Bulletin of the Mineral Research and Exploration

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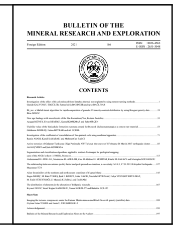

BULLETIN OF THE MINERAL RESEARCH AND EXPLORATION

CONTENTS

Investigation of the effect of fly ash released from Kütahya thermal power plants by using remote sensing methods

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Research Article

Keywords:
Ash Vegetation Interaction, Landsat 8, Seyitömer, Tunçbilek, Fly Ash.

Received Date: 23.05.2020
Accepted Date: 22.05.2021

ABSTRACT

In order to determine the long-term effect of thermal power plants, the satellite images of Seyitömer and Tunçbilek Thermal Power Plants and their vicinities were analyzed by using the software of ERDAS IMAGINE v9.1 and PCI Geomatica 2017. The normalized difference vegetation index (NDVI) was determined by using red and near-infrared bands of Landsat satellite images, and areas containing vegetation were revealed in the images. In order to obtain the temporal change in the vegetation areas, the relevant image change detection analysis was applied and the one-year and thirty-year temporal change of vegetation cover is for r = 4 km, r = 12 km, r = 50 km. In the remote sensing mapping studies, it was determined that as the diameter of the assessment area increases, the dominant wind loses its effect, and geomorphological conditions are more prominent.

1. Introduction

Our country is foreign-dependent because of energy needs and has to provide 95% of this need from neighboring countries. On the other hand, with high-speed train technology and increasing industrialization, it also provides some of this need with domestic resources. Fossil fuels such as lignite, especially in the western Anatolia found in the Neogene basins, have been used for many years. Despite climate change caused by greenhouse gases caused by the use of fossil fuels such as lignite and coal, and air pollution that directly affects human health, its use in global electricity generation continues both in our country and internationally. In their analyzes and evaluations based on the information obtained from different sources, Health and Environment Alliance (HEAL, 2018) stated that 65% of global electricity was generated from fossil fuels in 2016 and in Turkey, as of November 2018, lignite was used in 16 of 27 thermal power plants in operation and 52% of 19.9 GW coal-based installed power.

Consider the factors that may cause a decrease in vegetation; cases such as the effect of population, mining activities, climate, etc. come to mind first. While an increase is expected in the cultivated area as the population increases, there is a decrease in cultivation areas due to the reduction of population in the provinces such as Kütahya, which gives large numbers of immigrants. Due to the production methodology in mining activities, especially in open-pit mining, a reduction in vegetation areas is likely due to the removal of the cover soil. However, it is possible to see partial increases in vegetation areas with re-rehabilitation works in areas where production is completed. The impact of climate change can be

Citation Info: Kalyoncu Ergüler, G., Bayındır, M. F., Dağlıyar, A. 2021. Investigation of the effect of fly ash released from Kütahya thermal power plants by using remote sensing methods. Bulletin of the Mineral Research and Exploration 166, 1-18. https://doi.org/10.19111/bulletinofmre.946782

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evaluated by observing with longer-term studies. It has been emphasized in previous studies that thermal power plants cause environmental problems on a local scale, such as a decrease in vegetation areas in their vicinity, as well as their impact on human health and climate change. The main pollutants formed as a result of the burning of fossil fuels such as lignite used in these power plants can be listed as; carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (UOC), sulfur dioxide (SO_2), methane (CH_4) and such gases and particulate matters. Fossil fuels such as coal and lignite burned in thermal power plants cause ash and heavy metals such as cadmium, mercury, lead, arsenic, etc., contained in the ash (Kır, 2008) spread easily and quickly to the environment. In addition, sulfur, nitrogen, and carbon oxides released from the chimneys combine with water vapor in the air to form acid rain, and as a result, they mix with the groundwater and cause the stomata that control transpiration and gas exchange in the plant, not to work effectively. This condition of plant stomata can dry out the plant (Mol, 1986; Haktanır and Karaca, 1996; Ölgen and Gür, 2012). As a result of the effect of SO_2, NO_x and particulate matter released from the power plant chimneys, the fruit yield of many field crops, fruit trees, and olives in large areas may decrease significantly (Goncaloğlu et al., 2000). In the study by Haktanır et al. (2010), the effects of emissions of Muğla - Yatağan thermal power plant on the heavy metal content based on the dominant wind direction of agricultural and forest soils surrounding the plant were investigated. Karaca et al. (2009) stated in their study on the vicinity of Çayırhan thermal power plant that the total Cd values of the soils taken from the dominant wind direction are quite high compared to the soils taken from the opposite of the dominant wind direction and above the limit values of the soil pollution control regulation.

When examined as chemical composition, it is observed that fly ash consists of compounds including SiO_2, Fe_2O_3, and MgO. Fly ash surface areas are quite high and vary between 1 - 16 m^2/cm^{-3} according to grain size (Adriano et al., 1980; Schure, 1985). The amount of carbon that can be found in it varies according to the type of coal and the burning process. In addition, fly ash has been used as a raw material in various applications for over 80 years (Heidrich et al., 2013). According to the 2017 data of the Turkish Statistical Institute (TURKSTAT), a total of 19.5 million tons of waste, 87.8% of which is ash and slag, was generated in the thermal power plants. TURKSTAT (2017) stated that only 16.7% of these produced wastes were sent to waste recovery facilities and mines for filling material usage.

Subjects such as researching the effects of waste generated by thermal power plants on the environment and doing sustainable projects against possible environmental problems (Davraz and Kılınçarslan, 2020) have been studied by scientists using different methods in recent years. In this sense, in the study carried out by Akkartal et al. (2005) and Şekertekin et al. (2015), it was stated that remote sensing technology is also an effective method in terms of observing critical environmental changes. For this purpose, vegetation indices are used to determine the distribution of green vegetation on the earth and monitor the change in vegetation density. Many factors such as migration, population decrease, easy supply in developing city life, fly ash emission from thermal power plants are effective on the reduction in vegetation areas obtained in remote sensing. In order to determine the factor on the main plant decline, it is crucial to examine the wind direction, which is one of the meteorological data, to determine whether the reduction directions in the vegetation areas are related to the wind.

Ability to read satellite images by computer without the need for digitization and to be integrated with Geographic Information Systems (GIS), allowing them to be updated regularly and to monitor the changes that occur, and to display situations that the human eye cannot see with its multi-band sensors, make remote sensing methods even more important (Duran, 2007). Generally, plants absorb rays with a wavelength of 0.4 – 0.7 µm, called the visible ray region. Infrared rays, on the other hand, absorb very little and reflect a large part of it (Teillet et al., 1997). Singh et al. (1997) revealed that from 1975 to 1991, fly ash and other impacts from coal mining caused significant loss of forest cover and agricultural lands. Feng et al. (2013) analyzed the change in Wucai Wan open-pit coal mine between 2006 and 2011 based on vegetation index and Landsat TM satellite remote sensing data.

As summarized above, in international studies, many studies covering the effect of thermal power plants on plant decline and the investigation of the measures taken have been carried out until today. Also, in our country, many studies on the environmental effects of thermal power plants have been carried out in the form of soil, water and plant studies. Makineci and Sevgi (2005) investigated the effects of fly ash from the Seyitömer thermal power plant on the annual ring growth of larch trees. Akçın and Şekertekin (2016) generated pollution maps for the Western Black Sea Region with variogram models and kriging approximation in their study on the temporal investigating coal-based pollution using Landsat 8 images and geostatistical analyses for sustainable basin management. In order to investigate the air quality of Zonguldak province, Zeydan and Yıldırım (2013) examined the emission factors used in the calculation of the Çatalağzı thermal power plant emissions. The analysis of the environmental effects of Kangal and Çan thermal power plants based on their material properties was carried out by Şengül (2002) and Ilgar (2008), respectively. However, as can be clearly seen from these previous studies, it is understood that remote sensing analysis maps, which are thought to be important in terms of providing more accurate results and being less costly, are not used to investigate the effect of fly ash released from thermal power plants on the spatial change of plant reduction. Therefore, within the scope of this study, considering these limitations and the presence of 264 endemic plant species belonging to 40 plant families and many monumental trees in and around Kütahya (Tatlı et al., 1999), the release of two different fly ashes from Tunçbilek and Seyitömer thermal power plants was investigated in the remote sensing maps of the spatial variation of the plants originating from the thermal power plant. The increase or decrease in the vegetation areas with the dominant wind direction studies, the annual change with the remote sensing maps and the change in the thirty-year time period in order to compare with the situation before the thermal power plants were opened were examined.

