TURKGEO
TURKISH JOURNAL OF GEOSCIENCES

ISSN: *2717-7696*
Research Article
Vol; 3, Issue; 2, pp. 75-83, 2022
DOI: 10.48053/turkgeo.1132970
Journal homepage:
https://dergipark.org.tr/en/pub/turkgeo

Investigation of the Hamamayağı/Ladik (Samsun, Turkey) geothermal field and it's surroundings by optical Remote Sensing with GIS methods

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Keywords
Geothermal
Potential
Mapping
ASTER
Remote Sensing
GIS

ABSTRACT

In this study, the geothermal potential was investigated by remote sensing methods in the Ladik Hamamayağı region of Samsun province at the Central Black Sea region. The satellite images were evaluated in the GIS environment. Various parameters differ in remote sensing studies and post-exploration geothermal field remote sensing for exploration studies, and these parameters are explained in detail in the study., All alteration types that should be in a geothermal field were mapped with the ASTER data, lineaments were extracted, thermal anomalies were captured and interpreted with alterations in the GIS environment, since there are no alteration information in the Hamamayağı geothermal field that previous studies have uncovered. As a result of these processes and interpretations, remote sensing and GIS methods were used together for the Hamamayağı geothermal field to produce guiding data and maps for the discovery of new potential areas. Within the framework of these produced maps, technical suggestions were made to the authorities who have a say on the subject.

1. INTRODUCTION

Depending on the development and growth rate of countries, their energy needs are constantly increasing (Arslan et al., 2001). For this reason, those who undertake the administration of the country have to find energy in uninterrupted, reliable, clean and cheap ways and to diversify these sources (Akkoyunlu, 2006; Pamir, 2003). In this context, countries are trying to create their energy policies for the development and use of renewable energy resources, both to meet this demand and to take into account the cost of exhaustible fossil resources and their environmental effects. Geothermal energy, one of the renewable energy sources that ensure the sustainability of nature in its own cycle, has started to have an important share in meeting the energy needs of countries in recent years. (Akkuş, 2017). As it is known, Geothermal Energy is a domestic underground resource that is renewable, clean, cheap and environmentally friendly. Ozdemir, (2012) studied known geothermal fields in Turkey. Ozdemir et al. (2017) studied Kavaklıdere Geothermal Field with structural geological principles. Ozdemir and Palabiyik, (2019) developed a new evaluation method of magnetotelluric (MT) data for geothermal fields. Ozdemir et al. (2021a) studied Gediz Graben with structural geology and revealed the geological model of geothermal system. Since our country is located on an active tectonic belt. Ozdemir et al. (2021b) reevaluated the Çubukludağ geothermal field potential and produced 3D structural model of the geothermal system.

Due to its geological and geographical location, it is in a rich position among the world countries in terms of geothermal. There are many geothermal resources at different temperatures in the form of around 1000 natural outflows spread all over our country. Again, the geothermal potential of our country is quite high, and 78% of the potential-forming areas are located in Western Anatolia, 9% in Central Anatolia, 7% in the Marmara Region, 5% in Eastern Anatolia and 1% in other regions. 90% of our geothermal resources are low and medium temperature, and direct applications (heating, thermal tourism, various industrial applications,

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Received: 19/06/2022; Accepted: 07/11/2022

Cite this article

Uzun Ö.F., & Turgay O. (2022). Investigation of the Hamamayağı/Ladik (Samsun, Turkey) geothermal field and ıt's surroundings by optical Remote Sensing with GIS methods. Turkish Journal of Geosciences 3(2), 75-83.

etc.), and 10% of them are suitable for indirect applications (electric power generation) (MTA, 2021a). In this context, the distribution and application map of the geothermal resources of our country is shown in Figure 1.

