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DETERMINATION OF GEOTHERMAL ENERGY AREAS AND USAGE POSSIBILITIES IN GREENHOUSE HEATING

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Abstract

In this study, the determination of geothermal energy in the Aegean region and determination of the use of geothermal energy in greenhouse cultivation were investigated. The results were compared with the related literature. Heating of greenhouses with geothermal energy sources will help to increase our greenhouse areas by providing economic cultivation opportunities if technical and environmental precautions are taken. For the data on thermal areas and active faults for Denizli, Aydın and Afyonkarahisar provinces where geothermal resources are used, the data of the General Directorate of Mineral Research and Exploration was used. The geothermal energy potential map of the provinces has been tried to be obtained from these data. From these maps, the locations of the greenhouses and geothermal energy heating greenhouses were compared. The development of greenhouses making use of geothermal energy in Turkey will provide significant contributions to greenhouse cultivation in all regions and especially in the Aegean Region. In conclusion, we are of the opinion that the maps drawn during this study will shed light to producers who are considering the use of geothermal energy for their greenhouses in the study area.

***Key words**: energy, geothermal, greenhouse, heating.*

INTRODUCTION

Greenhouses are structures that enable economic growth of culture plants in periods when the climate conditions are not suited for open field plant growth (Sevgican et al., 2000). Greenhouses should be warmed in cold weather in order to obtain quality high yield from greenhouses. However, heating costs have a significant impact on production cost. Sustainability in greenhouses can be obtained by increasing energy efficiency. The increase of energy efficiency can be possible by using renewable energy resources that do not generate any waste instead of fossil-based energy resources (Zaimoğlu, 2017).

For this purpose, the use of renewable energy sources such as biomass, wind, sun, hydraulics, geothermal energy is important for heating greenhouses as well as the use of waste heat energy of industrial establishments (Yıldız, 2010; Çaylı et al., 2014). It is an important requirement with high priority to make use of natural energy resources instead of fossil-based energy sources for decreasing heating costs as well as for preserving the energy assets and preventing environmental pollution. Hence, research and development studies for the design of geothermal energy heating systems for greenhouses have gained importance in recent years (Yıldız, 2010).

Greenhouse cultivation is carried out mostly along the Mediterranean coastline in Turkey due to various climate advantages. However, greenhouse cultivation has recently gained importance in areas with geothermal resources and the modern greenhouses established in these locations have started to produce high quality yield (Zaimoğlu, 2017).

Geothermal energy can be defined as hot water and vapor that contains higher amounts of molten minerals, salts and gases in comparison with the normal ground and surface waters formed by the heat accumulated at various depths of the earth's crust with temperatures that are above the regional atmospheric average temperature values (Çetin, 2014).

It has been calculated that the total geothermal capacity of the already existing geothermal well and resources in Turkey is about 8000 MWt with a potential of up to 60000 MWt (Çerçioğlu & Şahin, 2016). According to the South Aegean

Development Agency (2011), 6% of the current geothermal energy applications are used for power generation, 67% for residential heating, 9% for thermal facility heating and 18% for greenhouse heating. Accordingly, it is observed that the use of geothermal sources in our country is focused mostly on heating residences and greenhouses. Greenhouse heating was 50 hectares in 2002 while it increased by 686% reaching 393.1 hectares in 2015 (Anonymous, 2016).

Greenhouse cultivation areas have increased rapidly along the Mediterranean and Aegean coasts due to the suitable climate conditions in these regions. Whereas greenhouse cultivation could not develop in other regions with low average temperatures due to the requirement of high heating costs. However, geothermal sources decreased the heating costs thereby making it possible to carry out greenhouse cultivation activities in regions with low average temperature values. The applications carried out have put forth that greenhouses heated with geothermal energy are much more economic in comparison with greenhouses heated by liquid and gas fuels (Milivojevic and Martinovic, 2003).

The purpose of the present study was to determine the extent to which greenhouses heated by geothermal energy make use of tectonic fault lines based on the geothermal energy maps of the cities of Denizli, Afyonkarahisar and Aydın where there are geothermal sources and greenhouse cultivation activities are carried out. It is considered that the study will be an important source for establishments that are planning to use geothermal energy for greenhouse heating.