2. Background and Geology of Study Areas

Tunçbilek and Seyitömer thermal power plants and their surroundings, located within the provincial borders of Kütahya, which provide a significant part of our country's energy needs, have been determined as the study area (Figure 1). The province of Kütahya is well-known as one of the most generous provinces in terms of many different mining activities, mainly lignite and boron, silver, magnesite, etc. Seyitömer thermal power plant is located approximately 20 km northwest of Kütahya city centre. This thermal power plant consists of four units, which were put into operation in 1973, 1974, 1977 and 1989, respectively, and has a total power of 600 MW. Tunçbilek thermal power plant is located approximately 51 km northwest of Kütahya city center, and it is nearly 36.4 km away from the Seyitömer thermal power plant. Tunçbilek thermal power plant, with an installed power of approximately 365 MW, uses about 7000 tons of lignite extracted from the Tunçbilek basin in the region (Oruç, 1999; Çiçek and Koparal, 2004).

Seyitömer lignite basin consists of Neogene aged lacustrine deposits (Sarıyıldız, 1987; Türkmenoğlu and Yavuz Işık, 2008; Özburan et al., 2012). Based on the paleontological studies, these sediments were dated as Late Miocene - Early Pliocene (Özcan, 1986). Serpentinites belong to the Mesozoic ophiolite assemblage from the basement rocks of the Seyitömer lignite basin. Basement sediments starting with conglomerate continue with base clays varying in blue-green hue. The main lignite seam, which is one of the most important sources of the Seyitömer thermal power plant, is located on the units consisting of these base sediments. On the ceiling of the main lignite seam, there is a series of clay-containing rocks such as marl. Above these units forming the ceiling series, there is an upper lignite seam with claystone, mudstone and marl interlayers. As mentioned in previous studies, the Seyitömer lignite field does not show a complicated case in terms of its geological structure since it is not under the influence of large-scale tectonic movements, and the layers generally have a low slope to the south in most of the basin. The thickness of the main lignite seam is about 16 meters, and the thickness of the upper lignite seam is about 10 meters (Sarıyıldız, 1987). The Kocayatak formation overlies the Seyitömer formation unconformably (Sarıyıldız, 1987). The Kocayatak formation generally consists of conglomerate and sandstones occurring in various components. The conglomerates are greenish grayish, less hardened and very loose. The layers of the conglomerates are thick and partly irregular, and the grains are medium and poorly sorted.

Metamorphics and ophiolitic melange constitute the basement rocks of the geological units outcropping in the Tunçbilek region. The Neogene units of the

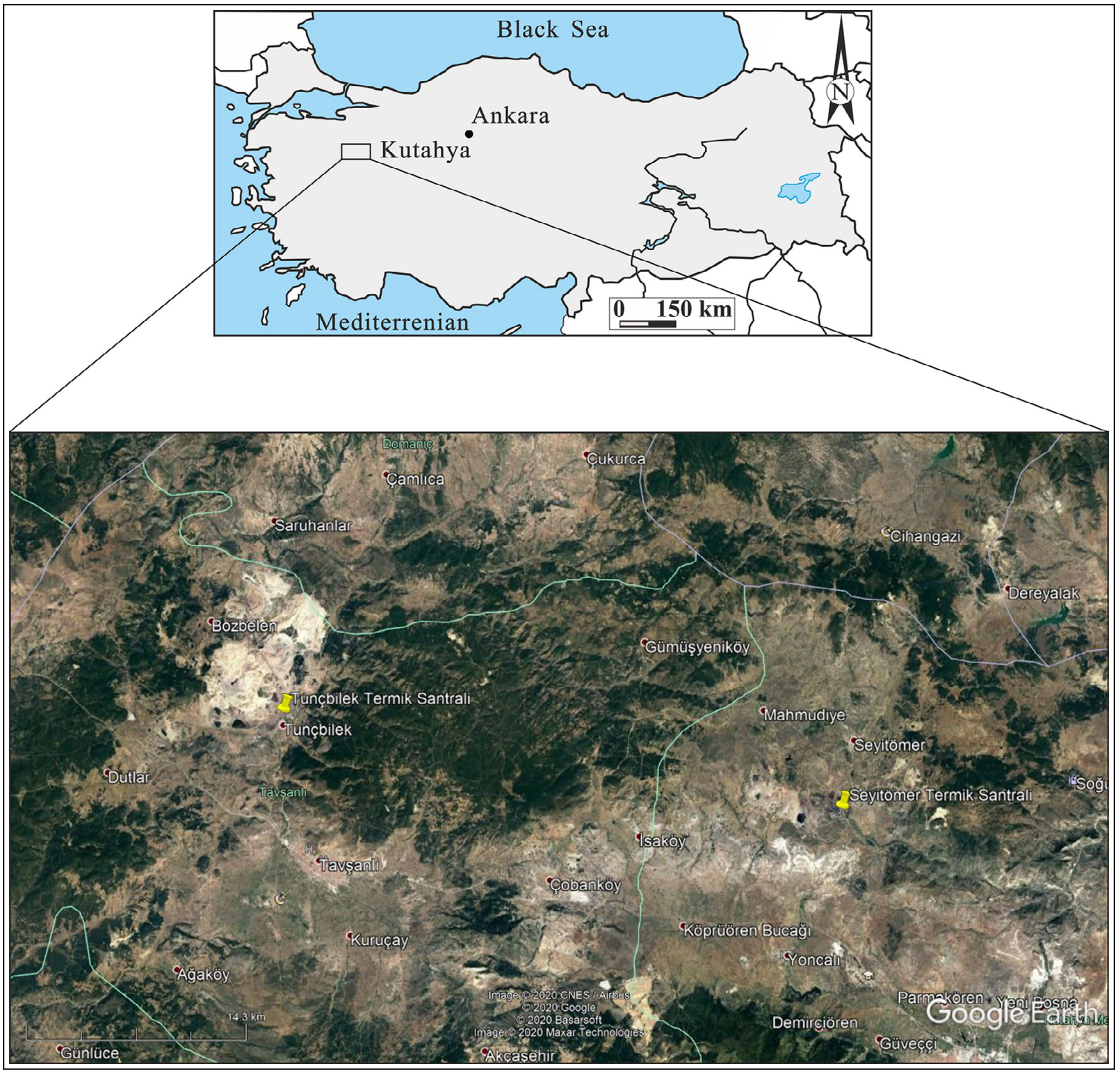

Figure 1- Location map of the study area (close-up satellite image prepared using Google Earth in 2020).

Tunçbilek basin begin with the Beke formation formed by the stream regime. The Beke formation, reaching up to 1000 m in thickness in some sections, is observed in the form of conglomerate, sandstone, mudstone and fine coal seams that thin out upwards (Çelik, 2000). It is determined that the conglomerates of this formation are generally older ophiolitic rocks. This unit is overlain by the Tunçbilek formation, which includes the economically important lignite layers in the Tunçbilek basin. As mentioned by previous researchers (Baş, 1983), the thickness of these lignite layer levels varies between 7 - 15 m. In addition, thin claystone layers are occasionally found in the lignite levels. Younger units occur an alternation of claystone and marl, which can reach up to 300 m, are located on the Tunçbilek formation, and the geological sequence in the region is complemented by clayey limestone. Lavas, tuffs, and limestones belonging to the Domanic Series are found on the top of the lignite and fine clastic sediments (Nebert, 1960).

3. Characteristics of Fly Ash Released from Thermal Power Plants

Fly ash released from Tunçbilek and Seyitömer thermal power plants was used in this study, and the ash samples are taken, typical images of the thermal power plant and its surroundings are given in Figure 2. The fly ashes taken from the Seyitömer thermal power plant generally have a composition with a high concentration of an amorphous substance, KCaFeMgAl - silicate. Fly ash grains contain silica, feldspar and Fe-oxide minerals, and the Ca and Fe content of the gray parts are low, while the Ca and

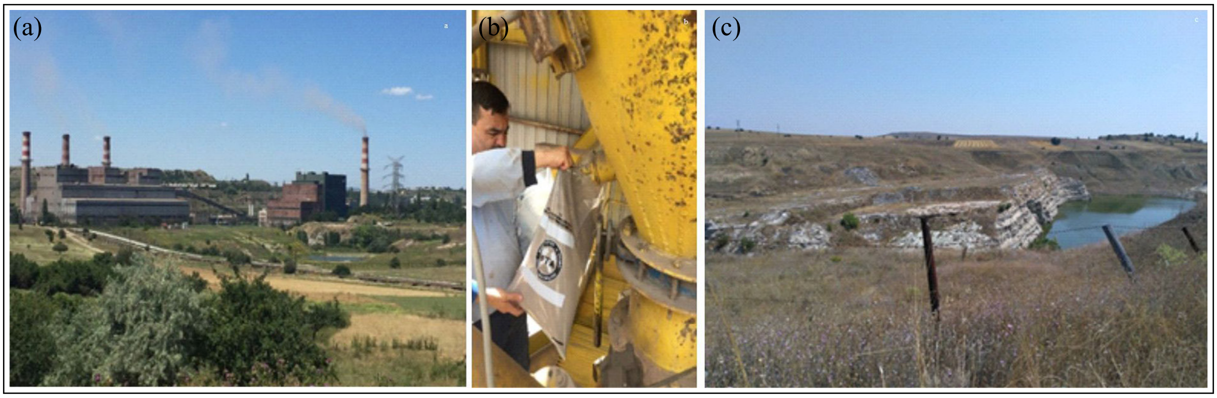

Figure 2- a) General view of the thermal power plant, b) taking the fly ash sample from the thermal chimney, and c) a general view of the area affected by fly ash.

