Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Geothermal Resource Database for Saudi Arabia (GRDiSA); GIS Model and Geothermal Favorability Map

Essam Aboud[1,2], Atef Qaddah[1], Hussein Harbi[1,3] and Faisal Alqahtani[1,3]

[1]GeoHazards Research Center, King Abdulaziz University, Jeddah 21589, Saudi Arabia

[2]National Research Institute of Astronomy and Geophysics (NRIAG), Helwan, Cairo, Egypt

[3]Faculty of Earth Sciences, King Abdulaziz University, Jeddah, 21589, Saudi Arabia

eaboudishish@kau.edu.sa

Keywords: Geothermal exploration, GIS model, Volcanoes, Hot spring, Saudi Arabia.

ABSTRACT

Saudi Arabia has many geothermal resources (volcanoes and hot springs) along the Red Sea coast. Researchers were looking for this type of energy five decades ago or even more, but studies are still on academic shelves and there are no real geothermal projects. In our current research, we are trying to collect previous studies and literature into a database format. This database will assist decision-makers with drawing up a road map to explore, evaluate, and assess geothermal exploration in the kingdom of Saudi Arabia.

Geological, geophysical, and related studies are collected in a digital form to build the first Geothermal Resource Database in Saudi Arabia (GRDiSA) using the powerful GIS environment. Additionally, a built-in GIS extension "Modeler" is used to target the potential of geothermal resources in Saudi Arabia. As a result, the first geothermal favorability map is generated based on the GIS model, indicating that the western side, where volcanoes and hot springs are located, is favorable for further geothermal exploration program.

1. INTRODUCTION

Saudi Arabia is rich in geothermal energy resources, particularly, Red Sea coast (Fig. 1). However, geothermal energy studies were initiated five decades ago or possibly earlier but they currently gather dust on academic shelves and no geothermal power plant has installed yet (Lashin, 2015). Some direct-use, low-grade geothermal applications have already been installed in the last five years. Some refreshment and swimming pools have been constructed in the Bani Malik-Jizan area, southern Saudi Arabia.

Using GIS tools in geosciences can be useful for various problems and can facilitate exploration (Bonham-Carter, 1994). Using GIS in geothermal studies is not a new idea since several authors have carried out this type of work. Abdel Zaher et al. (2018) built the first geothermal database for Egypt and recommended geothermal areas for further exploration. Schiel et al. (2016) used GIS modelling for shallow geothermal studies in Europe. Noorollahi et al. (2007) used the GIS tools to explore promising geothermal areas in northern Japan and Iran. The non-availability of geothermal energy databases for Saudi Arabia encouraged us to work on GRDiSA.

To explore and evaluate geothermal energy resources, considering the spatial distribution of these resources can be useful. The current work aims to build a general database to support the geothermal society. The GIS program with its built-in database extension allows us to visualize various geospatial data and generate various maps (Murai, 2008; Longley et al., 2005). GIS's technology is useful for managing, analyzing, integrating and displaying many forms of georeferenced data. The ability of GIS to combine maps and databases has been extremely effective in the context of planning growth. The GIS environment provides a modeling system to evaluate the geo-dimensions of favorable areas. Accordingly, using GIS tools, the current study will collect various geodata to form the backbone of the GRDiSA project. GRDiSA will be ready for modeling and targeting the geothermal favorability map within the Kingdom of Saudi Arabia. Finally, recommendations will be discussed.

Figure 1. Major geothermal features in Saudi Arabia. Volcanic fields (filled red polygons), hot springs (filled red triangles), and heat flow measurements (Gettings, 1982).