MATERIALS AND METHODS

The study covers Afyonkarahisar, Denizli and Aydın provinces in the Aegean Region. The selection of these provinces in the Aegean Region as a study area has been considered to be rich in terms of geothermal resources and effective implementation of greenhouse activities.

The location of the research area in the Qgis program is given in Figure 1.

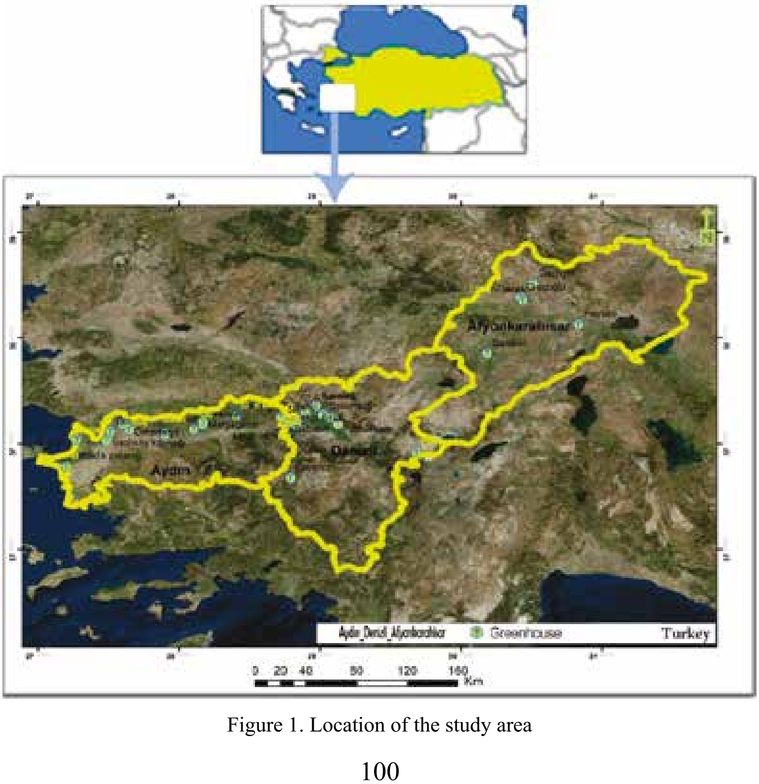

Figure 1. Location of the study area

To create digital maps especially thermal areas, fault lines and lake surface were included in the study.

The data of thermal areas and active faults were taken from the General Directorate of Mineral Research and Exploration.

Data of General Directorate of State Hydraulic Works is used for the lake areas. Thermal fields data type "point", Fault lines data "line" and Lake surface data "land" data were created in the open source Qgis program used in Geographical Information Systems (Ulazia et al., 2017). Map images are created for Aydın, Afyonkarahisar and Denizli provinces of the geothermal active fault lines by using Qgis program.

The stages of the study area in the provinces in the Qgis program are given in Figure 2.