Fe content of the white-coloured non-porous parts of the same grain are higher. Also, unburned carbon, Ca and S are present, and small amounts of pentlandite, apatite, melilite and Ti-Oxide have been observed. The detected mullites contain small amounts of Mg, K, Fe. The fly ash released by the Tunçbilek thermal power plant was commonly found to be an amorphous and MgAl - silicate composition. There is relatively more Fe, Ca and lesser amounts of Na, K and Ti. Mullite and albeit a little micron-sized ankerite, Ni-Sulfur containing traces of Co and Fe, FeAl - Oxide (spinel / hersinite), rutile and ilmenite were determined in the fly ash. The major element analyzes on fly ash samples taken from Tunçbilek and Seyitömer thermal power plants and analyses for determining their physical properties were carried out in MTA laboratories. The values and physical properties of the major elements obtained from the analyzes made in the XRF spectrometer are presented in Table 1. The physical properties of fly ash are the most important parameters that carry out transport, and the effect it gives to the environment varies in proportion to the amount of heavy metal it contains.

4. Meteorological Data and Vegetation

Although Kütahya is located in the Aegean Region, its climate is quite different from the coastal Aegean, depending on the distance from the sea and the altitude. The climate of Kütahya and its surroundings are transitional with the Aegean, Central Anatolia and Marmara climates. Based on climate and temperature conditions, it covers the characteristics of the surrounding regions, its temperature characteristics are more like Central Anatolia and its precipitation characteristics resemble the Marmara Region. The monthly variation of the average meteorological data of Kütahya province between 1929 - 2019 was obtained from the Turkish State Meteorological Service (TSMS) and presented in Table 2.

Considering the records given in Table 2, it is understood that Kütahya has a hot and dry climate in summers and a cold and rainy climate in winters. The annual average temperature in the region was 10.7º and the highest measured temperature was 39.5º. It was determined that the lowest temperature measured in Kütahya between the relevant dates was -28.1º. The

Table 1- Major element values and physical properties of fly ash emitted from Tunçbilek and Seyitömer thermal power plants.

Major element											
Central	A.Za. (%)	Al_2O_3 (%)	SiO_2 (%)	Fe_2O_3 (%)	Cr_2O_3 (%)	CaO (%)	K_2O_3 (%)	MgO (%)	Na_2O (%)	SO_3 (%)	SiO_2 (%)
Seyitömer	2.21	24.01	37.18	6.27	0.02	3.06	2.1	3.22	0.60	0.32	21.01
Tunçbilek	1.49	11.87	41.57	9.21	0.01	1.39	0.98	3.72	0.32	0.56	28.88

Physical properties				
Central	Grain size (µm)	Specific surface area (m^2/g)	Density (mg/m^3)	pH
Seyitömer	0.5-17.0	0.36	2.14	8.3
Tunçbilek	1.0-22.0	0.38	2.25	8.1

Table 2- Monthly variation of the average meteorological data for Kütahya 1929 - 2019 (TSMS, 2020).

Meteorological data	January	February	March	April	May	June	July	August	Septemper	October	November	Decemper	Annual
T (°C)	0.3	1.7	4.9	9.9	14.5	18.2	20.7	20.7	16.6	11.8	6.8	2.3	10.7
$T_{avg-max}$ (°C)	4.6	6.6	10.8	16.2	21.1	25.0	28.0	28.3	24.5	19.0	12.7	6.5	16.9
$T_{avg-min}$ (°C)	-3.3	-2.4	-0.1	3.8	7.8	10.8	13.0	13.0	9.1	5.5	1.9	-1.1	4.8
S (hour)	2.3	3.4	4.6	6.1	7.5	9.3	10.3	9.6	7.6	5.2	3.6	2.1	71.6
P_{day}	14.6	13.1	13.0	11.6	12.2	8.1	3.9	3.3	4.7	8.3	10.0	14.2	117.0
P_{top}	72.2	59.2	57.1	50.4	55.9	38.9	19.7	17.7	23.3	41.1	49.2	78.1	562.8
T_{max} (°C)	17.1	24.2	27.0	30.2	33.8	36.2	39.5	38.8	36.1	31.6	25.4	21.7	39.5
T_{min} (°C)	-26.3	-27.4	-16.6	-7.8	-2.8	0.5	2.6	-0.2	-3.9	-6.9	-11.0	-28.1	-28.1

T: average temperature. $T_{avg-max}$: average highest temperature. $T_{avg-min}$: average lowest temperature. S: average sunshine duration. P_{day}: average number of rainy days. P_{top}: average monthly total precipitation. T_{max}: highest temperature. T_{min}: lowest temperature.

wettest and driest months in the region are December and August, respectively and the annual average precipitation was recorded as 565 mm. It has been determined that 38.8% of these precipitations occur in winter, 29.4% in spring, 12.5% in summer and 19.3% in autumn. In winter, precipitation is generally in the form of snow due to the low temperature and high altitude while it is observed as rain in other seasons. The annual average number of snowy days is 19 days and the average snow thickness is around 12 cm.

As indicated in previous studies, wind speed and direction are the most important input parameters that are effective in the transport of fly ash released from thermal power plants. Considering the importance of these parameters in terms of fly ash transport, the records from the 17155 coded meteorology stations between 2010 and 2016 were evaluated. Based on these records, it was determined that the dominant wind direction was effective in all directions, especially N, NW, and NE. Although the dominant wind direction is similar in spring, summer and autumn periods. It has been determined that the E and SE winds are more dominant in the winter months (Figure 3). For Kütahya, the average wind speed was determined as

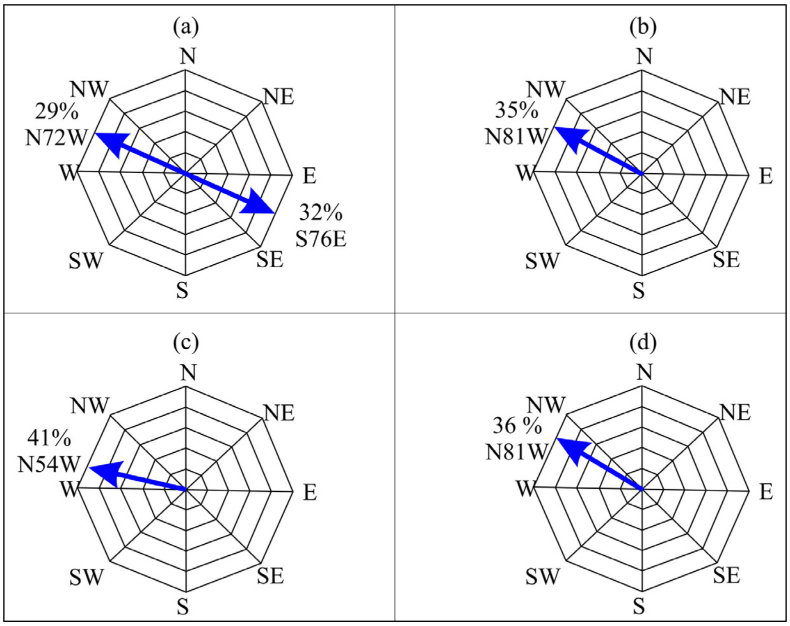

Figure 3- Kütahya province dominant wind direction diagrams; a) winter, b) spring, c) summer, and d) autumn (modified from Karpuz, 2015).

1.7 m/s when all seasons were evaluated with 5% frequency of 0 - 2 km/h calm breezy winds in annual and seasonal wind roses. 11% frequent north and northeast winds in the summer. It was determined that the highest measured wind speed was 27.6 m/s and it belongs to the northwestern wind. Since the winds at low speeds observed in Kütahya will not contribute much to the horizontal transport of emissions from air pollution sources. They will be more effective in the region where pollution occurs at these speeds. Air pressure around Kütahya varies between 873 and 928.4 millibars with an average value of 904.7 millibars. Karpuz (2015) examined the climate of Kütahya province between 1971 and 2014 in his study.