2. GRDISA STRUCTURE

GRDiSA or a geodatabase is a vital part in GIS-based applications. Once data is georeferenced, they can be used and presented in the form of maps. Different data layers can be viewed in a successive overlapping manner and can be used simultaneously. GRDiSA is a mixture of public data as well as data collected from available geothermal reports. It is built to cover numerous targets as a guide for geothermal exploration in Saudi Arabia. Within GRDiSA, the factors that contribute in generating the geothermal favorability map are collected with two indicator groups: a temperature group and a permeability group (Figure 2). Temperature and permeability are the most important factors that determine the productivity of a geothermal resource. Each indicator group contains various data. For example, the temperature group has four data categories: geothermal gradient, heat flow, Curie depth, and volcanic density. The permeability group contains two sub-categories for fault density and seismic density. The model builder in GIS encompasses the available datasets to run the model, and the geological and geophysical datasets.

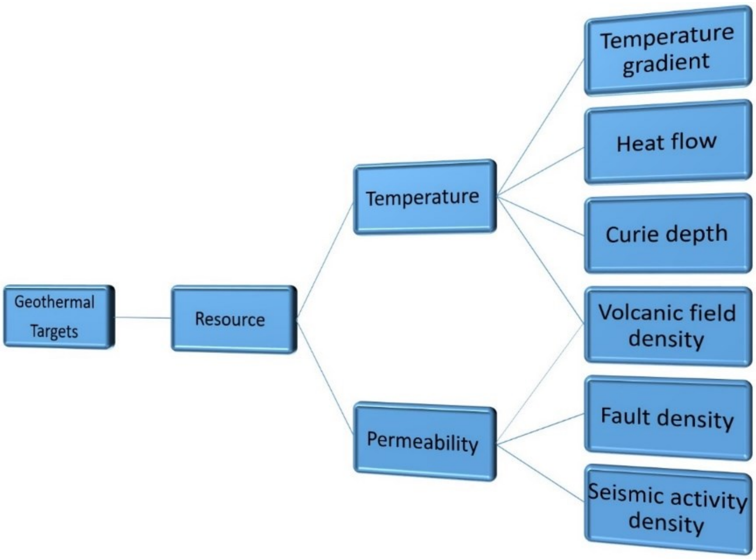

Figure 2: Structure of GRDiSA, showing the indicator groups as well as sub-factors.

3. GIS MODEL

The GIS model is based on various geothermal datasets such as temperature at different depths and heat flow, geological data (e.g. faults, volcanic information, and rock types), and geophysical data (seismic activity and Curie depths). To define the more promising geothermal areas, the above-mentioned categories were employed in the GIS model which comprises the thematic categories that can be combined to provide a geothermal favorability map. These parameters are spatially variable and depend on geography; the integration of these parameters will result in a specific map with several categories. The current study prepared six influential factors for geothermal favorability mapping. These factors are temperature gradient, heat flow, fault density, volcanic density, seismic densities, and Curie point depth. Figure 3 shows the maps for each factor. For the Curie depths, the shallower depths reflect a high possibility for a geothermal area and a high value of the assigned favorability class. Also, the higher the heat flow and geothermal gradient, the shallower the geothermal reservoir.

The Kernel Density and The Point Density tools were used to prepare the fault density, volcanic field density, and seismic density maps. The Kernel Density tool calculates the density of features in a neighborhood around those features. According to (Silverman, 1986), by using this tool, over each line a smoothly curved surface is fitted; on the line the value is greatest and away from the line the value diminishes till it reaches zero at the specified search radius distance from the line. The density of features that have a point geometry can be calculated by the Point Density tool; the number of points that fall within the neighborhood (around each raster cell center) is totaled and divided by the area of the neighborhood or the item's value determines the number of times to count the point (Silverman, 1986).

4. CONCLUSIONS AND RESULTS

The available digital data for geothermal resources in Saudi Arabia were organized in a geodatabase format, where various datasets can be displayed. Various maps give more insight about the potential of geothermal resources. For example, shallow Curie depths (Figure 3c) suggest a high possibility for a geothermal reservoir. Also, a high heat flow (Figure 3b) or a high geothermal gradient (Figure 3a) indicate the average location of the geothermal reservoir. Seismic density (Figure 3f) and fault density (Figure 3d) maps indicate that the eastern and western side of Saudi Arabia are favorable for geothermal exploration. However, on the western side, there are volcanic fields that confirm the favorability of those locations.