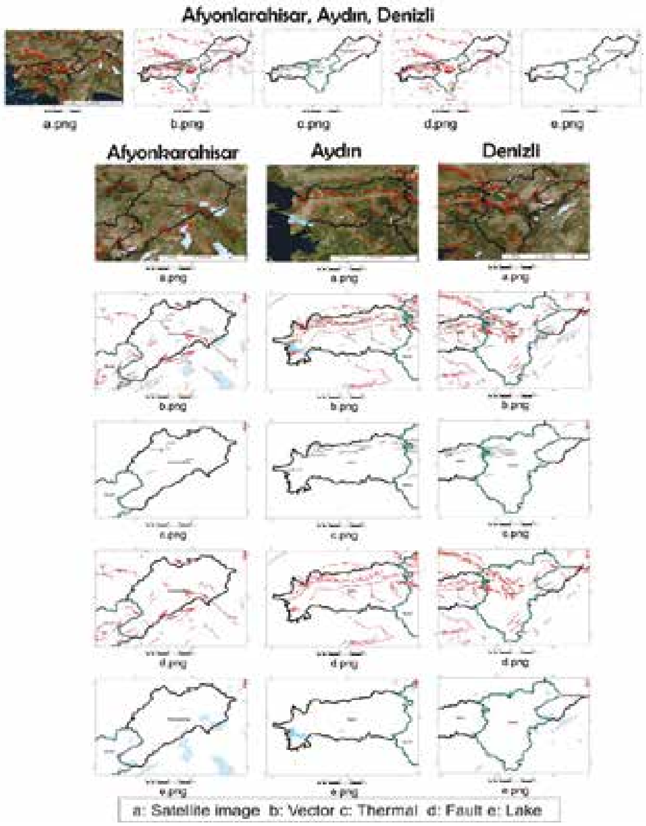

Figure 2. The stages of study area in the provinces of the Qgis program

Separate numerical maps are generated from the obtained data. Then, in the geographic information system software, these digital maps are combined. The coordinates of the greenhouses heated by geothermal energy are taken from the Provincial Directorates of Agriculture and Forestry. In determining the number of greenhouses, 5 greenhouses with approximately 10% of the greenhouses heated by geothermal energy were taken as basis for each province in the study area. These greenhouses were randomly selected before the maps were created and also the ease of access was taken into account. The locations of the greenhouses heated by geothermal energy were determined in the coordinate plane of Aydın, Afyonkarahisar and Denizli provinces.

Using the open-source Qgis program, maps of the 5 greenhouses selected for each province to the fault lines were created. From these maps, the distance of greenhouses in each province to the fault line was taken into consideration.

The selected greenhouses were considered to have the same product design and same physical characteristics and have the same initial investment and operating costs. It has been tried to determine which greenhouses have the highest and lowest geothermal heating potential.

RESULTS AND DISCUSSIONS

Maps were prepared making use of the fault lines present in the study area due to its tectonic structure as well as the potential for the heating of the greenhouses via the geothermal energy in the region.

Figure 3 shows the positions of the fault lines of the cities of Aydın, Denizli and Afyonkarahisar as well as the greenhouses heated using geothermal energy.

It was determined upon examining Figure 3 that the fault lines in the city of Aydın continue along the northern side of the city passing over to the city of Denizli to combine with the fault lines in northwest Manisa thereby forming the fault lines in the city of Denizli.

While it was determined that the fault lines in the city of Afyonkarahisar are located in some local regions and that they do not overlap with other fault lines. Figure 4 illustrates the geothermal energy potential for the city of Aydın.

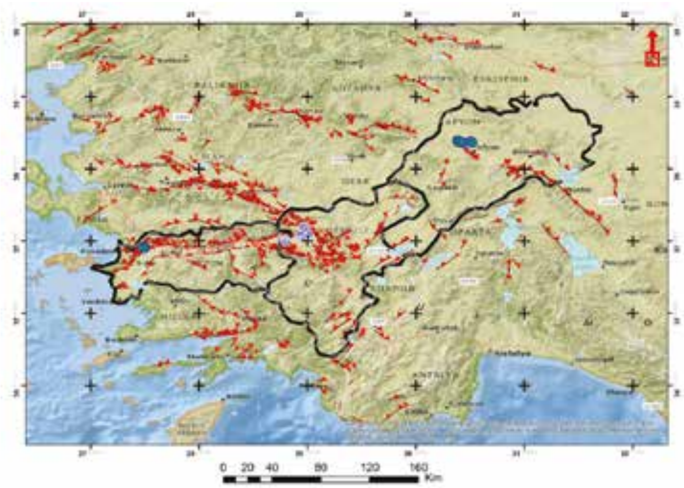

Figure 3. Location of geothermal energy heated greenhouses in the study area to fault line