Kütahya has an area of 1.279.000.000 hectares. and 611.592.000 hectares of this area are forests. According to Tatlı and Tel (1999), 52.97% of the province comprises forest areas while the proportion of forests in the plateaus is around 2 - 3%. 296.644.000 hectares of forest areas can be defined as productive forests with an economic value of 48%. Nearly half of the trees are larch. The rest is 14% oak, 6% juniper, 5% red pine, 2% beech and rarely cedar, alder, chestnut, poplar, fir as listed according to the degree of density. On the other hand, steppe plants such as poppy, sagebrush, sorrel, shepherd's purse, snapdragon are also commonly observed (Tatlı et al., 1999). As altitude increases, temperature and relative humidity decrease, and precipitation, evaporation, daily temperature differences and radiation intensity from wind and sun increase in general. In addition, with the increase in height the vegetation and soil formation period is shortened. The effect of topography on plant life depends on the exposure as well as altitude. It has been mentioned in previous studies (Aydınözü, 2008) that tectonic movements as well as the river network play an important role in the change of morphology in the region.

5. Remote Sensing Studies

Landsat is a series of earth observation satellites that was launched with the name of Earth Resources Technology Satellite by the United States on 23 July 1972 Landsat 1 sent to space by NASA in 1972 can make land mapping by 3 multispectral bands in the near - infrared region. The dimensions of the images taken from these satellites are 170 x 183 km. Landsat 8 is the latest launched (in 2013) Landsat satellite and carries Operational Land Imager (OLI) and the Thermal InfraRed Sensor (TIRS) devices. The data obtained from uninterrupted space-sourced earth images in over fifty years are very commonly used in application areas such as mining, geology, forestry, city - region planning, oceanography, land applications and field change determinations. Used images were provided from the web page of the United States Geological Survey (USGS).

In this study, Seyitömer and Tunçbilek thermal power plants and their surroundings are examined by using remote sensing data and techniques. Landsat MSS image dated 1987 and Landsat 8 OLI/TIRS image dated 2017 were used. Information on satellite images is given in Table 3. Satellite images were analyzed by using the Global Mapper 12 ERDAS IMAGINE v9.1 and PCI Geomatica 2017 software and mapped to 1/250.000 scale with the ArcMap v9.2 software by performing geometric and atmospheric corrections.

Table 3- Satellite information of Landsat MSS and 8 OLI/TIRS used in the study area.

Image Name	Granul ID - Path/Row	Date
Landsat MSS	LM05_L1TP_179032	30.06.1987
	LM05_L1TP_179033	30.06.1987
	LC08_L1TP_179032	02.07.2017
Landsat 8 OLI/TIRS	LC08_L1TP_179033	02.07.2017
	LC08_L1TP_179032	05.07.2018
	LC08_L1TP_179033	05.07.2018

6. Research Findings

The remote sensing methods have a great importance in determining the information to be used in the correct determination, usage and protection of natural resources, ensuring balanced and sustainability, multi-faceted use and approaches that can adapt to environmental changes in the long term. With today's conditions, the right decisions can be made in a short time with less costs.

The Landsat 8 OLI / TIRS images were mapped by using pseudo-color composites in order to observe the vegetation areas in the study area. Red hues in pseudo-color composite images show the flora. The 2018 dated Landsat 8 OLI / TIRS image used in the study indicates a cloud and its shadow. To analyze the correct vegetation, the water, cloud and cloud shadows in the images were masked and were not included in the analysis. By using the red and near-infrared bands of the Landsat satellite images, the normalized plant diversity index was calculated and the areas containing vegetation were revealed in the images. The plant areas are shown with a red colour in Figures 4a and b by using pseudo-color composite (KYM: 543) on the Landsat 8 OLI / TIRS images. Normalized plant difference index maps obtained for Landsat 8 OLI / TIRS images are given in Figures 4c and d. NDVI parameters are shown in Table 4. Among the parameters required for the temporal variation technique; i) two satellite images with different dates covering the same area, ii) the same resolution value, and iii) having the same projection information are provided in this study in order to obtain the temporal change in the vegetation areas of the study area. Change detection analysis was applied by using the

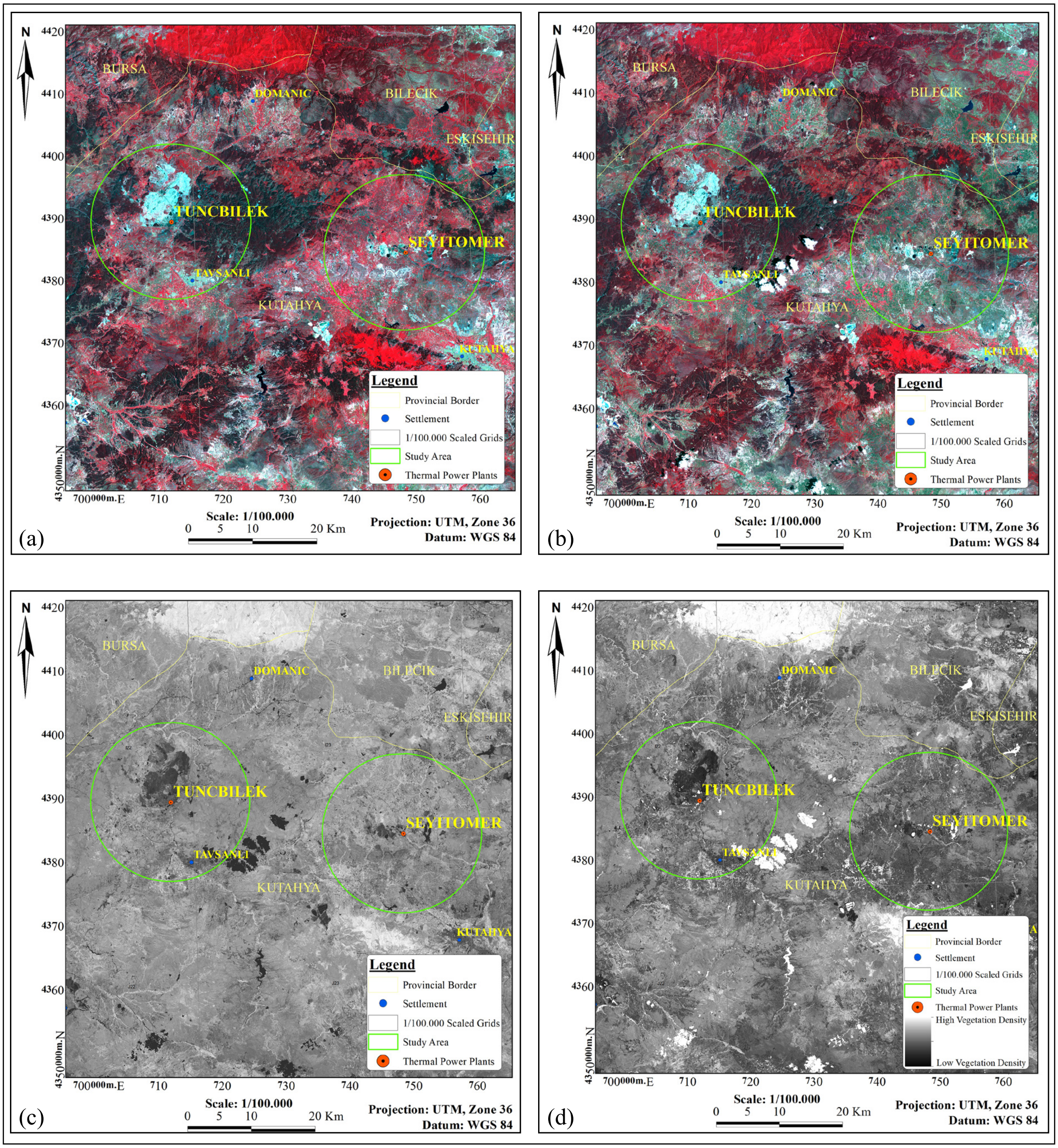

Figure 4- 1/100.000 scale false color composite (KYM: 543) of Landsat 8 OLI / TIRS images; a) 2017, b) 2018 and normalized plant diversity index maps, c) 2017 (threshold value = 0.51) and, d) 2018 (threshold = 0.47).

relevant images and the 1-year temporal change of the vegetation was obtained. Very light (white and near-white) and dark (black) tones emphasize the changes of vegetation over time. Lighter tones indicate an increase in the plant while darker tones indicate a decrease in the plant.

Table 4- NDVI parameter findings belongs to the examination area.

