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Vegetation Cover Change of Çeşme Alaçatı Wind Power Plant Using Normalized Difference Vegetation Index (NDVI)

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Abstract: The environmental impacts of wind power plants, one of the most widely used renewable energy sources in the world, are still being discussed. In this study, the effects of Çeşme Alaçatı Wind Power Plant on vegetation cover change are evaluated by using normalized difference vegetation index (NDVI) between the pre and post-turbine periods. The satellite images of SPOT June 1996 and Pleiades June 2014 have been used for the analysis process. According to the results of the study; it has been determined that the presence of plants increased by 1.3% in the whole area including the health protection band. However, the results showed that the rate of plant presence has been decreased by 27.1 % in the main area excluding the health protection band. Only spatial changes and field studies were considered in evaluations for vegetation cover change.

Key words: W*ind power plant, NDVI, GIS, vegetation cover, Çeşme*

Introduction

Today, with industrialization, the need for energy is also increasing (Ishugah et al., 2014). The renewable energy sources, which do not consume limited resources such as wind power plants, is widely used in the world and the importance of these energy production methods is increasing day by day (Bozdoğan, 2003; Bayraktar and Kaya, 2016). In order to prevent the spreading and development of wind power plants to cause environmental problems, the installation and maintenance of wind power plants should be planned and supervised during pre and post-operation processes (Çoban & Erol, 2015). Otherwise, indirect effects which may be negatively associated with wildlife, vegetation and human health may arise (Doğan & Kılıç, 2014).

Wind power plants also change the functioning ecosystem mechanism. Some of these effects continue only during construction, while others continue throughout the duration of the project and other effects continue even if the project is deactivated (Çoban & Erol, 2015; Bradley *et al*., 2010).

The most significant impact of WPPs (Wind power plants) on a landscape is the visual effect it creates (Tsoutsos *et al*. (2009), Wolsink, (2010), Frantal & Kunc, (2010), Abbasi et al. (2013), Kokologos *et al*. (2014), Mirasgediz et al. (2014). It has been proposed to reduce the visual contrast by plant design around the WPPs (Tsoutsos et al., 2009). Manchado et al. (2013) used visibility analysis and visibility software for the optimization of the wind power plant.

Environmental effects of wind energy according to Jaber (2013); are considered to be more positive than non-renewable energy sources. Those who argue against this opinion suggest that the use of wind energy turbines has negative effects on people and the ecosystem visually and environmentally; such as the cause of death for wildlife such as birds and bats by the facilities of wind farms, power plants, turbines, transportation routes etc. They also argue that wind energy plants are also environmental effects even though they are very low compared to other industrial and human activities. However, these effects may be vital for some sensitive species, and the removal of these effects should be ensured through analysis during the planning phase (Jaber, 2013). According to Abbasi *et al*. (2013), the effects of wind power plants are the effects on wildlife, birds and bats. Meyerhoff *et al*. (2010) stated that the positioning of wind power plants in coastal areas is not a globally accepted phenomenon.

Cowell (2009) studied about creating a strategic spatial planning guide for wind farms in Wales. According to this study, wind power plants should be established on the areas at least 500 m. far away from protection areas such as national parks, Ramsar sites and human settlements. It was declared that wind power plants should be as isolated as possible from the houses and these certain regions.

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With the spread of Geographical Information Systems (GIS) and Remote Sensing (RS) methods, these technologies have been extensively used as a tool in landscape planning studies since 2000 (Yazici *et al*. 2016). By using a geographic information system (GIS) physical and natural data can be assessed according to a model, so that realistic and applicable protection plans or maps can be established (Turkyilmaz *et al*. 2007).

Wu, (2016), investigated the change of the growth of vegetation after the establishment of the wind power plants to find if there is a change over local earth-atmosphere system state energy balance. The results showed that the vegetation coverage increased in the study area with time, that the absolute value of NDVI difference between the study area with wind farms and the control area without wind power system during summer increased after 2004 and that the correlation of the vegetation growth between the study area and the background field is less than the correlation between the control zone and background zone. Therefore, the establishment of wind farms has an impact on the local climatic conditions and ecosystem change.