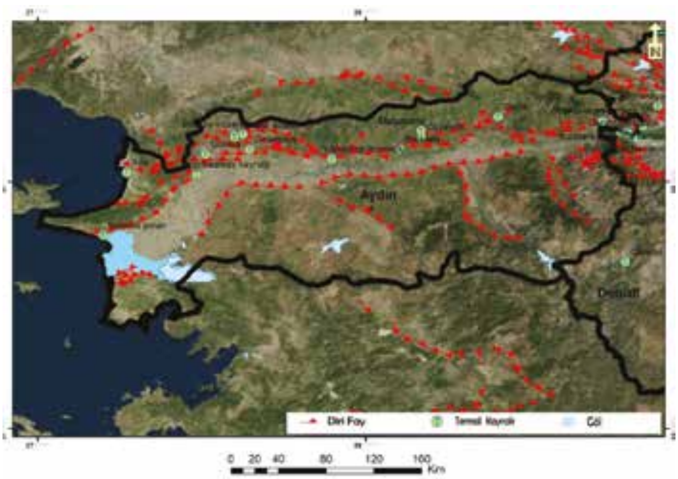

Figure 4. Geothermal energy potential map of Aydın province

It is observed that the active fault lines in the city of Aydın are concentrated in the norther part of the city and that the fault line stretches along the east-west line. It can be seen that the fault lines in the north intersect with north-south extension fault lines. It was determined that the fault lines in the city of Aydın are concentrated in thermal regions such as BozköyIlıcası, Ömerbeyli, Yılmazköy, Sazlıköy, İmamköy, Gümüş, Güvendik, Salavatlıand Malgaçemir. The geothermal energy required for heating the greenhouses can be provided in these thermal regions while it is also considered that these areas will be suited for selling the produced foods due to the proximity of these thermal regions to the city of İzmir.

Table 1 shows the distances from the fault line of the five greenhouses heated via geothermal energy selected in the city of Aydın while Figure 5 depicts the locations of these greenhouses with respect to the fault line.

Table 1. Distances from fault line of the selectedgreen houses in Aydın province

Greenhouse Number	Distance to Fault Line (km)
1	0.45
2	0.23
3	0.76
4	0.46
5	0.24

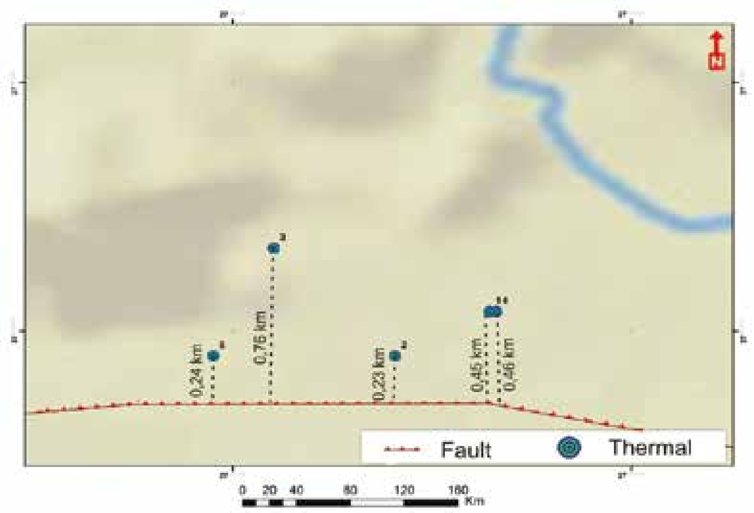

Figure 5. The location of selected greenhouses in Aydın province to fault line

It can be observed when Figure 5 is examined that the five greenhouses selected make use of the same fault line. The greenhouses heated using the geothermal energy in this fault line are observed to be as close to the fault line as possible. These greenhouses are in the Sazlıköyregion. It was determined that the fault lines in the city of Aydın are concentrated more in BozköyIlıcası, Ömerbeyli, Gümüşregions as well as Güvendik, Salavatlıand Malgaçemir. It will be possible to make use of more than one fault line in case the geothermally heated greenhouses are located in these regions. Therefore, it was concluded that a greenhouse that will be established in these regions will benefit from more than one fault line thereby having a higher heating potential in comparison with the greenhouses in Sazlıköy.

According to Tatar et al. (2006), two methods are used for the heating of greenhouses using geothermal energy. The first is to circulate the geothermal hot water inside the greenhouse by way of heating pipes and then mixing it with ground water via re-injection method, while the second is to pass the geothermal water through a heat exchanger system thereby resulting in an

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exchange of heat between the geothermal water and domestic water after which the heated domestic water is circulated inside the greenhouse by way of pipes. Heating efficiency may decrease in case of corrosion that may develop when geothermal energy is used for heating. Yıldız (2010) reported that the fluids in the geothermal sources of the city of Aydın generally have high chlorine content and that the chlorine content of the geothermal fluids in the region vary between 16-2750 mg/l and hence corrosion issues should be taken into consideration when making use of fluids with high chlorine content. It was concluded when the problems that may develop during the transmission of the geothermal fluid as well as the distances to the fault line were considered that greenhouses numbered 2 and 5 had the highest heating efficiency while greenhouse 3 had the lowest efficiency. Geothermal energy potential map for the city of Denizli is shown in Figure 6.