Parameters	NDVI 2017	NDVI 2018
Arithmetic Mean	0.251449	0.2264444
Standard Deviation	0.163527	0.151905
0.5 sigma	0.3332125	0.3023969
1 sigma	0.414976	0.3783494
1.5 sigma	0.4967395	0.4543019
2 sigma	0.578503	0.5302544
2.25 sigma	0.6193848	0.5682307
2.5 sigma	0.6602665	0.6062069
3 sigma	0.74203	0.6821594
Mask	Vnir Mask	Vnir Mask
Threshold Value	0.51	0.47

NDVI is a standard and effective method that is one of the important classification methods widely used in determining land cover and land use changes (Lyon et al., 1998; Rouse et al., 1974). The NDVI positive values indicate active vegetation while values are close to zero or negative represent other types of material. Accuracy analyses were carried out including both conditions considering the field of study with and without vegetation. 40 points were determined on the Google Earth program. 20 of which were vegetated and 20 of which were not vegetated (Figure 6). The 2017 and 2018 NDVI images were classified into two groups: i) the vegetated area above and below the threshold value and ii) the non-vegetated area below the threshold value. The characteristics of the NDVI images and the characteristics of the points taken from Google Earth were combined in the same table and their differences were taken. According to this, the accuracy of the 2017 NDVI image is 67.5% while the accuracy of the 2018 NDVI image is 62.5%. Since it is taken into consideration that the dates of the Google Earth image and NDVI images are different. The accuracy percentages for the same possible dates are going to be higher and therefore the comparison is going to be quite meaningful.

As Erener (2011) stated in her study when traditional data collection methods and remote sensing studies are compared, changes in plant areas can be determined with a clearer and lower cost in environmental conditions. Mondal et al. (2016) stated the change according to the dominant wind direction in their study to interpret the effect of a thermal power

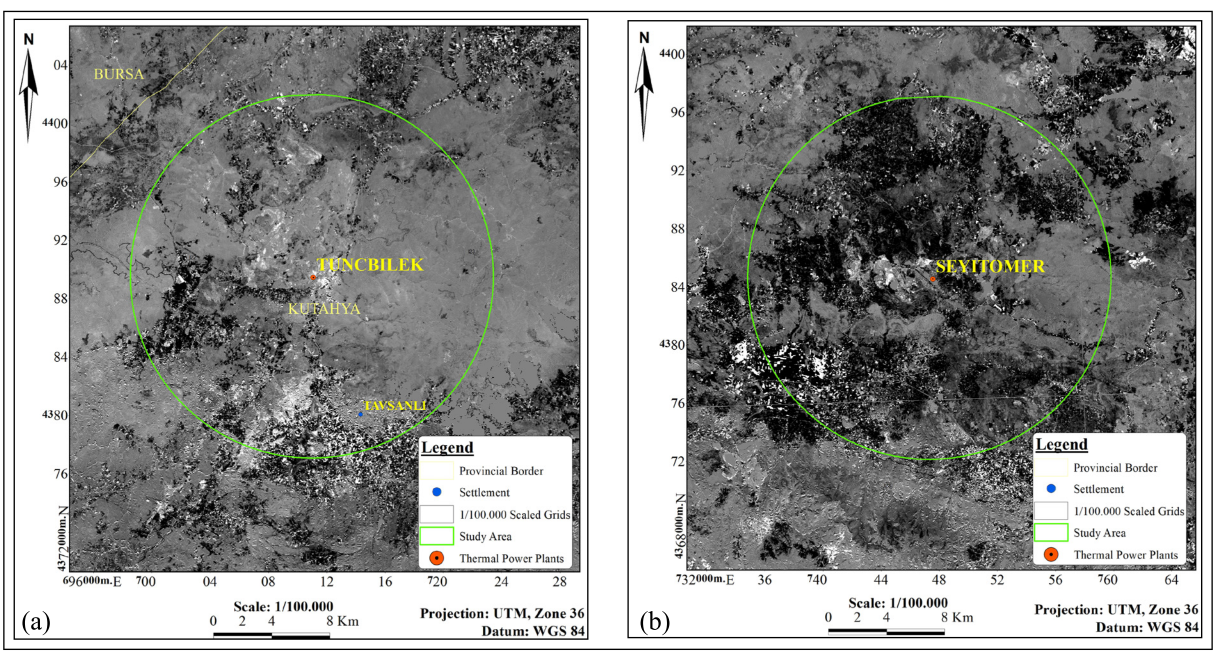

Figure 5- 1/50.000 scaled temporal change map of ; a) Tunçbilek and, b) Seyitömer thermal power plant and its surrounding vegetation obtained from Landsat images dated 2017 and 2018.

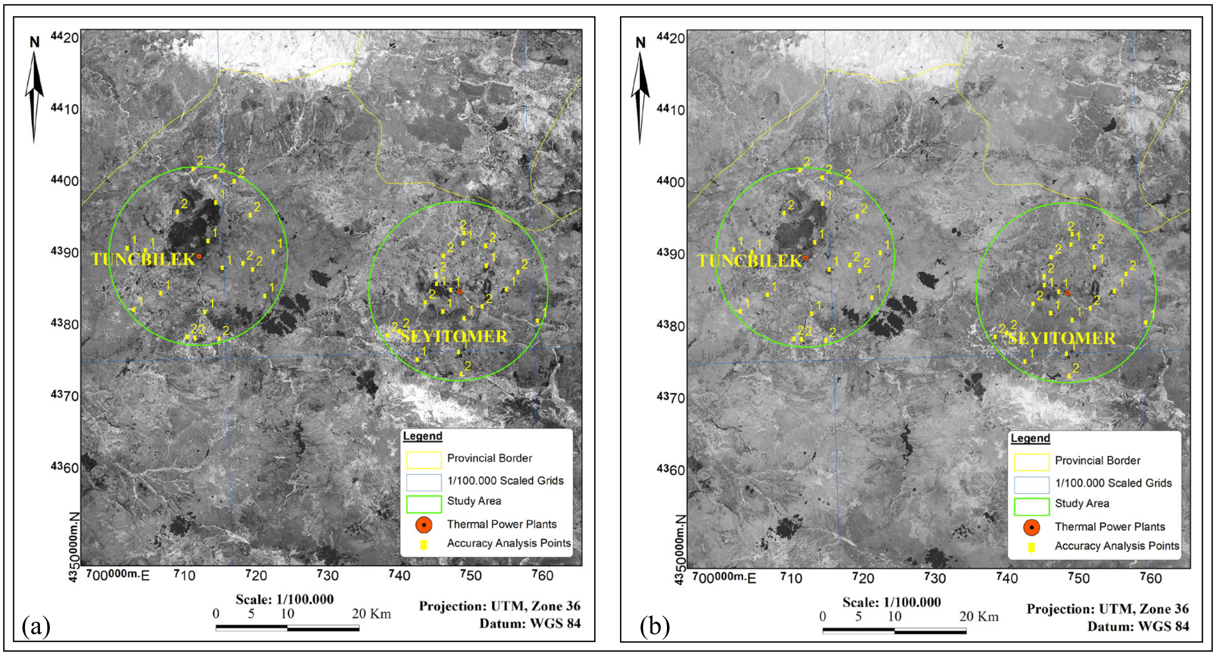

Figure 6- Accuracy analysis points shown on the 1/100.000 scaled normalized plant diversity index maps of Landsat 8 OLI / TIRS images of ; a) 2017 and b) 2018.

plant in Kolaghat on the vegetation and soil in the surrounding areas. For the one-year change finding within the scope of this study; the decrease in the vegetation areas on the map obtained as a result of the temporal variation technique applied to the images dated 02.07.2017 and 05.07.2018 were calculated by means of remote sensing techniques considering the spatial resolutions of the satellite images (Figure 5). The direction of change in plant areas was determined with the help of the ArcGIS program - Polar Plots application and shown with the direction diagram in Figure 7. The decrease in the vegetation areas in Tunçbilek and its surroundings is N - S oriented and is shown in Figure 7a with green. The increase in the plant areas observed in this vicinity was determined to be predominantly N30° E - S30° W oriented, and N - S and N45° E - S45° W oriented in the second degree. According to this, while a decrease of approximately 65.8 km^2 was observed in the plant areas in Tunçbilek and its surroundings (Figure 7a; black areas), 8.9 km^2 increase was determined (Figure 7a; white areas). The increase in the vegetation areas in Seyitömer and its surroundings is N30° W - S30° E oriented and shown in Figure 7b with red while a decrease of approximately 250 km^2 was observed in the plant areas around the same thermal power plant (Figure 7b; black areas). It was determined that there was an increase of 5.8 km^2 (Figure 7b; white areas). The decrease in the vegetation areas in Seyitömer and its surroundings is N - S directional and is shown in Figure 7b with green.

In this study, a period of thirty years has been examined by using remote sensing data and techniques covering the area which includes Seyitömer and Tunçbilek thermal power plants and their surroundings. For this long process time period, the 1987 Landsat MSS image and the 2017 Landsat 8 OLI/TIRS image were used. The satellite images were analyzed using ERDAS IMAGINE v9.1 and PCI Geomatica 2017 software and mapped at 1/250.000 scale with ArcMap v9.2 software. In the study, the temporal vegetation change analysis map obtained by

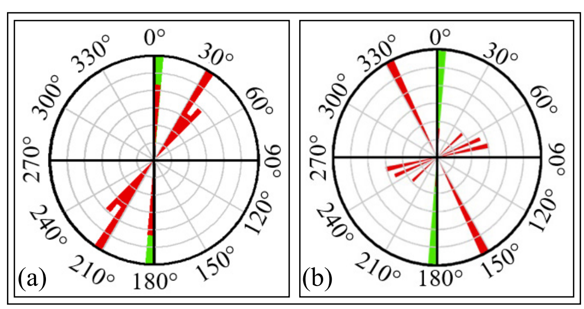

Figure 7- Rose diagrams showing the increase and decrease in the plant areas in and around the thermal power plant; a) Tunçbilek power plant and, b) Seyitömer power plant.

using Landsat satellite data dated 1987 and 2017 is given in Figure 8.