Shen *et al.*, (2017), stated that the construction of a single wind turbine was found to damage nearly 3000 m^2 of grassland. Because wind farm construction will cause vegetation damage, soil erosion, and other ecological problems, appropriate measures should be taken to restore the ecological environment of wind farms. The study defines the area of grassland occupied by wind power construction to include grassland areas damaged by turbine construction and access road construction, which are the main components of wind farm construction. Automatic classification methods should be studied for use in the monitoring process and improving the interpretation efficiency should be a focus of further studies.

Tang *et al*, (2017), stated that there is still no evidence to demonstrate whether wind farms can affect local vegetation growth, a significant part of the overall assessment of wind farms effects. Tang et al, (2017), published a research, based on the moderate-resolution imaging spectroradiometer (MODIS) vegetation index, productivity and other remote-sensing data from 2003 to 2014, the effects of wind farms in the Bashang area of Northern China on vegetation growth and productivity in the summer (June–August) were analyzed. The results showed that: (1) Wind farms had a significant inhibiting effect on vegetation growth, as demonstrated by decreases in the normalized difference vegetation index (NDVI) of approximately 8.9% in the 2003–2014 summers; and (2) the major impact factors might be the changes in temperature and soil moisture: Wind Farms suppressed soil moisture and enhanced water stress in the study area. This research provides significant observational evidence that wind farms can inhibit the growth and productivity of the underlying vegetation.

Xia *et al*, (2017), examined the possible impacts of real-world wind farms on vegetation growth focusing on two large wind farms differ distinctively in terms of land cover, topography, and background climate for the period during the pre- and post-turbines. The results indicate that the wind farms have insignificant or no detectible impacts on local vegetation growth. At the regional level, there is no systematic shift in vegetation greenness between the pre and post-turbine periods. At interannual and seasonal time scales, there are no confident vegetation changes over wind farm pixels relative to non-wind farm pixels.

The spatial effects of the wind power plants have been evaluated by comparing the pre and post-operation situations of the first wind power plant area in Turkey. Within this context, satellite images of the study area before (1996) and after (2014) establishment of the plant were compared in terms of vegetation existence.

Materials and Methods

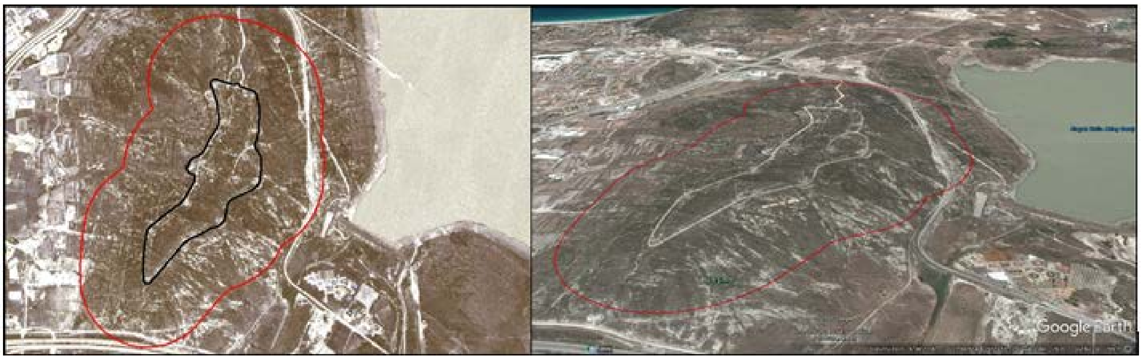
Materials

The research area is located in the province of Çeşme, İzmir (Figure 1). The wind power plant which has been chosen as the case for the study is located between 38 ° 17'35.03 "N 26 ° 23'26.24" E and 38 ° 16'38.79 "N 26 ° 24'14.77" E. The research area is 125 ha. in size. The wind energy tribunes of the wind power plant with 7.2 MW installed power have been producing energy since 1998. The research area was determined by including the 300 m wide buffer zone based on the transport line linking the inland wind energy tribunes (Figure 2).