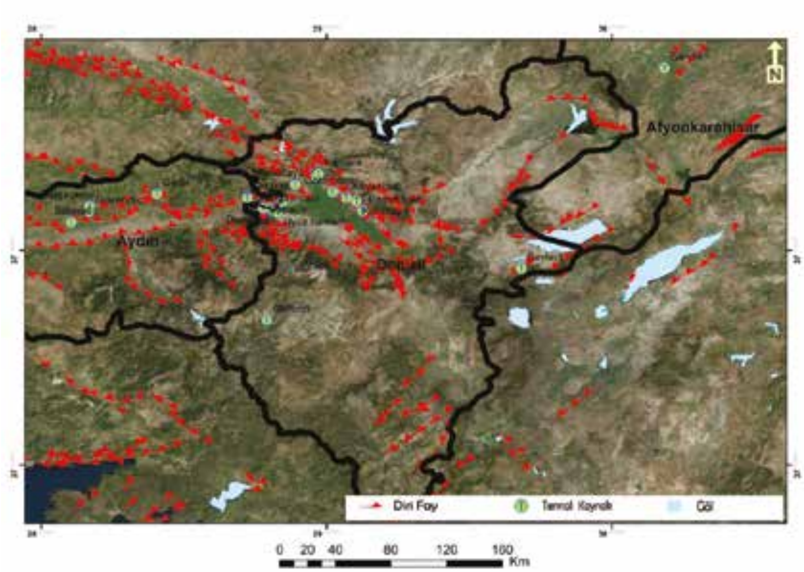

Figure 6. Geothermal energy potential map of Denizli province

It was observed that the active fault lines in the city of Denizli are concentrated to the northwest section of the city. It was also observed that the fault lines concentrated in this region are extensions of the fault lines in the cities of Aydın and Manisa and that these extensions intersect in the city of Denizli. In addition, it was also determined that the fault lines in the city of Denizli are concentrated in regions such as Bölmekaya, Ortakçı, Babacık, Kamara, Gölemezli, Kavakbaşı, Pamukkaleand Karahayıt. It was concluded that these regions may more suited in comparison with other parts of the city due to various advantages such as the high probability of acquiring geothermal energy as well as the supply and transportation of geothermal energy. Table 2 presents the distances to the fault lines of the greenhouses in the city of Denizli heated via geothermal energy while Figure 7 shows the locations of these greenhouses with respect to the fault line.

Table 2. Distance from the fault line of the selected green houses in Denizli province

Greenhouse Number	Distance to Fault Line (km)
1	1.80
2	0.23
3	1.98-2.26
4	0.90
5	2.22

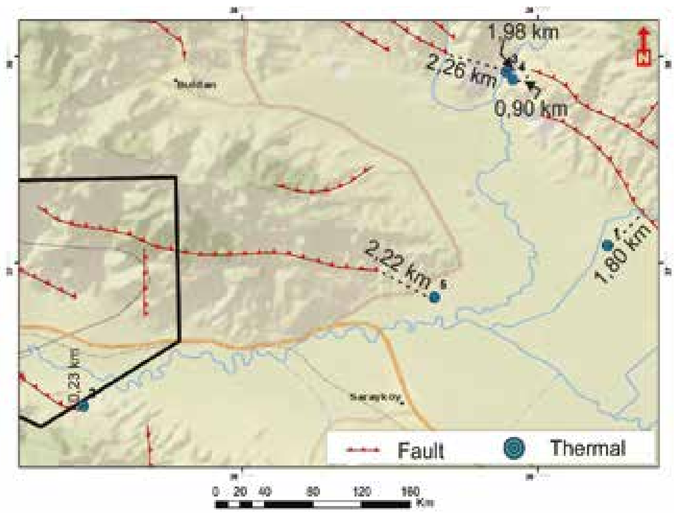

Figure 7. Location of selected greenhouses in Denizli Province to fault line

It was determined when Figure 7 was examined that the five selected greenhouses are not on the same fault line. It was also observed that the fault lines in the city are concentrated more in Bölmekaya, Ortakçı, Babacık thermal regions as well as Kamara, Gölemezli, Kavakbaşı, Pamukkale, Karahayıt thermal regions.

