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GIS Articulates Well with Geothermal Energy Goals

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ABSTRACT

Facilitating an expansive renewable energy production and their development such as geothermal system (GS) resource, utilization of GIS is vital. A detailed geological mapping forms a base. This could also include the gravity, resistivity, InSAR, remote sensing, digital field mapping of geothermal features, soil and gas surveys. This information can help in identifying the suitable rocks, rock structures, and understanding of the systems 3D configuration and changes over time.

Integration of these studies (Geophysical, Geological, Geochemical, GIS and Remote sensing) helps in development of techniques for better detection of the concealed geothermal resource and structures.

Analysis of diverse geodata in GIS context results in potential exploration targets for both conventional and EGS geothermal system. Evidence provides clues about the location of the resource. These include location and orientation of fault lines, crustal strain rates from GPS stations, heat flux anomalies, anomalous ground water chemistry, gravity and other geophysics and hydrothermal alteration.

Determination of spatial distribution of known geothermal resource using evidence layers, a spatial relationship analysis was conducted in the respective area of study. This was conducted using ArcGIS to determine the dominant spatial association of production wells to the data in the GIS model layer indicators.

1. INTRODUCTION

In the developed world, interests in renewable energy are ongoing towards replacing the traditional fossil fuel. The developing countries like Kenya are streamlining its interest towards the renewable energy goals especially in geothermal development.

More significant amount strides are being made to expand the geothermal type of generation. The motives for development of renewable energy in the world vary from country to country, Kenya not being exceptional. However, the recurring theme is in the reduction of the greenhouse gas emissions which is a smaller carbon footprint. All nations have an agreement to tread more lightly. The GIS technology enables the path to geothermal energy development to become clearer.

2. HOW IS GIS VITAL IN GEOTHERMAL DEVELOPMENT?

Identification of areas which are technically suitable for geothermal development encompasses the collection of existing information like historical geological, geochemical, geophyisical, terrain and slope information. Geospatial and non-geospatial data have to be analyzed for currency (lineage), accuracy and completeness. In addition, more data collection may be required to infill the existing information. These data form a base for generation, thus become base data.

With the availability of base data, development requirements are singled out, modeled and applied against the base data. Geothermal generation demands availability of geophysics data (seismic, resistivity and gravity), geochemistry and geology data; to identify suitable area for geothermal development. With the application of technical models against the base data, sites that are technically suitable are classified.

As with analysis for technical suitability of an area, a similar analysis is conducted using data that identifies lands of limited or highly undesirable usability. Typically these are lands of cultural importance, national parks or serene areas of scenic beauty. The area could be a protected animal habitat or migration zone. The result of this analysis indicates geographic areas that represent few or no barriers to geothermal generation development.

Datasets from the first two types of analysis can be merged to depict suitable sites where generation facilities could be constructed. This is with confidence that the site is technically appropriate and where there is no social objection to their presence.

Proximity to a transmission grid to deliver power into the grid should be considered as the last step. It would be unusual to find that no transmission lines are required; the goal is to find sites that minimize the construction of this requirement.

GIS technology is appropriate in geothermal energy development. The following example about geothermal, describes how GIS technology has been utilized in its development and highlight of the methods and successes used. The aims are to determine the relationships between geothermal wells and geological, geochemical, and thermal data layers within the GIS. These relationships are also used to identify promising areas for geothermal development.

3. UTILIZATION OF GIS IN GEOTHERMAL DEVELOPMENT

Geothermal exploration involves combination of the results of exploration methods such as geological, geochemical, and geophysical surveys to locate prospective areas for geothermal development. The basic function of exploration is to identify the location and extent of areas that warrant further detailed investigation. Identification of areas with high geothermal potential can be a taxing. However, the decision-making process can be made less cumbersome if it is broken down into general steps (Yousefi, Ehara, and Noorollahi, 2007)

- Geodata acquisition and processing
- Assessment and characterization of the focus area
- Establishment of site selection criteria and definition of promising areas based on all data sets collected.

The decision-making process for locating prospective areas involves combining the results of a number of different surveys and studies; human error is unavoidable during this complex procedure.

Geothermal exploration demands for the analysis of data. This is by combining various sets of geo-scientific information such as surface geology, the location (GPS) of geothermal manifestations,

geomagnetic and gravity measurements, thermal data (temperature gradient and heat flow), the geochemistry of surface manifestations and remote sensing data.