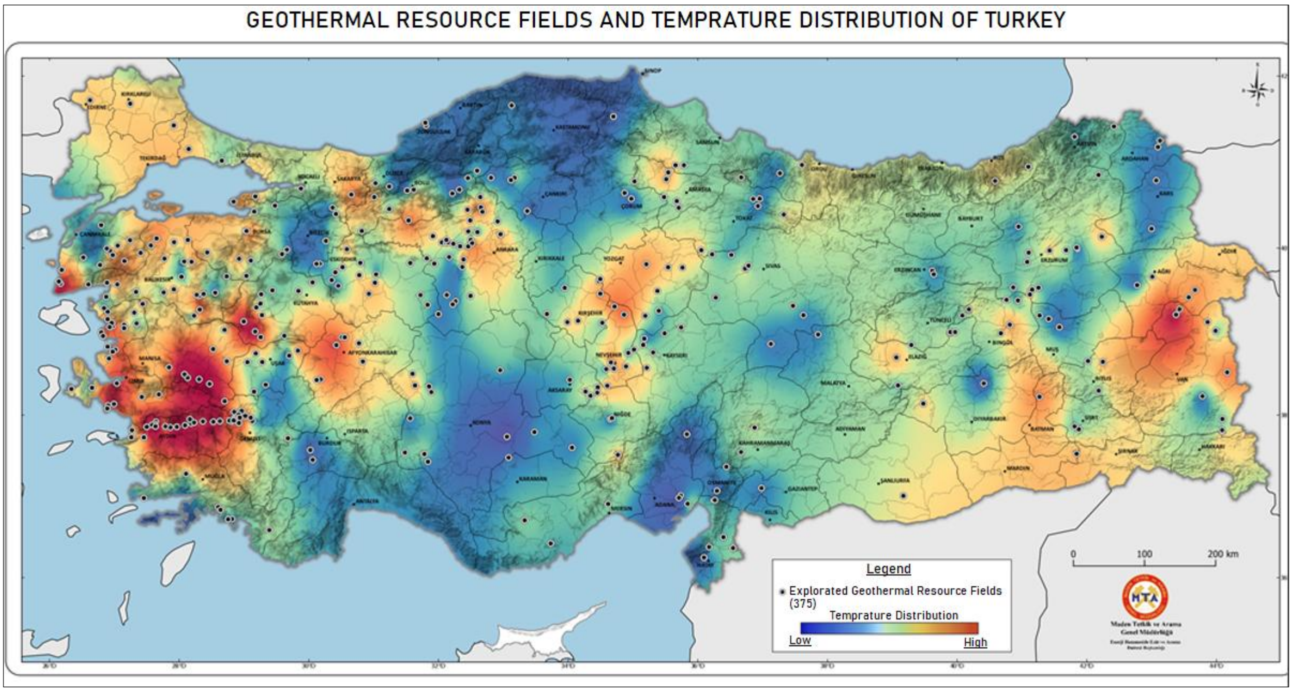

Figure 1. Geothermal map of Turkey (MTA, 2021b)

Within the framework of the mentioned issues, it is extremely important to find new potential geothermal resources in our country and to include them in energy production. Because although Turkey is lucky in terms of its geothermal resources, it is one of the countries with hundreds of geothermal resources that can use these resources at a minimum rate and are waiting to be uncovered (Akın et al., 2014). Remote Sensing technology has started to take its place in the scientific literature as one of the most effective methods involved in the preliminary research of these resource studies. In recent years, there have been important studies conducted in Turkey with Geographical Information Systems and Remote Sensing methods in geothermal exploration (Yalçın and Gül, 2017; Yıldız et al., 2017; Balçık and Ergene, 2017; Yurteri and Şimşek, 2017; Melikoğlu, 2017). Surface temperature distribution mapping using surface temperature analysis (STA) calculated using satellite images performed in these studies is widely used to determine geothermal fields. For studies such as geothermal research, land surface temperature is an important parameter. (Oğuz, 2015). In addition, in the use of remote sensing and GIS for geothermal exploration, suitable areas for exploration were determined by combining volcanic units, faults, hot water outlets, alterations, fumeroles, heat flux and temperature gradient with various GIS methods for exploration with spatial analysis in the study of Moghaddam et al. (2014). Apart from this, in the study of Noorollahi et al. (2015), in addition to the study of Moghaddam et al. (2014), geoelectric data were combined with geological and geochemical data in the GIS environment and suitable locations for exploration were determined. In the study of Noorollahi et al. (2008), the distance to the faults, the distance to the calderas, the distance to the alteration zones, the distance to the hot water outlets and the distances to the volcanic domes were evaluated in the GIS environment, and results were obtained for the well location selection and geothermal exploration. The Ladik-Hamamayağı Geothermal Area, which has been studied within the framework of these aforementioned issues, is located in the Northwest of Ladik, 12 km away. The region is 73 km from Samsun Province. Within the scope of the study, potential geothermal resources were investigated by remote sensing methods in and around Samsun Ladik Hamamayagi Geothermal Zone. Aim of this article is using remote sensing derived parameters which are weighted in GIS environment can be used for remote detection of geothermal anomalous zones in study area.