It was concluded that Greenhouse number 2 has the highest heating potential due to its location inside the Babacık thermal region in the city of Denizli and its proximity to the fault line from where geothermal energy will be provided in comparison with other greenhouses. It was observed that the greenhouse numbered 5 in the study area is located outside the thermal regions and that it was farthest away from the fault line among all the other greenhouses. Even though there was no numerical difference between the distances to the nearest fault lines of greenhouses numbered 5 and 3, it was determined that the greenhouse numbered 5 had the lowest heating potential since greenhouse numbered 3 can benefit from 2 fault lines.

Ataman (2007) reported that the minerals contained in the geothermal fluid result in water and soil pollution. While Akova (2008) set forth that chemical waste material in geothermal fluid such as mercury, arsenic, lead, lithium, ammoniac may cause environmental issues. It is necessary to carry out proper recycling procedures in order to prevent these harmful substances in geothermal fluids from polluting the environment. The fluid that cools during the flow of the generated hot water should be mixed with ground water by way of re-injection wells. When the probability is considered for having an insufficient number of re-injection wells in areas where the greenhouse is located, the cooled fluid should be recirculated back to the fault line from where hot fluid was obtained.

The costs that will incur during this cycle along with the environmental pollution that will occur in case of a leakage should be evaluated. It can be assumed that the greenhouse numbered 2 is more suited than the other greenhouses due to its proximity to the fault line as well as its economic advantages.

The geothermal energy potential map for the city of Afyonkarahisar is given in Figure 8.

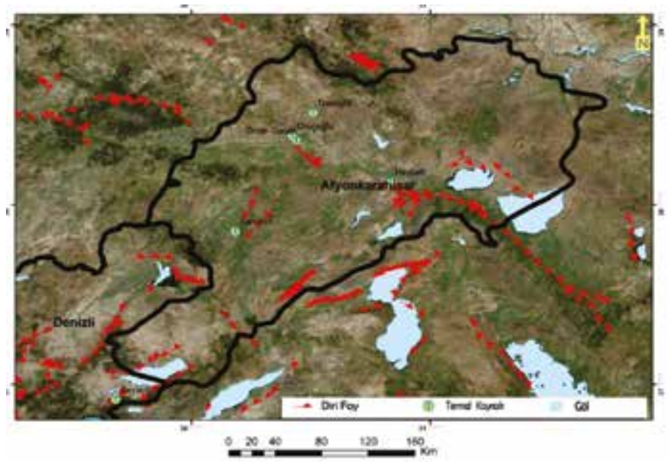

Figure 8. Geothermal energy potential map of Afyonkarahisar province

It was determined that the fault lines in the city of Afyonkarahisar are not concentrated in a specific region as was the case for the cities of Aydın and Denizli and that it has a smaller number of fault lines.

In addition, it was concluded that the greenhouses that will be established in the Heybeli thermal region in the city of Afyonkarahisar will be more suited for geothermal energy heating due to the fact that the active fault lines are concentrated in this region and that there is a greater number of natural water springs. The distances between the fault line and the greenhouses heated via geothermal energy in the city of Afyonkarahisar are given in Table 3 while the positions of these greenhouses with regard to the fault line are shown in Figure 9.

Table 3. Distance from the fault line of the selected greenhouses in Afyonkarahisar province

Greenhouse Number	Distance to Fault Line (km)
1	3.80
2	8.90
3	1.76
4	2.67
5	8.25

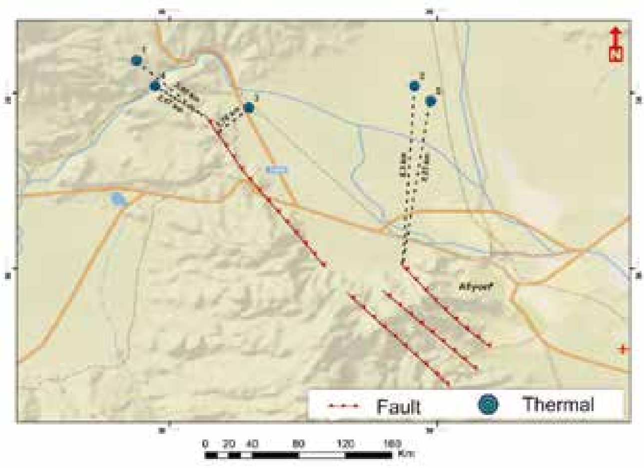

Figure 9. The location of selected greenhouses in Afyonkarahisar province to fault line