The decrease in the vegetation areas on the map obtained as a result of the temporal variation technique applied to the images dated 30.06.1987 and 02.07.2017 used within the scope of the project was calculated as 1137 km^2 in a radius of approximately 50 km with the help of remote sensing techniques applied considering the spatial resolutions of the satellite images. Among the necessary parameters for the temporal variation technique: i) two satellite images with different dates covering the same area, ii) the same resolution value and, iii) having the same projection information were taken into consideration in the analysis studies. In order to obtain the temporal change in the vegetation areas of the study area, change detection analysis was applied using the relevant images and the 30-year temporal change belonging to the vegetation was obtained. Very light (white and near-white) and dark (black) tones emphasize the change of vegetation over time. While lighter tones indicate an increase in the plant, darker tones indicate a decrease in the plant. This area is shown with dark colored areas in Figure 8. The direction of change in the plant areas was determined with the help of the ArcGIS program

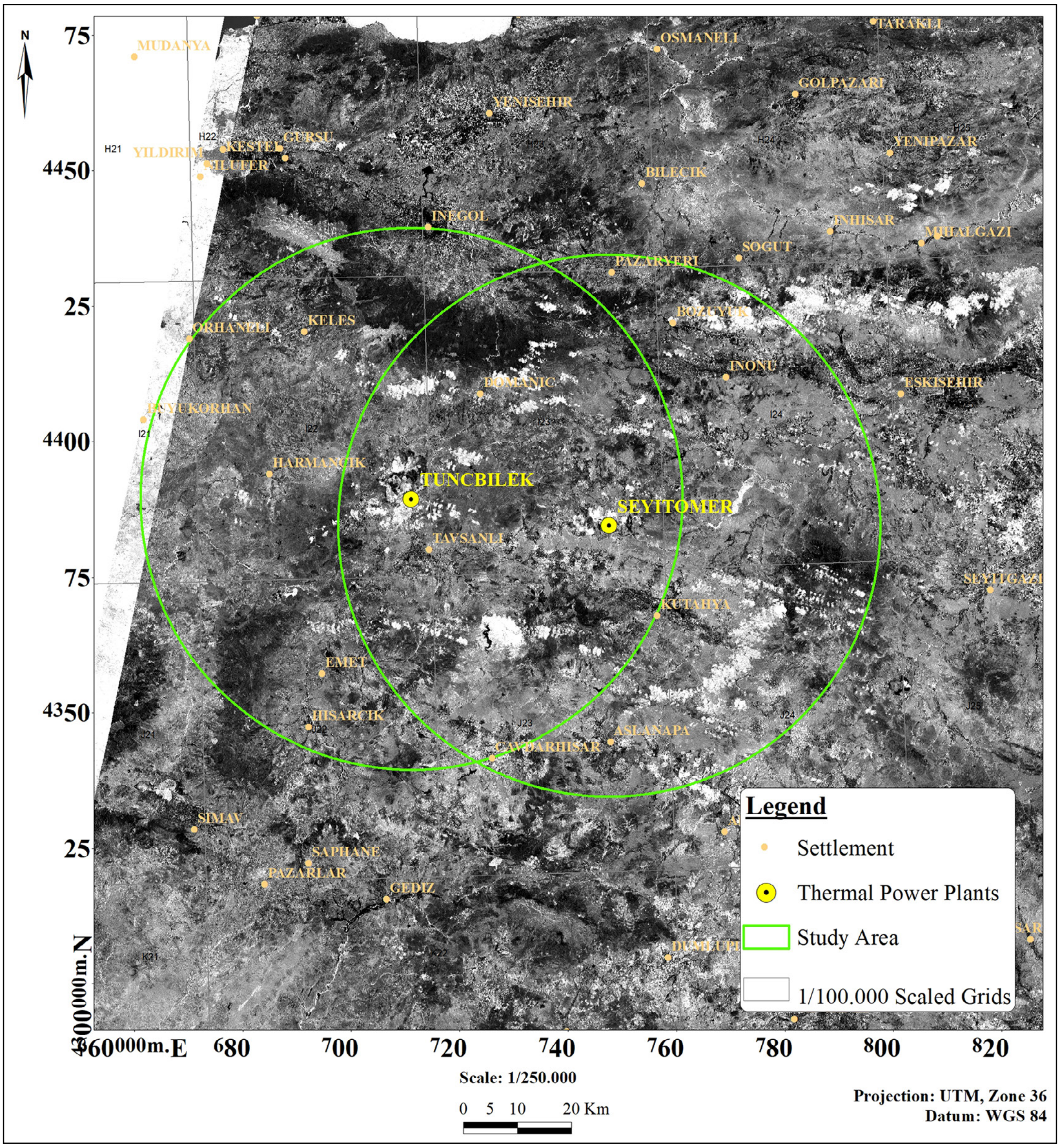

Figure 8- Temporal variation map of vegetation obtained from Landsat images dated in 1987 and 2017.

- Polar Plots application. and the directional diagrams of Seyitömer and Tunçbilek thermal power plants are shown in Figure 9 and Figure 10, respectively.

There could be many reasons for reductions in plant areas obtained in remote sensing; migration, population decrease, lack of soil cultivation that requires more labor due to easy supply in the developing city life, fly ash emissions from thermal power plants. etc.

In order to determine the main factor, it was necessary to examine the wind direction. which is one of the meteorological data in order to determine whether the reduction directions in the plant areas are related to the wind. With this method, it provides the most obvious view of the long-term effect. It has been determined that there has been a decrease of 1137 km^2 in a radius of approximately 50 km in a 30-year period in the plant areas around Seyitömer thermal power plants. The direction of change in plant areas was determined with the Polar Plots application and shown with a directional diagram. The decrease in the plant areas in and around the thermal power plants is in the N - S direction and it has been determined that it has similar characteristics with the dominant wind direction in the region.

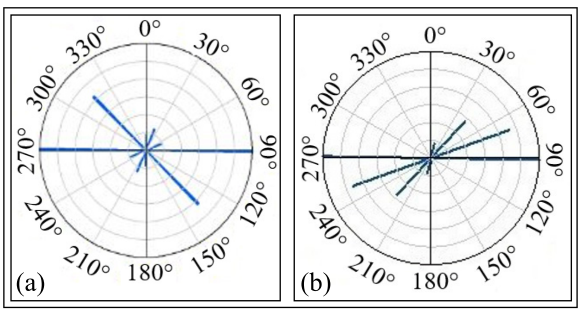

Figure 9- a) Direction diagram showing the total change in plant areas around Seyitömer and, b) Tunçbilek thermal power plants (r=50 km, thirty years change).

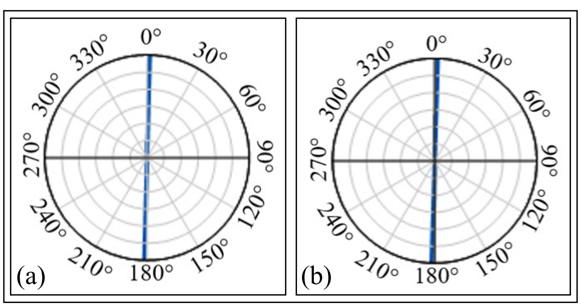

Figure 10- a) Direction diagram of Seyitömer (azimuth N number in the area; 370) and, b) Tunçbilek (azimuth N number in the area; 290) showing the total change in the plant areas around the thermal power plants (r=4 km. 2017 - 2018 years between and shown in the bearing method).

7. Discussion

Keser (2002) stated that Kütahya's basin geomorphology and slope (orographic) lines extending perpendicular to the dominant wind direction constitute the main topographical negativities. Similarly, dynamic origin inversion formations are controlled by the geomorphological structure, high local pressure values and humidity in winter months when the amount of emissions increases. accumulation of industrial emissions on the city and the low number of days with strong winds are considered as the main climatic negativities that increase the effects of air pollution in the city (Keser, 2002). Karpuz (2015) examined the climate of Kütahya province between 1971 and 2014 in his study. The study includes the meteorological data covering the year 2019 also shows that the dominant wind direction is compatible with Karpuz (2015).