4. SUITABILITY SITE SELECTIONS

4.1 Geological evidence layer suitability analysis

Integration of areas that are defined by factoring on volcanic rocks, volcanic craters and geological structures can be used to determine geological suitability of a place for geothermal. These layers are overlaid (Figure 1) and identified areas are combined by using Union tool in ArcMap. Using this tool creates a new coverage as a result of overlaying two or more polygon coverage (Figure 2). A spatial query tool (buffer) is applied to generate factor maps for each data layer. The factor maps are combined in order to identify the suitable geological area using the expression below;

*Suitable geological area= **(VR U VC U GS)*** **(**1)

Where VR, VC and GS denotes, volcanic craters and geological structures respectively and U is 'OR' (Union) Boolean operator.

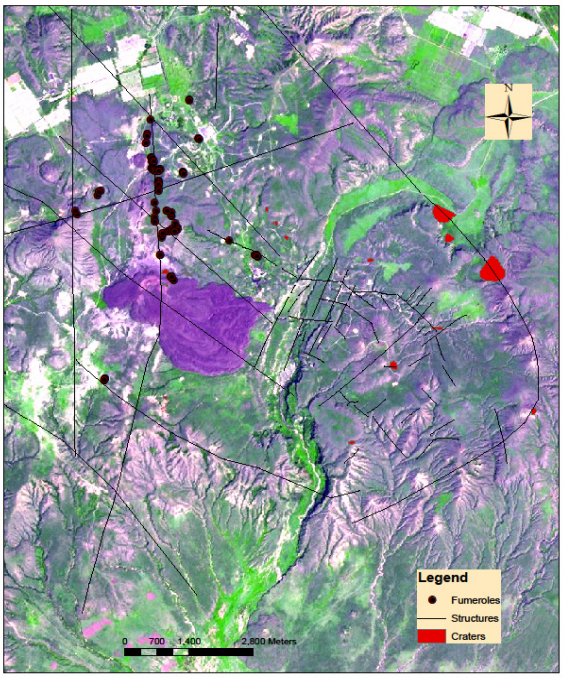

FIGURE 1: Overlay of geological features on a LandSat Satellitte data

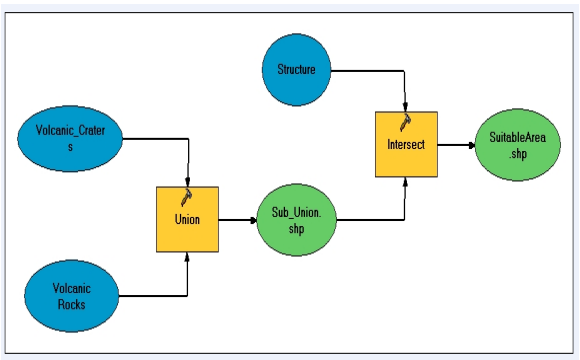

FIGURE 2: Combination of selected geological features into one new feature. Although the features may be from different layers, the layers are of the same geometry type—either line or polygon

4.2 Geochemical evidence layer suitability analysis

Geochemical analysis of evidence layer involves integration of selected areas on the basis of hydrothermal alteration zones, fumaroles and hot springs. These evidence layers are overlaid and the selection combined with Union operator tool to identify geochemical suitable area as in Expression 2 and Figure 3a. Besides, Figure 3b is a sample example of specific gas geothermometric concentration.

Suitable geochemical area= ***(HA U F U HS U G)*** (2)

Where HA, F, HS,G denote hydrothermal alteration zones, fumaroles, hot springs and geothermal gases respectively and U is 'OR' (union) Boolean operator.