It was determined that the five greenhouses selected in the city of Afyonkarahisar are not on the same fault line. It was observed that the greenhouses are located in the thermal regions of Ömer, Geçekand Oruçoğlu and that they have different distances to the fault line.

While greenhouses numbered 1, 3 and 4 are located on the same fault line; greenhouses numbered 2 and 5 also make use of the same fault line. It was observed that there is a greater number of fault lines in the Heybeli thermal region of Afyonkarahisar when compared with the fault lines in the thermal regions of Ömer, Geçekand Oruçoğlu. It was concluded that in case the greenhouses heated with geothermal energy are established in the Heybeli thermal region, they will benefit more from the fault line in comparison with the greenhouses in the thermal regions of Ömer, Geçekand Oruçoğlu thereby resulting in a higher heating potential.

Satman (2001) suggested that the hydrological conditions in the region where the water used for geothermal energy is re-injected should be determined properly. It was also put forth that in case the re-injected water does not directly flow to the geothermal region it may spread out thereby leading to pollution issues.

The geothermal energy used for heating the greenhouses in the city of Afyonkarahisar may have adverse impacts on the water sources in case it is not re-injected properly.

Greenhouse numbered 3 was observed to be the best among the greenhouses selected in the city of Afyonkarahisar, while it was also observed that the greenhouse numbered 2 had the lowest heating potential.

Çetin (2014) reported that there is a temperature loss of about 0.1-0.3°C/km when geothermal fluid is transported by way of specially insulated pipes. This loss was determined as 0.2°C/km on average and the temperature loss that may occur in the greenhouses in the study area were calculated as in Table 4.

Table 4. Heat loss during heat conduction in selected greenhouses

Province	Greenhouse Number	Distance to Fault Line (km)	Total Temperature Loss (°C)
Aydın	1	0.45	0.09
	2	0.23	0.046
	3	0.76	0.152
	4	0.46	0.092
	5	0.24	0.048
Denizli	1	1.80	0.36
	2	0.23	0.046
	3	1.98-2.26	0.396-0.452
	4	0.90	0.18
	5	2.22	0.444
Afyonkarahisar	1	3.80	0.76
	2	8.90	0.178
	3	1.76	0.352
	4	2.67	0.534
	5	8.25	1.65

According to Table 4, temperature losses will increase with increasing distances subject to the locations of the selected greenhouses.

It can be stated based on these results that greenhouses numbered 2 and 3 have the highest and lowest heating potential in the city of Aydın, while greenhouses numbered 2 and 5 in the city of Denizli and greenhouses numbered 3 and 2 in the city of Afyonkarahisar have the highest and lowest heating potentials respectively.

CONCLUSIONS

Thermal maps were prepared and evaluated for determining the geothermal energy potentials of the selected sample greenhouses from each city in the study area. Factors such as distance, transportation losses and environmental factors have been effective in the determination of the geothermal energy potentials of these greenhouses. It was observed that the greenhouses numbered 2 and 5 in the city of

Aydın, greenhouse numbered 2 in the city of Denizli and greenhouse numbered 3 in the city of Afyonkarahisar had the best heating potential.

When it is taken into consideration that the Aegean Region is rich in geothermal energy sources and that greenhouse cultivation activities are carried out effectively, the use of geothermal energy for greenhouse heating can reduce heating costs significantly which is an important factor that increases the costs involved in greenhouse cultivation. The development of greenhouses making use of geothermal energy in Turkey will provide significant contributions to greenhouse cultivation in all regions and especially in the Aegean Region. In conclusion, we are of the opinion that the maps drawn during this study will shed light to producers who are considering the use of geothermal energy for their greenhouses in the study area.

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