. However, it can be seen that some boreholes located along the faults have low yield. These could be related to lack of interconnectivity of the lineaments and therefore, shallow weathered bedrock.

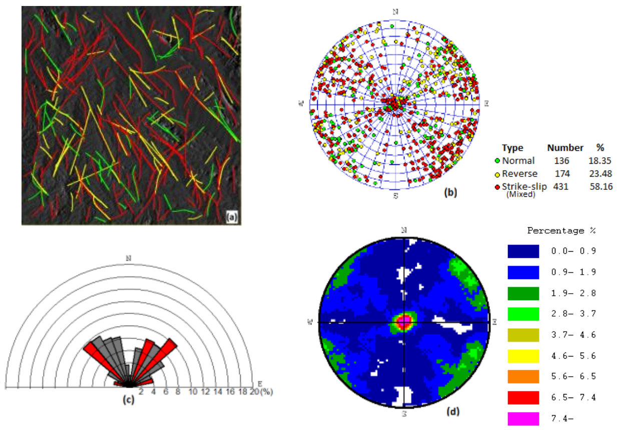

Fig. 2. (a) Shaded relief map overlaid by modeled faults, (b) fault type frequency, (c) rose diagram showing strike of the lineaments and (d) Schmidt net.

By integration of lineaments, vegetation covers and analysis of physical properties we can extract potential groundwater zones. For NDVI classification, a threshold of 2.5 was used to charge if the pixel value represents vegetation or other land cover, without taking into account different types of vegetation. Although different soil types influence the reflectance values, this effect was not considered. Health vegetation is more likely to occur along lineament zones (Fig. 3), which suggests shallow presence of groundwater.

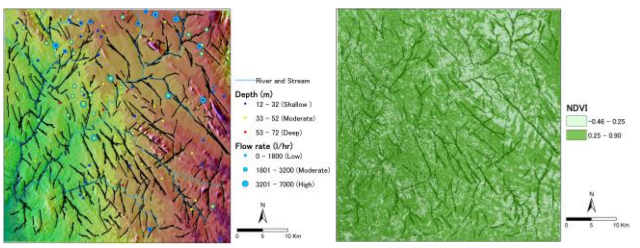

Fig. 3. Grouped lineaments overlaid by water borehole data (*left*) and by NDVI (*right*).

4. Concluding remarks

STA was confirmed in this study to be able to extract more segments that are candidates to form long lineaments. Most of the modeled faults from the STA are not present in the current geological map of the country. The depth and flow rate of the water boreholes is more likely to correlate with extracted lineaments from STA. Accordingly, health vegetation inferred from NDVI occurs along the lineaments and fault zones. Therefore, we conclude that, the lineaments might be controlling the presence of groundwater in this hard environment of crystalline rocks. However, more research is still required to infer the groundwater potential in this areas. Areas with stable vegetation between the two seasons and greater concentration of lineaments are selected for future geophysical survey in situ to confirm the potential using the time domain electromagnetic method.

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