Built-in GIS extensions for modeling were successfully used to validate expectations that the western side of the Kingdom of Saudi Arabia is promising for geothermal exploration. However, it also attracts our attention to the eastern side of the country where oil and gas are produced. The GIS model can be used to generate a geothermal favorability map for Saudi Arabia (Figure 4). Such maps help to visualize and understand the spatial distribution of the geothermal potential within the Kingdom. It indicates that within volcanic fields, along the Red Sea coast, there is a high potential for geothermal exploration. Hot springs (Al-Laith and Jizan) cannot be ignored, as they suggest a potential geothermal resource that may be developed, but the GIS model favors Al-laith more than Jizan (Figure 4).

In conclusion, from the geothermal favorability map shown in Figure 4 it can be stated that, the western side of the Kingdom of Saudi Arabia is highly recommended for further geothermal development where shallow Curie depths, high heat flows, volcanic fields, and seismic activity are present. These factors support more studies for geothermal exploration in those localities. The application of this research will assist decision-makers when exploring and evaluating geothermal resources in the Kingdom of Saudi Arabia.

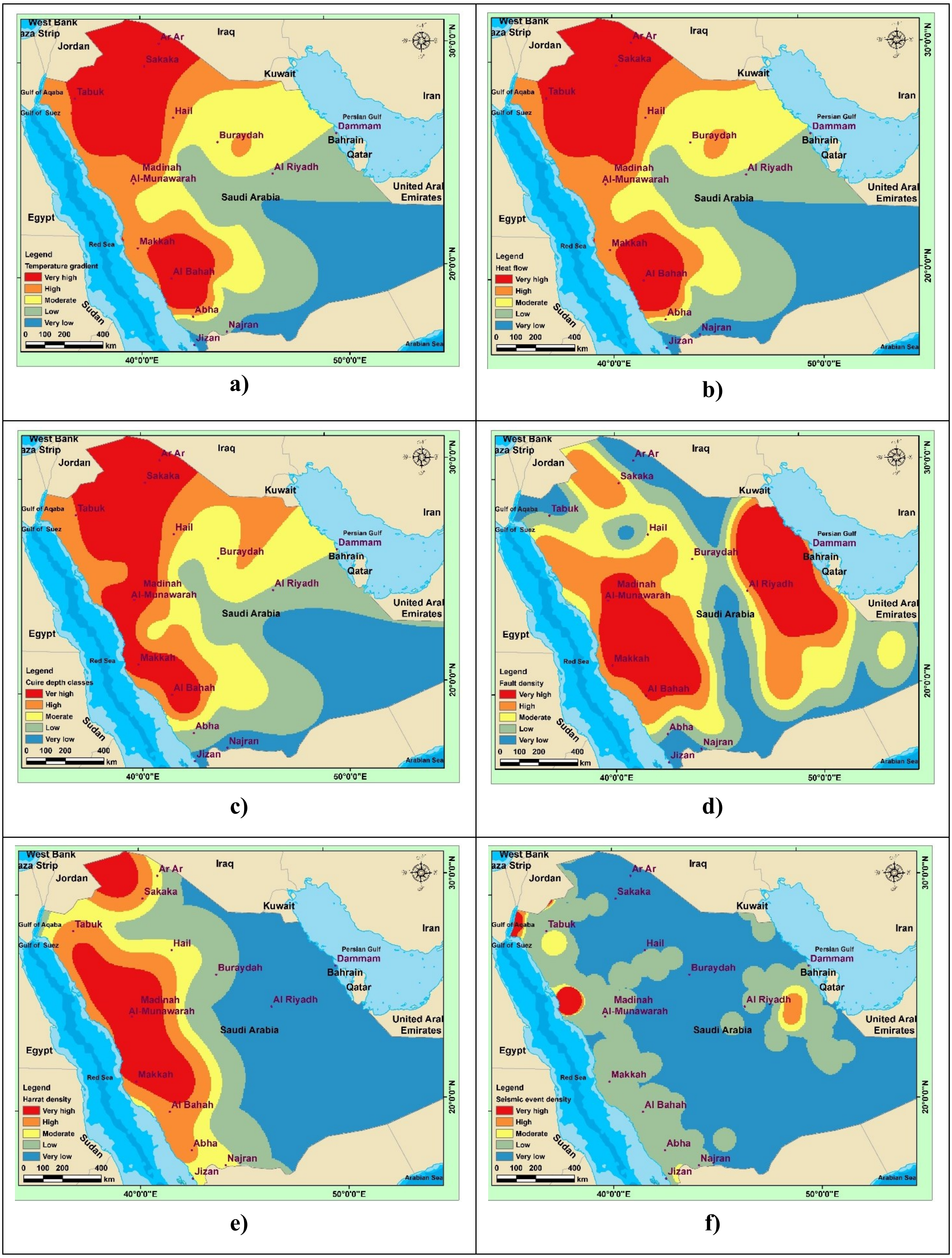

Figure 3: The evidence categories: a) geothermal gradient, b) heat flow, c) Curie depths, d) fault density, e) volcanic field density, and f) seismic densities.