1.1. Study Area

The Ladik-Hamamayağı Geothermal Area (Figure 2) which has been studied within the framework of these aforementioned issues, is located in the Northwest of Ladik, 12 km away. The region is 73 km from Samsun province away. Within the scope of the study, potential geothermal resources were investigated by remote sensing methods in and around Samsun Ladik Hamamayagi Geothermal Zone. The study area that is the subject of the study is given in Figure 2. Gültekin et al. (2010) studied the hydrochemistry of geothermal waters of Hamamayağı-Ladik area.

Gray, gray colored, hard, heavily cracked Permian aged recrystallized limestone's can be found at the bottom of the Ladik Hamamaya geothermal area (Figure 3). The unit is overlain by beige, cream-colored chert nodules and cracked Jurassic-Cratese aged limestone's. It is covered by an Eocene-aged unit made up of sandstone and claystone. The sequence then moves on to Neogene-aged units with conglomerate, claystone, and sandstone lithology. The youngest rock units are Quaternary-aged alluvium cone with old and new alluviums (MTA, 2005).

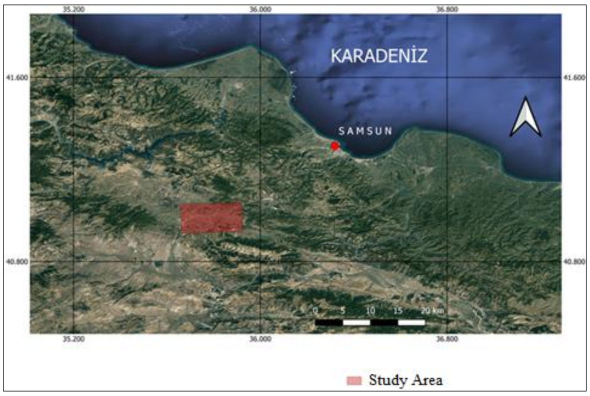

Figure 2. Study area

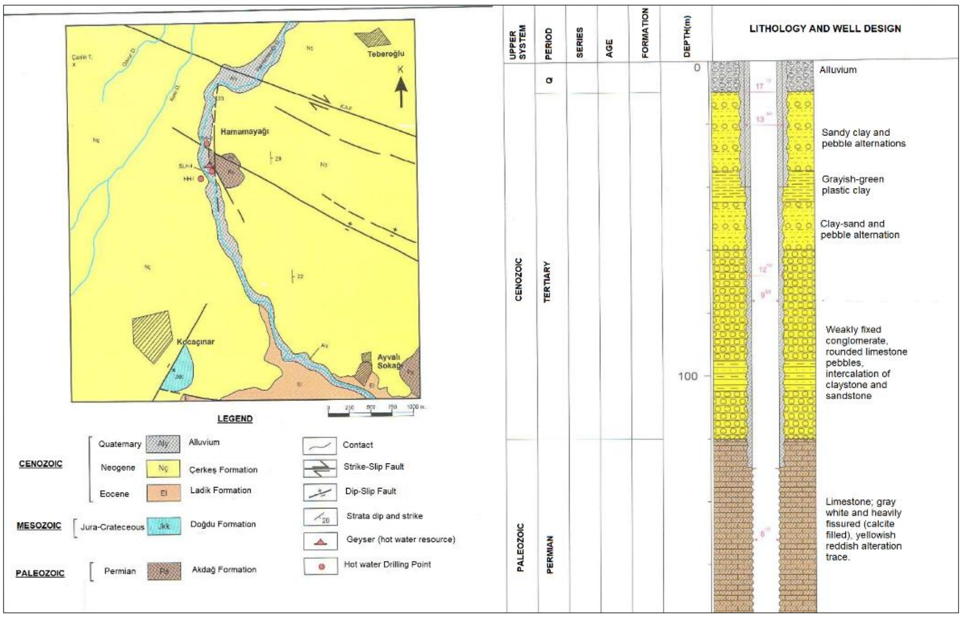

Figure 3. Geology of Hamamayağı-Ladik Geothermal area (MTA, 2005) and Bekdiğin BK-2 Well design with drilling log

2. METHOD

For remote sensing, ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) L1T dataset was used for gaining alteration parameters which used in GIS environment.

The ID of ASTER L1T dataset is AST_L1T_00303202004083222_20150503172907_68414. Alteration parameters gained from ASTER dataset by ENVI 5.3 software later parameters processed in ArcGIS PRO software. In ArcGIS, map visualizations and gridding made also in ArcGIS weighted overlay analysis was applied. For lineament extraction, LINE module of PCI Geomatica was used with Öztürk and Uygucgil, (2018)'s method later, extracted linements transformed to the lineation density with the line density module of ArcGIS software. Every raster data weighted to the five level from minimum to maximum level with ArcGIS Pro overlayed with Weighted Overlay tool to extract geothermal potential zones as map.