The main material of this study is the study area itself. Other materials used to define the change in vegetation are listed below:

1. In this study, since the same high resolution satellite images as the NDVI comparison data can not be found, 14 June 1996 SPOT satellite image and PLEIADES-1a satellite image of June 12, 2014 covering the research area were used.
2. Magellan Explorist 710 gps device was used to determine the coordinates to be used in the rectification process.
3. ARCGIS 10.0 geographical information system software of ESRI® company was used for transferring the obtained geographical data to the computer environment and NDVI processes.

Figure 1. Location of the study area (Google Earth, 2017 and HGK, 2017)



Figurel 2. The boundaries of the study area (Left: Pleiades, 2014, Right: Google Earth 2016)

Methods

The Spot and Pleiades satellite images of the research area were converted by ED 1950 35N European Datum projection system using the coordinates obtained by gps in field studies. The selected images were marked and cut off according to the study area boundaries covering the wind power plant site and within the coverage area of the 300m health protection area. In order to determine the vegetation existence of the research area, NDVI analysis and field observation studies were performed using ArcGIS software 'image analysis' tool. The Spot and Pleiades satellite images that have been exposed to NDVI operation were compared and discussed.

Calculation of normalized difference vegetation index (NDVI)

Vegetation indices have long been used in remote sensing for monitoring temporal changes associated with vegetation (Yacouba et al., 2009). NDVI technique can be employed to evaluate the vegetation cover and hence monitor the environment (Anim et al., 2013). In NDVI calculation NDVI = (NIR VIS) / (NIR + VIS) equality is used. Whereas the NIR expresses the near infrared; VIS stands for visible spectral measurement. In theory, NDVI measurements are between -1 and +1. In practice, however, it is 0,1 to 0,7. While clouds, water, snow and ice give negative values, the bare soil and other soil materials take a value between -0,1 and +0,1, while the plant cover gets higher value (Goward et al, 1985). While healthy vegetations absorb most of the visible light, the rate of reflection in unhealthy plants is higher. In this case, NDVI value in healthy plants is higher than that of unhealthy plants. Nevertheless, the absence of a green component means a value close to "0", whereas a "0" means no vegetation. Proximity to "+1" indicates the highest probability of green leaf density (NASA, 2017).

Calculation of change of vegetation existence

The images obtained after NDVI treatment are classified according to reflection values and land type and plant density. These classified images are reclassified as plant and non-plant areas. During this classification, both satellite images were evaluated with their field observations in consideration. On the images in the raster format and reclassified images, the classification process was carried out in such a way that the bare areas with no vegetation or very weak vegetation cover are "0" and those with dense vegetation have "1" value. Reflection values used during classification are given in Table 1.

Table 1. NDVI Reflection Ranges of the Satellite Images

Satellite Images	Spot	Pleiades 1 A	Class Value
No Vegetation Existence or Low (NDVI Reflection Value)	Between -0,092233 – +0,07964419	Between -1 – +0,21	0
Vegetation Existence High (NDVI Reflection Value)	Between 0,07964419 - +0,139665	Between +0,21 - +1	1

Following the classification process, both the Spot and Pleiades satellite images were taken separately and the spatial variation of the vegetation existence was calculated.

"Zonal geometry" command of the ArcGIS software was used in the zonal subheading under the "Spatial Analyst" tool to calculate the sizes of the areas classified on raster images previously classified according to vegetation availability. The differences between the areas calculated to determine the change between years and the data obtained are given under the heading “Results and discussion”.

Results and discussion

No surface coatings were found in the roads of the area during the field studies conducted in research area (Figure 3 and Figure 4).