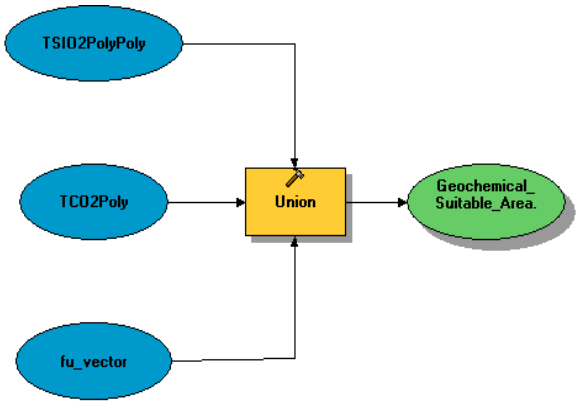

FIGURE 3a: Combination of gas geothermometry, fumaroles and temperature layers

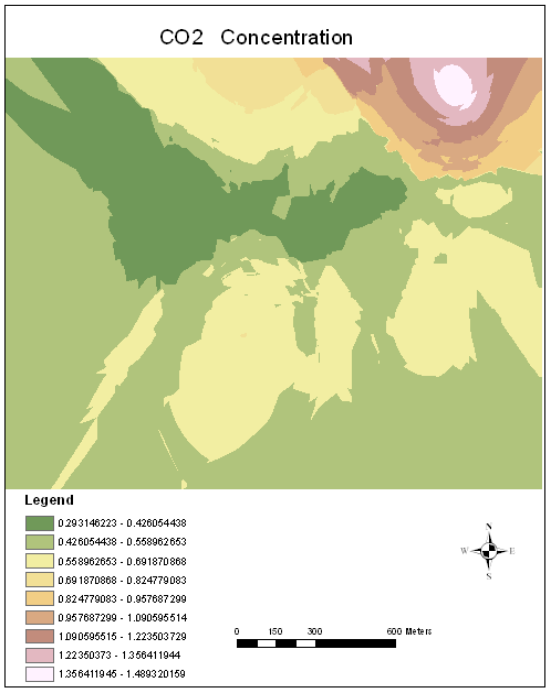

FIGURE 3b:CO2 geothermometry concentration

4.3 Geophysical evidence layer analysis

Resistivity anomaly data layer analysis is carried out in ArcMap environment by carrying out Geostatistic analysis using Kriging method. This method forms weights from surrounding measured values to predict values at unmeasured locations, thus resulting in Figure 4.

4.4 Environmental evidence layer suitability analysis

During geothermal development, environment is of concern. Environmental analysis is conducted using data that identifies lands of limited or highly undesirable usability. Typically these are lands of cultural importance, national parks or serene areas of scenic beauty. The area could be a protected animal habitat or migration zone. The result of this analysis indicates geographic areas that represent few or no barriers at all to geothermal development.

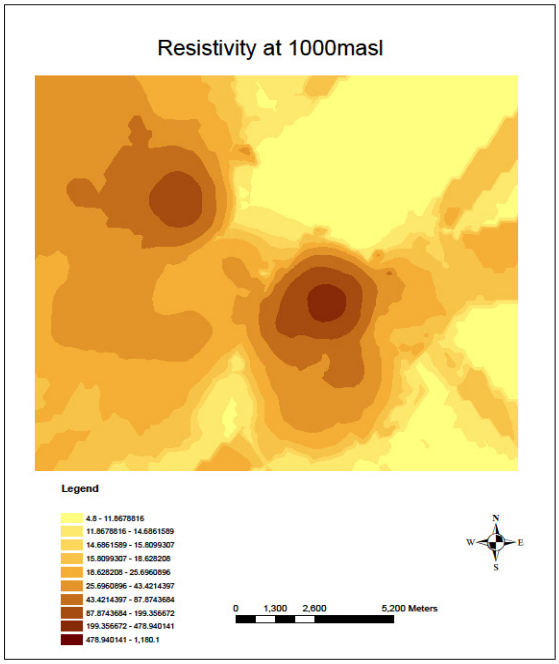

FIGURE 4: A map showing Resistivity information at 1000 masl

4.5 Suitability areas integration analysis

As a result of areas suitable in each discipline, the outcomes are integrated once again using Intersect tool (AND operator). The Intersect (AND) tool in ArcMap calculates the geometric intersection of any number of feature classes and data layers that are indicative of geothermal resource (Yousefi et al., 2007). Common features to all input layers are selected using (Bonham-Carter, 1994) method.

Each evidence layer is assigned and classified using unique values. The values are assigned to the sites as follows: 1 and 0 for area with and without geothermal resource respectively (Noorollahi and Itoi, 2008). The Intersect tool (AND operator) is used in overlaying the three layers(geological, geochemical and geophysical layers). The areas which are common for all three layers are selected as the best suitable area. Integration of data layers for the selection of the promising geothermal area is done by:

$$\textit{Geothermal Potential Site} = (GEOL \cap GEOPH \cap GEOCH \cap ENV.) \quad (3)$$

Where GEOL., GEOPH, GEOCH and ENV. Denote geological, geophysical, geochemical and environmental layers respectively.

5. DISCUSSION AND CONCLUSION

From the various outcome of the analysis, it is evident that GIS is a powerful tool within geothermal development site location. GIS is utilized to carry out the suitability analysis and site selection by

assigning a set of suitability and weighting factors. The analytical methods utilized in selection queries are three: the union, intersecting and weighted overlay raster. Therefore, GIS technology is quite appropriate in potential geothermal site selection for its development.

REFERENCES

Bonham-Carter, G. E. (1994). Geographical information systems for geoscientists. *: Modeling with GIS. Computer Methods in the Geosciences, 13*, 398.

Noorollahi, Y., and Itoi, R. (2008). *GM-GRE:* An integration method for geothermal potential site selection.

Yousefi, H., Ehara, S., & Noorollahi, Y. (2007). *Geothermal potential site selection using GIS in Iran.* Paper presented at the *32nd Workshop on Geothermal Reservoir Engineering*, *Stanford University, Stanford, California,*.