2.1. Preprocessing of ASTER Data

In preprocessing step, radiometric calibration and atmospheric correction of dataset was completed in ENVI 5.3 software, SWIR, VNIR and TIR bands of ASTER radiometrically calibrated then VNIR and SWIR data stacked in one file after this processing step radiometrically calibrated TIR bands atmospherically corrected by thermal atmospheric correction and Emissivity Normalization applied the corrected TIR dataset. While TIR dataset converting the Emissivity, surface temperature data in Kelvin obtained later it was transformed to the Celsius with (b1-273.15) formula.

2.2. Geological Image Processing of Aster Data

Hydrothermal alterations were extracted from ASTER SWIR and VNIR dataset and with Emissitvity Normalization Thermal anomaly map extracted. Also Quartz and silisification images obtained from corrected TIR dataset. Images of alterations obtained from ASTER dataset are Potassic alteration, sericitization, propylitic alteration, argillic alteration, advanced argillic alteration which are important for hydrothermal alterations. Also these images were evaluated in GIS environment with Weighted Overlay algorithm. Lineament density maps were also evaluated in GIS environment. Weighted overlay analysis is using for desicion making in GIS. In ArcGIS, analytical hierarchy model is most common in weighted overlay analysis.

3. RESULTS

The use of remote sensing in studies on the existence of geothermal potential was given in the introduction with previous studies. This study can be given as an example of geothermal potential maps that can be obtained with different data processing methods. The methodology of the study is to extract hydrothermal alterations such as alunitization (Figure 3), argillic alteragion (Figure 4), fengite (Figure 5), Kaolenitization (Figure 6), propylitization (Figure 7), Quartz distribution (Figure 8), sericitization (Figure 9), that may indicate geothermal exactly and after being subjected to weighted overlay analysis as a set, they are subjected to weighted overlay analysis together with surface temperature (Figure 11) and lineament density (Figure 10) maps. In this geothermal potential study carried out in the Hamamayağı region, the existence of a geothermal potential in Yenice, Bekgın and Hamamayağı regions was determined by remote sensing methods. In addition, it has been determined that the most visible alteration type in the Hamamayağı geothermal area is propylitization. Based on all this analysis, it has been determined that the study area has a paleotemperature history of up to 400 degrees and a geothermal potential. According to the maps obtained from the study, it is thought that positive results can be achieved if geothermal exploration studies are carried out in the red areas on the maps.

Table 1. Hydrothermal alteration formulas for ASTER L1T dataset

INDEX/INDICE	ALTERATION	REFERENCE
(B4+B6)/B5	Advanced Argillic Alt.	Fakhari et al., (2019)
(B6+B9)/(B7+B8)	Propylitization	Shahi and Kamkar-Rouhani, (2014)
(B7/B5)*(B7/B8)	Alunitization "ALI"	Ninomiya, (2002)
(B4/B5)*(B8/B6)	Kaolenization "KLI"	Ninomiya, (2003)
(B5+B7)/B6	Argillic Alteration	Testa et al., (2018)
B5/B6	Fengitic Mica "Fengite"	Bakardjiev and Popov, (2015)
(B11*B11)/(B10*B12)	Quartz Indice "QI"	Ninomiya, (2003)
(B5+B7)/B6	Sericitization	Fatima et al., (2017)