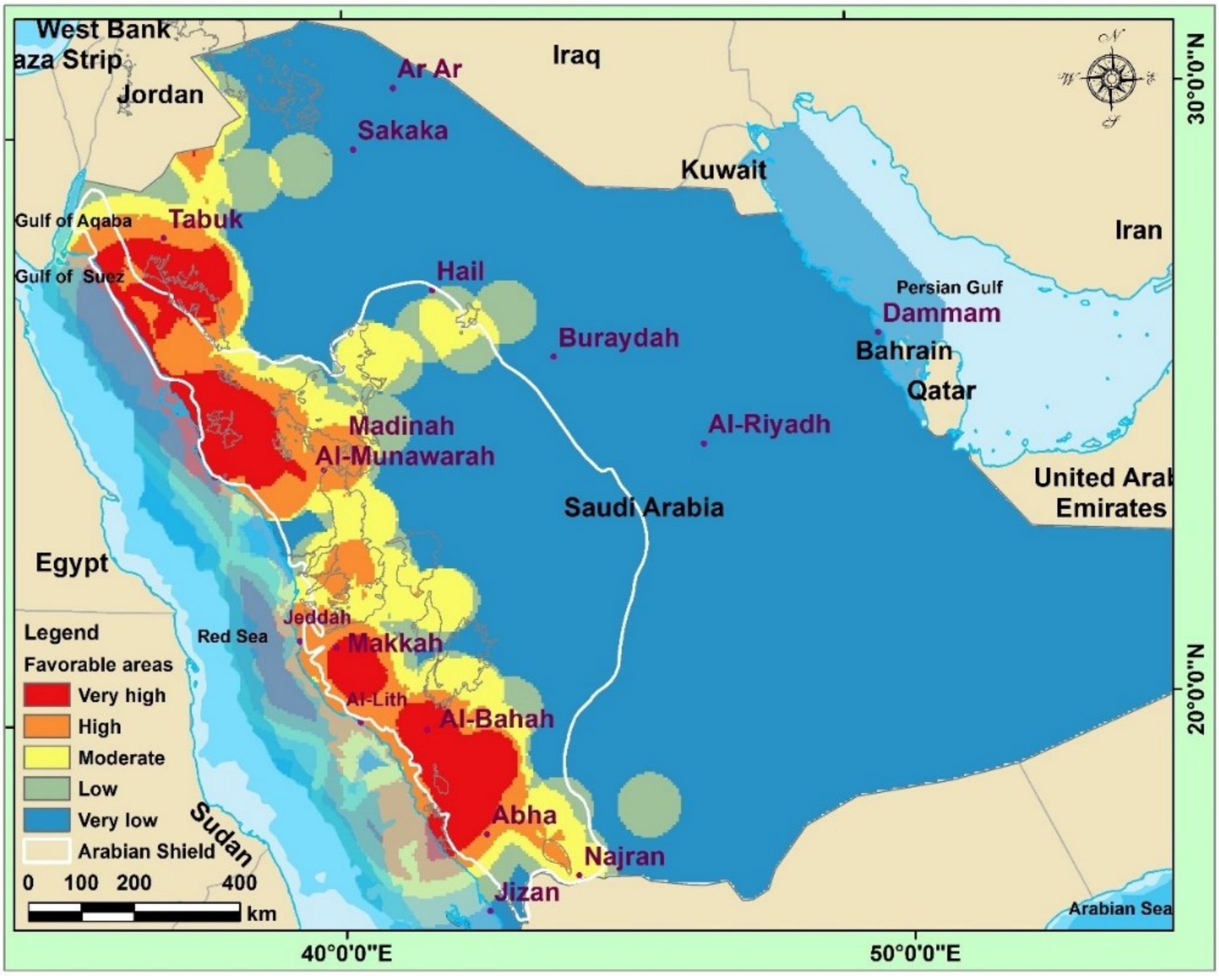

Figure 4: The resulting geothermal favorability map for Saudi Arabia.

REFERENCES

Abdel Zaher, M., Elbarbary, S., El-Shahat, A., Mesbah, H., & Embaby, A. (2018) Geothermal resources in Egypt integrated with GIS-based analysis. Journal of Volcanology and Geothermal Research, 365, 1-12.

Bonham-Carter, G.F. (1994) Geographic Information Systems for Geoscientists: Modelling with GIS. Pergamon, New York.

Gettings, M.E. (1982) Heat-Flow measurmenst at shot points along the 1978 Saudi Arabian seismci Deep-refraction Line. In Part 2: Discussion and interpretation. U. S Geological Survey

Hussein, M.T., Lashin, A., Al Bassam, A., Al Arifi, N., & Al Zahrani, I. (2013) Geothermal power potential at the western coastal part of Saudi Arabia. Renewable and Sustainable Energy Reviews, 26, 668-684.

Lashin, A. (2015) Geothermal Energy Resources of Saudi Arabia: Country update. In Proccedings World Geothermal Congress. Melburne, Australia.

Lashin, A. & N. Al Arifi (2014) Geothermal energy potential of southwestern of Saudi Arabia "exploration and possible power generation": A case study at Al Khouba area – Jizan. Renewable and Sustainable Energy Reviews, 30, 771-789.

Lashin, A., Chandrasekharam, D., Al Arifi, N., Al Bassam, A., & Varun, C. (2014) Geothermal energy resources of wadi Al-Lith, Saudi Arabia. Journal of African Earth Sciences, 97, 357-367.

Longley, P.A., Goodchild, M.F., Maguire, D.J., & Rhind, D.W. (2005) Geographic Information Systems and Science. John Wiley & Sons.

Murai, S. (2008) JICA net distance education on remote sensing and GIS for developing countries. The International Archives of the Photogrammetry. In Remote Sensing and Spatial Information Sciences, 5.

Noorollahi, Y., Itoi, R., Fujii, H., & Tanaka, T. (2007) GIS model for geothermal resource exploration in Akita and Iwate prefectures, northern Japan. Computers & Geosciences, 33, 1008-1021.

Schiel, K., Baume, O., Caruso, G. & Leopold, U. (2016) GIS-based modelling of shallow geothermal energy potential for CO2 emission mitigation in urban areas. Renewable Energy, 86, 1023-1036.

Silverman, B.W. (1986) Density Estimation for Statistics and Data Analysis. New York: Chapman and Hall.