Figure 3. The northern aspect of the study area and the general vegetation cover

Figure 4. The southern aspect of the study area and the general vegetation cover

It has been observed that the ground surface of the area has been developed by the natural structure, as shown in Figure 3 and Figure 4, and at the same time the vegetation cover has developed in some places along the roads due to intensive use and natural conditions.

This situation leads to the impression that the reflection values on the satellite image of inland roads and inland roads are very close to each other and that the NDVI operation is the result of the planting of the whole area (Figure 5 and Figure 6).

This situation leads to the reflection values on satellite images of inland roads and the low density vegated parts of the area seem very close to each other, and so that the NDVI process results in the impression that the whole area is covered by vegetation (Figure 5 and Figure 6).

The NDVI image of the SPOT satellite in June 1996 in the study area's health protection area is shown in Figure 5. According to this map, the vegetational density is higher in the parts that value close to 1, which means parts coloured close to green.

The NDVI image of the Pleiades satellite in June 2014 in the study area's health protection area is shown in Figure 6. According to this map, the vegetational density is higher in the parts that value close to 1, which means parts coloured close to green.

Figure 7 shows the NDVI field sizes (including the health protection area) of the June 1996 SPOT Satellite View. Accordingly, the plant area is 734.761 m^2 and the non-plant area is 520.483 m^2. In other words, the proportion of vegetative area in the borders of the health protection area is 58.5% and the ratio of non-vegetation area is 41.5%.

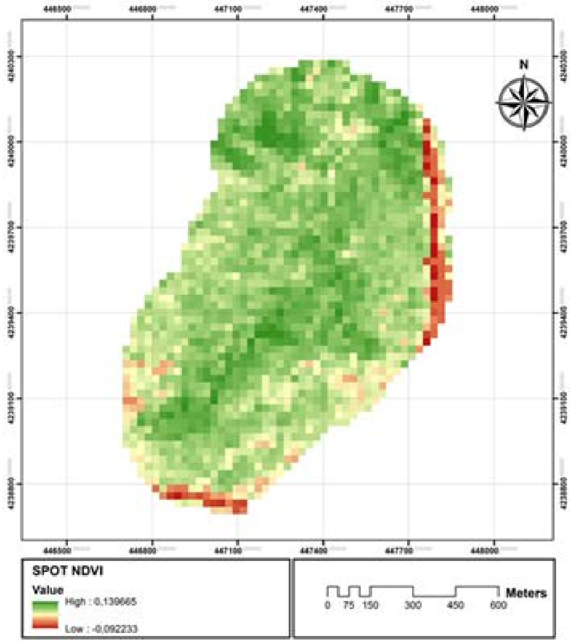


Figure 5. Study Area SPOT Satellite Image (Including the health protection area) NDVI Values (June 1996)

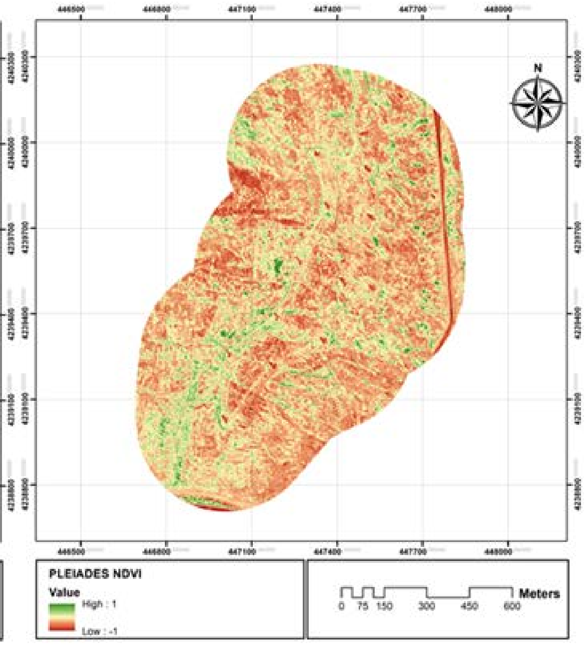


Figure 6. Study Area Pleiades Satellite Image (Including the health protection area) NDVI Values (June 2014)