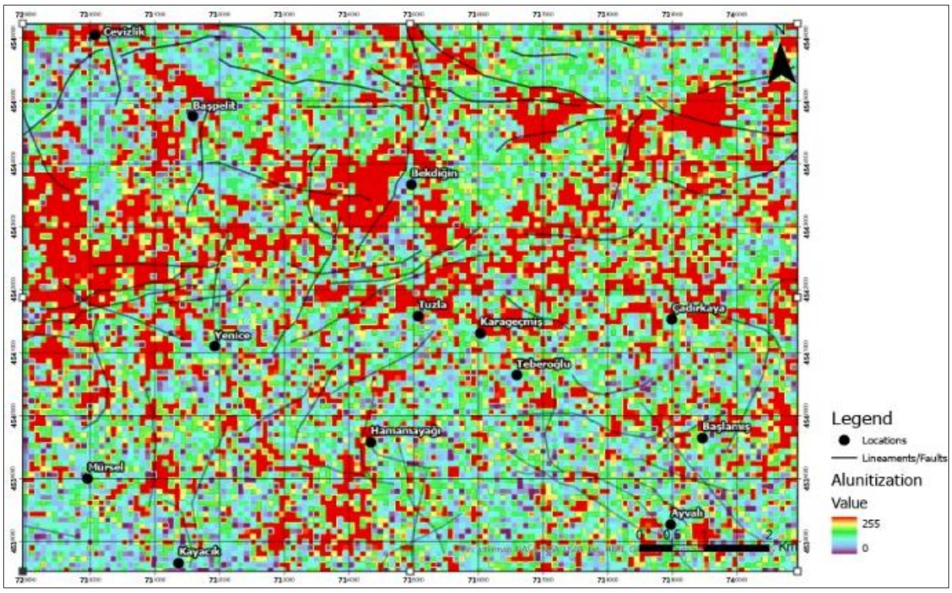

Figure 4. Alunitization distribution in study area

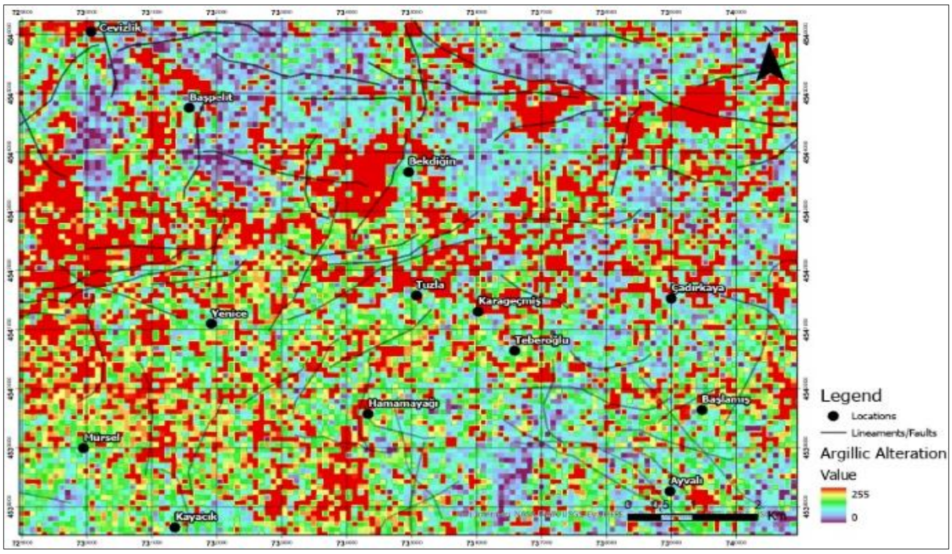

Figure 5. Argillic alteration in study area

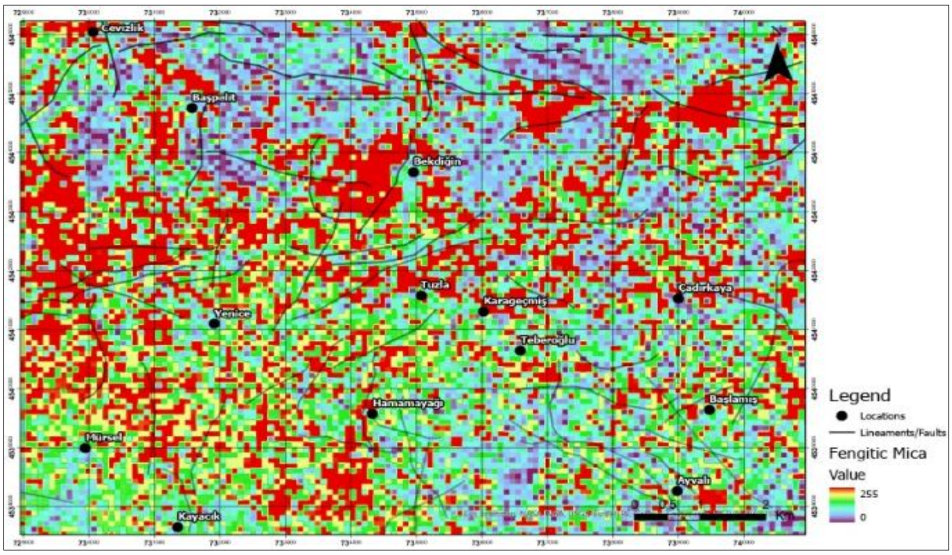

Figure 6. Fengitic mica in study area

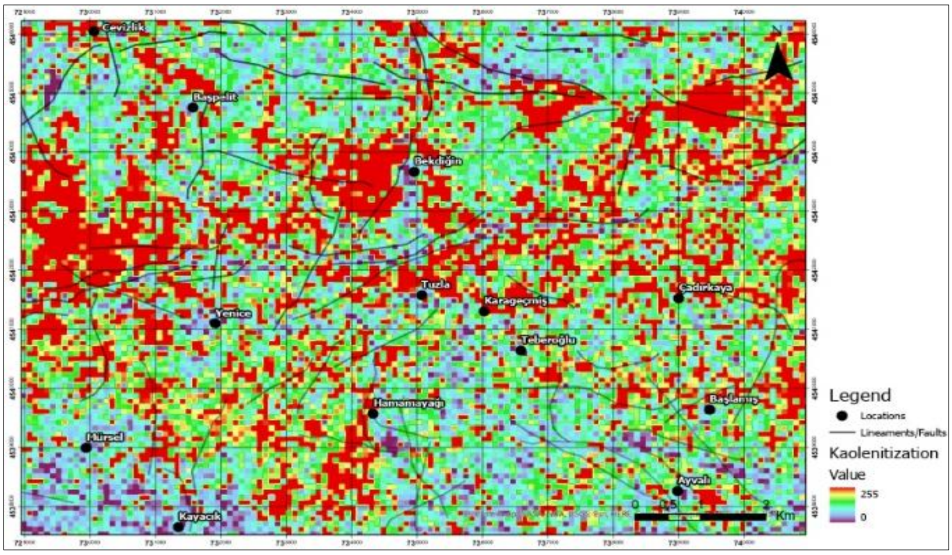

Figure 7. Kaolenitization in study area

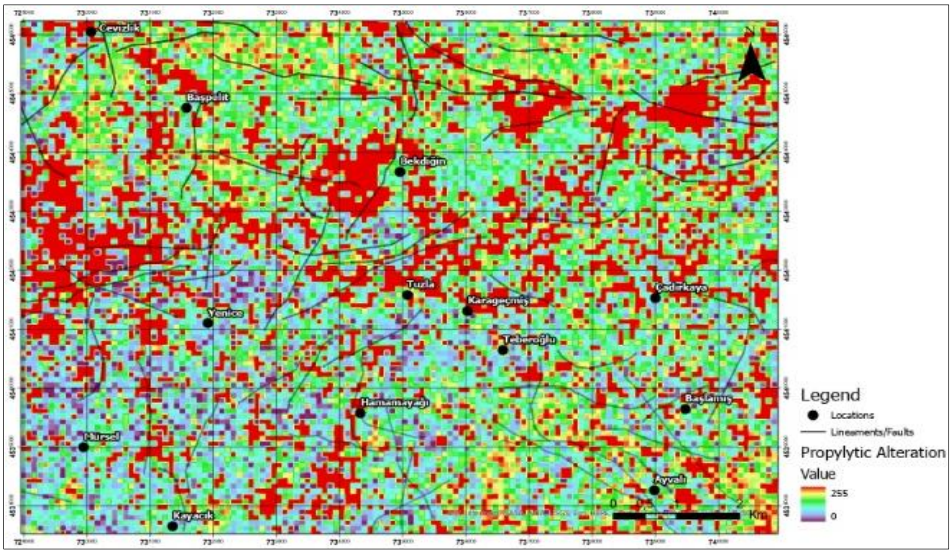

Figure 8. Propylitic alteration in study area

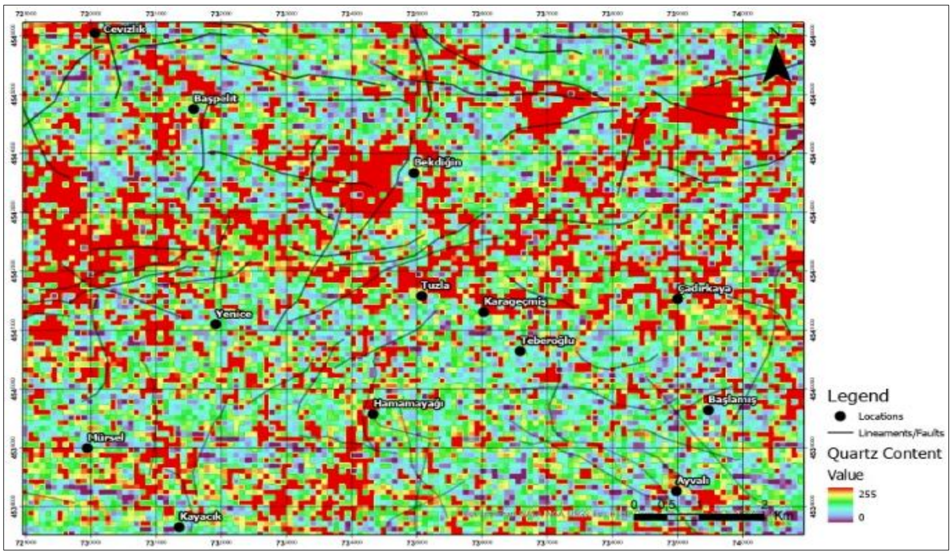

Figure 9. Quartz distribution in study area

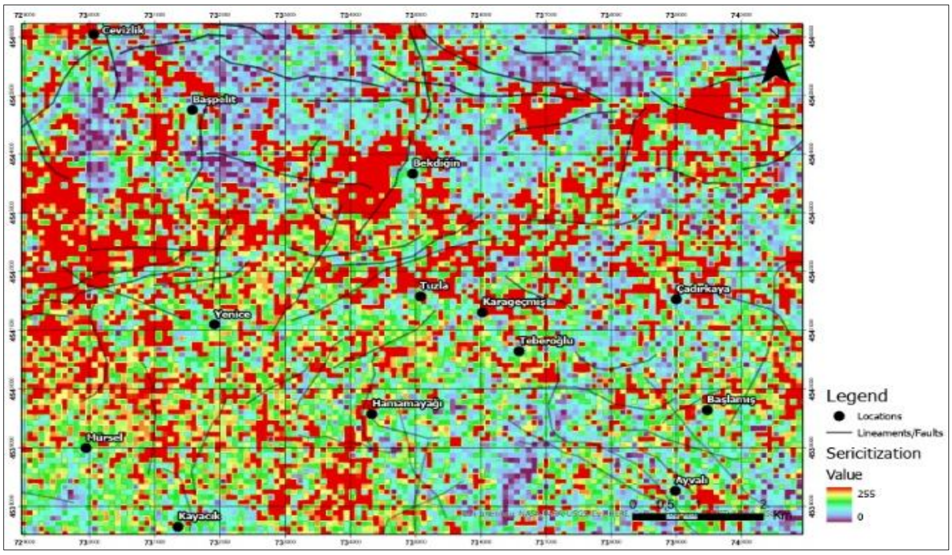