The effect and orientation of unwanted particles for geomorphological data which contains important information in terms of environmental management with remote sensing maps has been examined within the scope of this study. Within the scope of the study, a three-dimensional (3D) digital elevation model (DEM) was created with the help of Landsat satellite images of Tunçbilek and Seyitömer thermal power plants using a 3’ x 3’ resolution digital elevation model produced by using SRTM (Shuttle Radar Topography Mission) data supported by local altitude information. In the specified digital elevation model, SRTM data digitized from 1/25.000 scale topographic maps and supplemented with elevations produced by interpolation technique were used. The digital elevation model of Tunçbilek and Seyitömer thermal power plants and their surroundings is given in Figure 11. The digital elevation data used within the scope of the study were converted to the UTM - WGS84 projection system and a 3D model of the field was obtained in the ArcGIS / ArcScene program together with the Landsat satellite images.

There are 22 settlements around Seyitömer and Tunçbilek thermal power plants and around 10.000 people live in these settlements. It is thought that

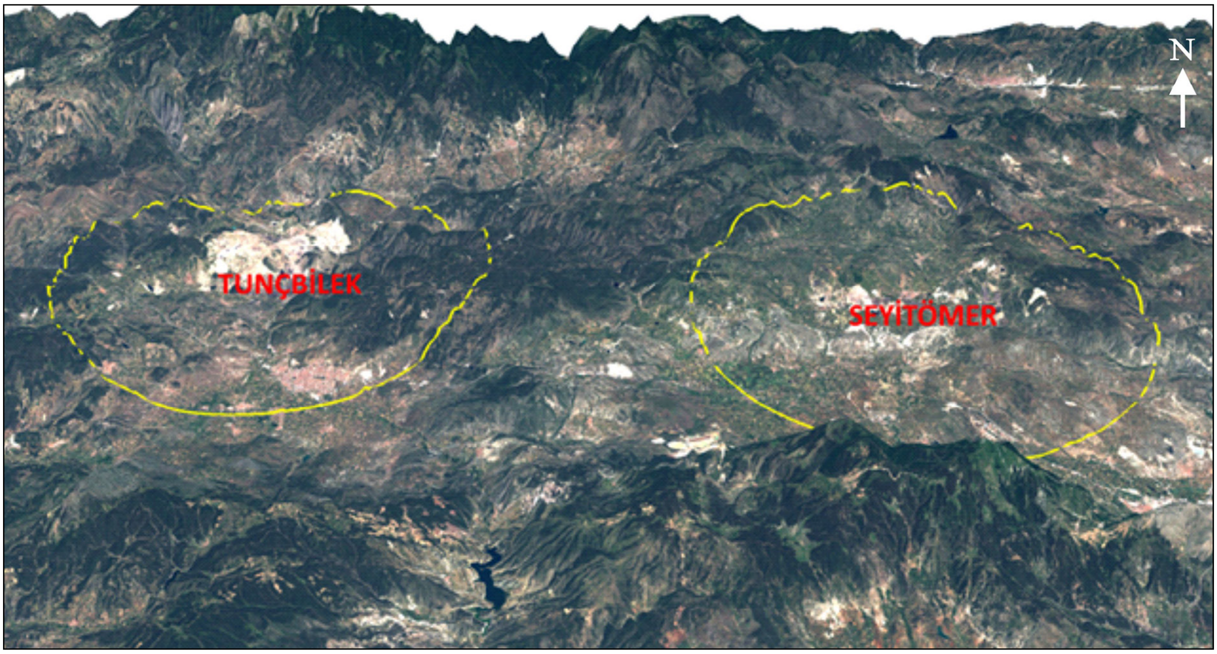

Figure 11- Physical factors seen in the digital elevation model of Tunçbilek and Seyitömer thermal power plants and their surroundings.

this population will be affected by the possible environmental problems of the thermal power plants in the region. Air pollution emissions of Seyitömer thermal power plant; particulate matter 650 - 1330 kg/hr. SO_2 8000-18000 kg/hr, NOx 1600-3600 kg/hr, CO 80-180 kg/hr, volatile organic compounds 10 - 24 kg/hr, CH_4 average 4-9 kg/hr. It has been determined that the amount of SO_2 given to the air is very high (Çiçek et al., 2001). The SO_2 emission of the Tunçbilek thermal power plant is 3.30 g SO_2/106 cal and the upper limit value was determined by the Enviromental Protection Agency (EPA,1991) as 2.20 g SO_2/106 cal. Çiçek and Koparal (2004) stated that both thermal power plants were among the two hundred largest SO_2 pollutants in Europe in 2004. The pollutant emissions of the 11^{th} - ranked Seyitömer thermal power plant are 149 kt SO_2, 20 kt NOx. 4 Mt CO_2 and 0.1 kt PM per year. Tunçbilek thermal power plant is in the 56th place with pollutant emissions measured as 43 kt SO_2, 8 kt NOx, 2 Mt CO_2 and 10.1 kt PM per year (Barret, 2004). In addition, SO_2 pollution reaches even higher values in Kütahya city center due to the use of coal for heating purposes, especially in winter. When looking at the values of four years between 1998 and 2001 (Makineci and Sevgi , 2005). It is emphasized that the SO_2 value can rise up to 450 µg/m^3. The annual average values vary between 148 and 201 µg/m^3 and these values are well above the limit values for plant growth. As a result of the literature research, it has been determined that the environmental effects of the lignite - based thermal power plants are the most effective in the first 4 - 5 km of the power plant and the effects of the power plants are minimized between 20 - 25 km (Haktanır and Karaca, 1996; Mol. 1986; Akbay et al., 2011; Güleç et al., 1999). Güleç et al. (1999) in their study on the suspended particulate matter and SO_2 content in the air with the ISCT computer model in order to determine the environmental impact of Seyitömer thermal power plant ash stated that no regional pollution occurred and was limited to Bozcahöyük and Kınık villages.

Bajpai et al. (2010) found that wind direction plays an important role in distributing heavy metals. On the other hand, Shahzad Baig and Yousaf (2017) stated that the fly ash released from thermal power plants could be transported between 40 - 50 km even at low wind speeds. Feng et al. (2013) stated that the average distance affected by fine coal ash is about 3.2 km. Bajpai et al. (2010) found that the wind direction plays an important role in the distribution of heavy metals. Considering the results obtained in these studies, what kind of effect will occur on a wider scale has been examined within the scope of this research. In Figures 12 and 13, the temporal changes in the vegetation, which were made by taking thermal power plants in the center, were examined at a radius of 12 km and 50 km. respectively and it was determined that

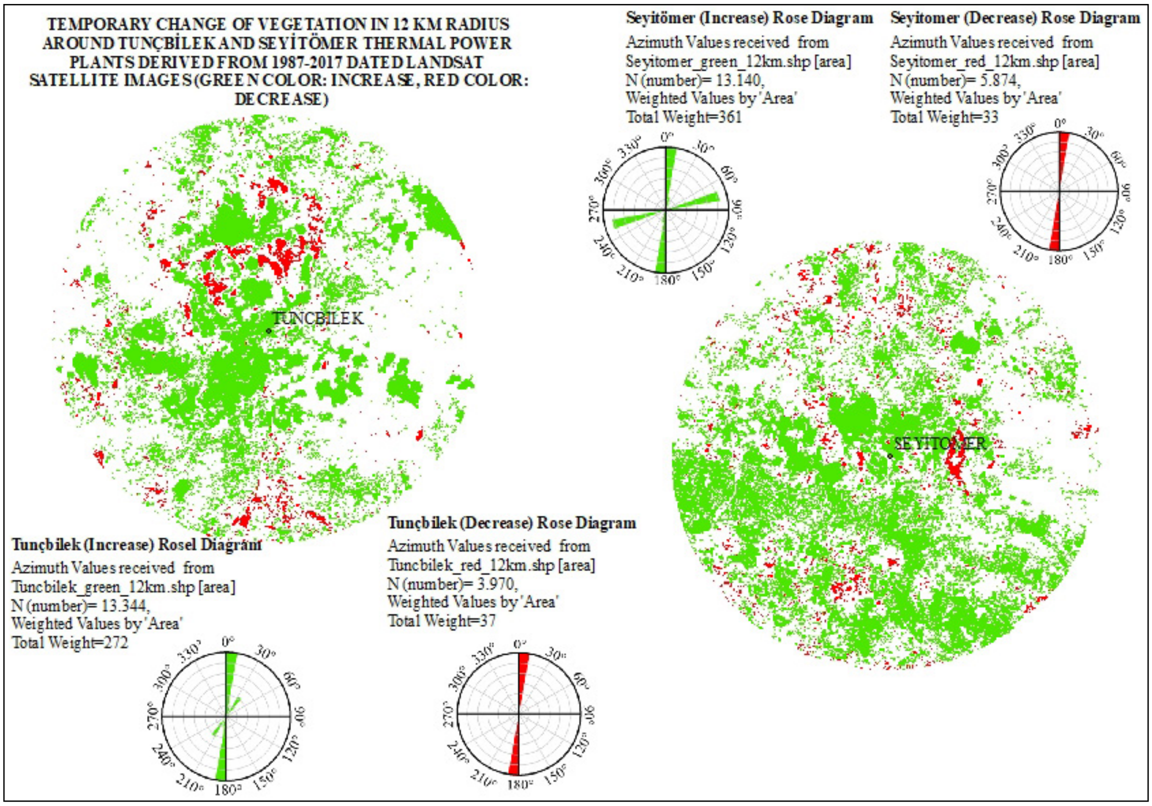

Figure 12- Temporal variation of the vegetation of the long - term Tunçbilek and Seyitömer thermal power plants and their surroundings (12 km radius).