Figure 10. Sericitic alteration in study area

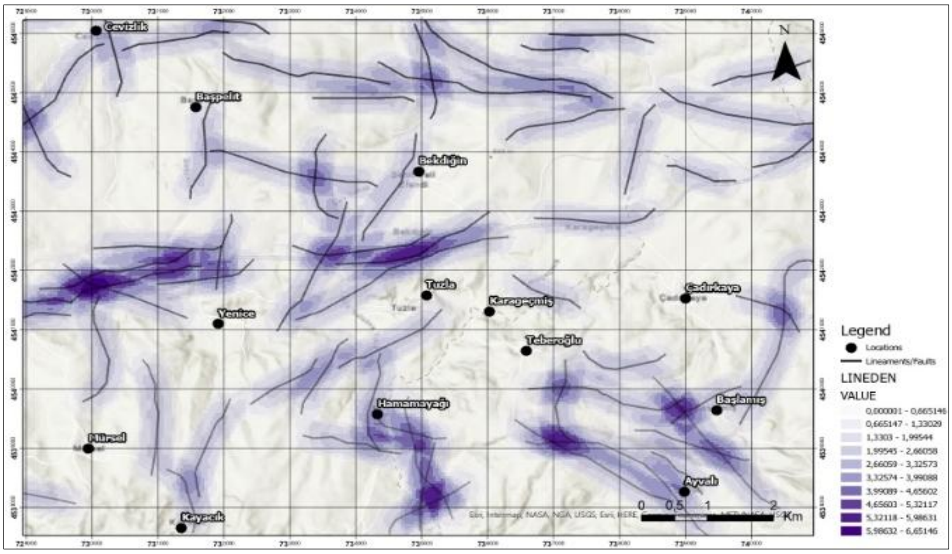

Figure 11. Fault (lineation) density in study area

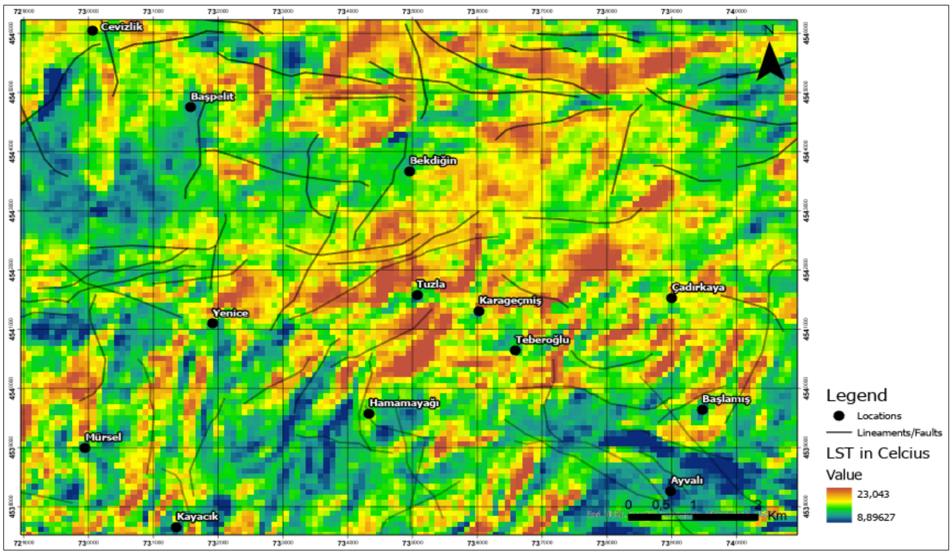

Figure 12. Land surface temperature (LST) in study area

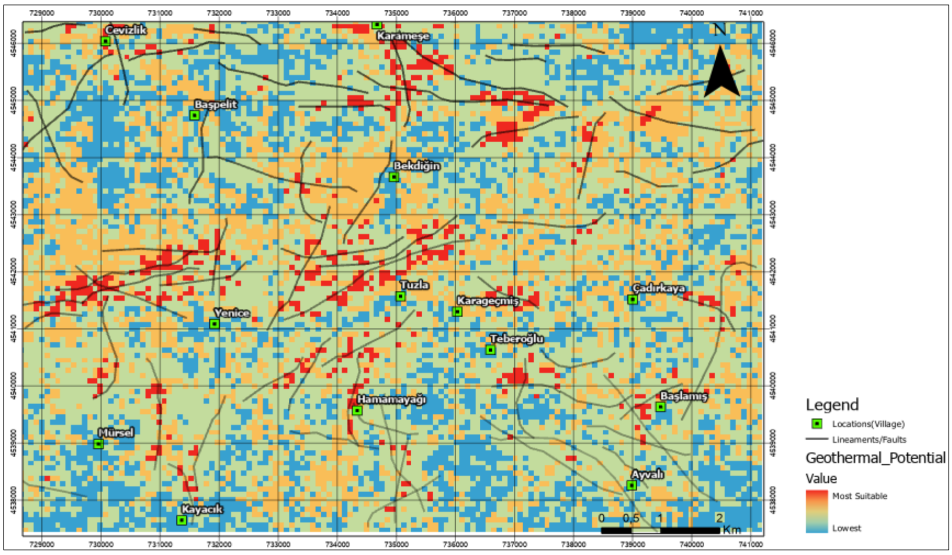

Figure 13. Resultant image of the study, geothermal potential map of study area

4. CONCLUSIONS

Among the alterations that can be form in the geothermal field, ASTER data has been processed for Advanced argillic alteration, Alunitization, Argillic alteration, Phengitic mica, Kaolinization, Propilitization/Propilitic alteration, silicification and sericitization (Table 1). The data obtained from the ASTER data, the lineament data and the temperature data were combined in the GIS environment. The results obtained as a result of the conducted studies are given in Figure 3 to 12.

It has emerged that the propylitic alteration in the Hamamayağı geothermal field should be defined as a pathfinder alteration. Because the geothermal field and the propylitic alteration image exactly coincide. The presence of thermal hotels in Hamamayağı province draws attention in places where there is propylitic alteration. The temperature of formation of propylitic alteration (epidote-chlorite) is between 250-400 degrees. This means that the paleo-temperature reaches 400 degrees.

Author Contributions

Ömer Faruk Uzun: Conceptualization, Methodology, Software. **Orkun Turgay:** Data curation, Writing- Original draft preparation and Data processing

Conflicts of Interest

The authors declare no conflict of interest.

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