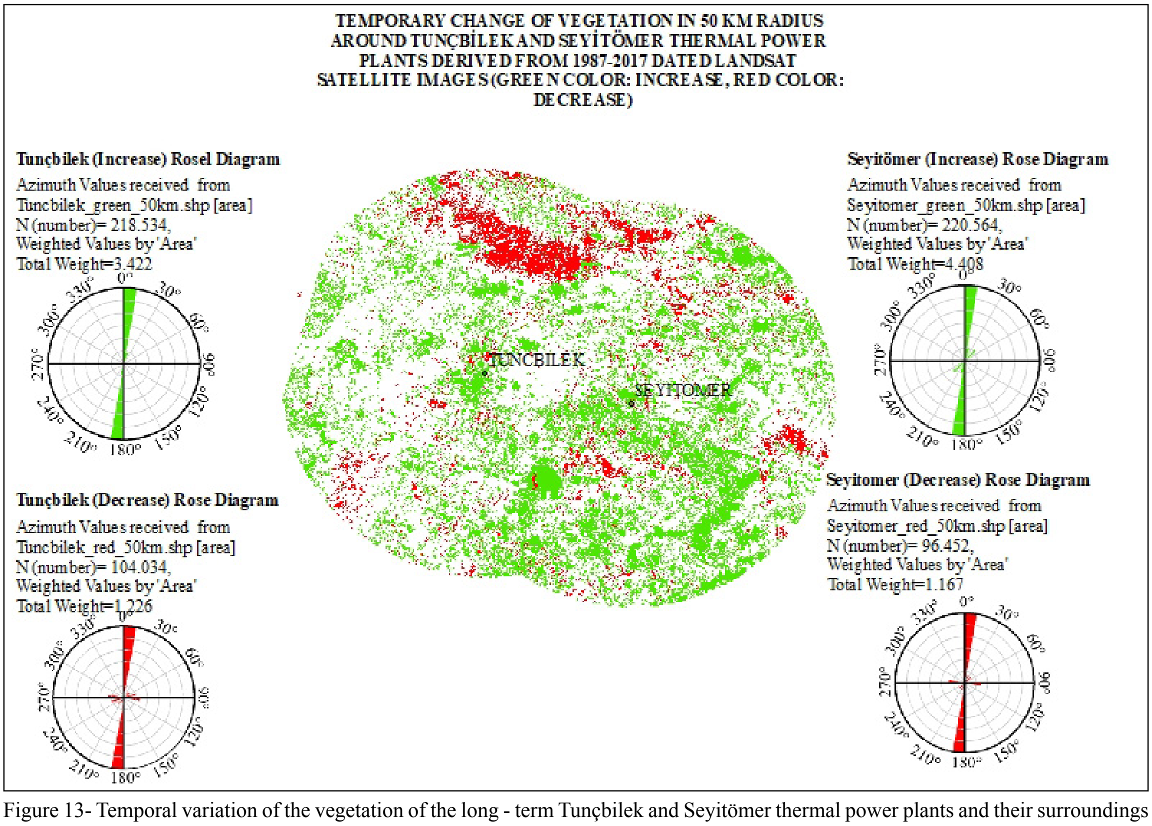

Figure 13- Temporal variation of the vegetation of the long - term Tunçbilek and Seyitömer thermal power plants and their surroundings (50 km radius).

the effect depending on the dominant wind direction disappeared. The numerical findings of these analyzes are presented in Table 5 and it has been determined that the effect of fly ash on plant areas decreases with the increase in diameter. It is observed that the effect of fly ash decreases as the diameter increases while the ratio decreases in plant areas because of urbanization.

A directional chart is a circular graph used to display directional data. In this study, while creating the direction diagram, the area polygons of the increase and decrease changes were calculated within themselves. The area was chosen as the source of the direction of the azimuth values and the source of the weight. In the findings given in Figure 13 as a result of investigating whether the two power plants have an environmental effect that causes a decrease in plant areas in case of coexistence (Haktanır and Karaca, 1996; Mol, 1986; Akbay et al., 2011; Güleç et al., 1999; Feng et al., 2013). Similarly, there was no evidence of a change in the dominant wind direction. It has been determined that there is an effect in the basin due to geomorphological conditions.

8. Results

Remarkable results have been found by detailed evaluation of the numerical data obtained as a result of meteorological data and remote sensing studies for the purpose of determining environmental impacts that may occur in the immediate vicinity of Seyitömer and Tunçbilek thermal power plants due to fly ashes. By transferring change in plant areas to the direction diagram, the similarities of the direction of the dominant wind and direction diagram were identified.

Within the scope of this study, it was observed that annual change is approximately 65.8 km^2 decrease in the plant areas in and around Tunçbilek while there is 8.9 km^2 increase due to rehabilitation studies. The change in the plant areas in and around Seyitömer is in the N-S direction while a decrease of 250 km^2 was observed. It was determined that there was an increase of 5.8 km^2 with planting studies.

The decrease in the vegetation areas on the map obtained as a result of the temporal variation method applied to the images dated 30.06.1987 and 02.07.2017 used within the scope of the study was calculated as 1137 km^2 in a radius of approximately 50 km around the Seyitömer thermal power plant with the help of remote sensing techniques applied considering the spatial resolutions of the satellite images. While a decrease of approximately 65.8 km^2 was observed in the plant areas in and around Tunçbilek, it was determined that there was an increase of 8.9 km^2 mainly due to rehabilitation studies. The change in the plant areas in and around Seyitömer is in the N - S direction while a decrease of 250 km^2 was observed. It was determined that there was an increase of 5.8 km^2 with planting studies.

It has been observed that the decrease in the plant areas in and around the thermal power plants has similar characteristics with the dominant wind direction in the region. It has been determined that as the remote sensing mapping diameter increases, the relationship with the change of plant areas and the dominant wind direction loses its significance and that the ashes of both power plants do not carry each other due to geomorphological conditions. In

Table 5- Numerical findings of both power plants.

<table>
<tr><th>Change Time</th><th>Reactor</th><th>Change in Vegetation (km^2)</th><th>Radius (r=12 km)</th><th>Rate of Change (r=12 km)</th><th>Radius (r=50 km)</th><th>Rate of Change (r=50 km)</th></tr>
<tr><td rowspan="4">30 years (1987-2017)</td><td rowspan="2">Tunçbilek</td><td>Increase</td><td>136</td><td rowspan="2">+7.55*</td><td>1711</td><td rowspan="2">+2.79*</td></tr>
<tr><td>Decrease</td><td>18</td><td>613</td></tr>
<tr><td rowspan="2">Seyitömer</td><td>Increase</td><td>181</td><td rowspan="2">+10.64*</td><td>2204</td><td rowspan="2">+3.77*</td></tr>
<tr><td>Decrease</td><td>17</td><td>584</td></tr>
<tr><td rowspan="5">One Year (2017-2018)</td><td></td><td>Change in Vegetation (km^2)</td><td>Radius (r=4 km)</td><td>Rate of Change (r=4 km)</td><td rowspan="5" colspan="2"></td></tr>
<tr><td rowspan="2">Tunçbilek</td><td>Increase</td><td>0.8</td><td rowspan="2">-6.4*</td></tr>
<tr><td>Decrease</td><td>5.12</td></tr>
<tr><td rowspan="2">Seyitömer</td><td>Increase</td><td>0.53</td><td rowspan="2">-446.03*</td></tr>
<tr><td>Decrease</td><td>236.4</td></tr>
</table>

*The *(-) sign indicates the decrease multiple and the (+) sign indicates the increase multiple.*

other words, as the study area increases, the effect of geomorphological conditions comes to the fore. It has been determined that the dominant wind impact area the radius for both power plants is 4 km and this situation remains within the radius range specified for lignite thermal power plants in the literature. It is thought that it would be beneficial to examine the effects of thermal power plants on human health on the scale of Kütahya with the central thermal power plant in a circle with a radius of four km.

Acknowledgments

This study was supported by the General Directorate of MTA within the scope of the 2020-38-14-01-3 project named as Investigation of the characteristics of fly ashes and their effects on the environment: its usability in the making of synthetic zeolite.

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