Figure 8 shows the NDVI field sizes of the Pleiades satellite image (including the health protection area) for June 2014. Accordingly, the plant area is 746.045 m^2 and the non-plant areas are 501.841 m^2. In other words, the vegetative area rate in the health protection area is 59,8% and the non-vegetation area rate is 40,2%.

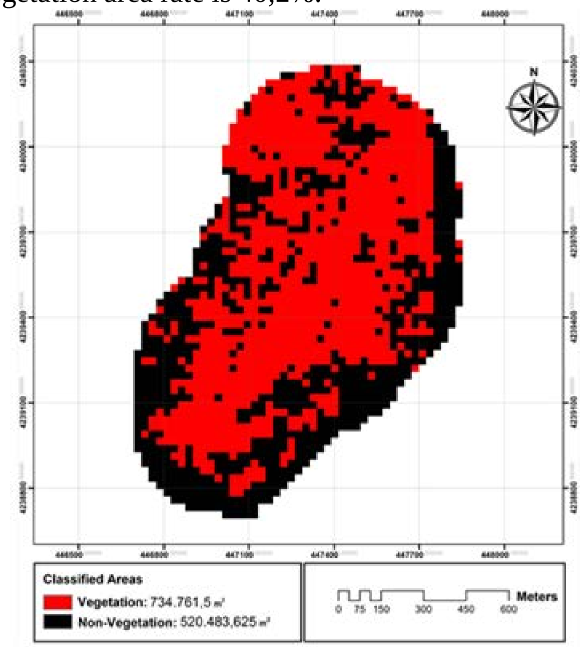


Figure 7. NDVI field sizes (including health protection area) of SPOT satellite image (June 1996)

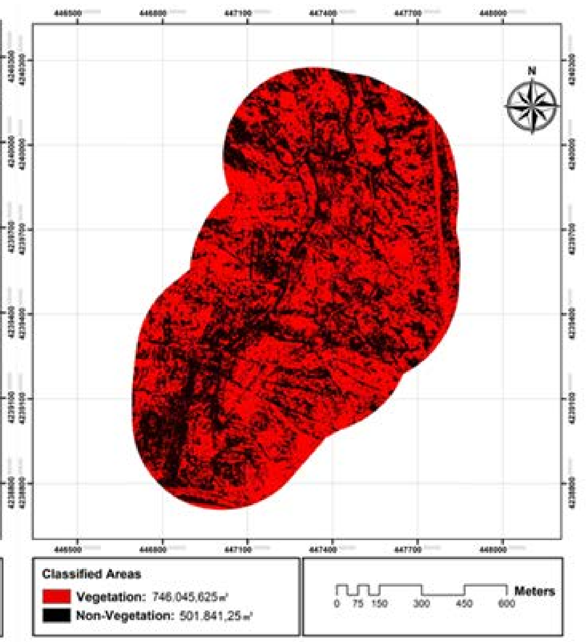


Figure 8. NDVI field sizes (including health protection area) of Pleiades satellite image (June 2014)

Figure 9 shows the NDVI field sizes of the SPOT Satellite Image (excluding the health protection area) of June 1996. Accordingly, the plant area is 185.839 m^2 and the non-plant area is 23.808 m^2. In other words, the plant area rate is 88.6% and the non-plant area rate is 11.4%.

Figure 10 shows the NDVI field sizes of the Pleiades Satellite Image (excluding the health protection area) for June 2014. Accordingly, the plant area is 129.011 m^2 and the non-plant areas are 80.778 m^2. In other words, the plant area rate is 61.5% and the non-plant area rate is 38.5%.

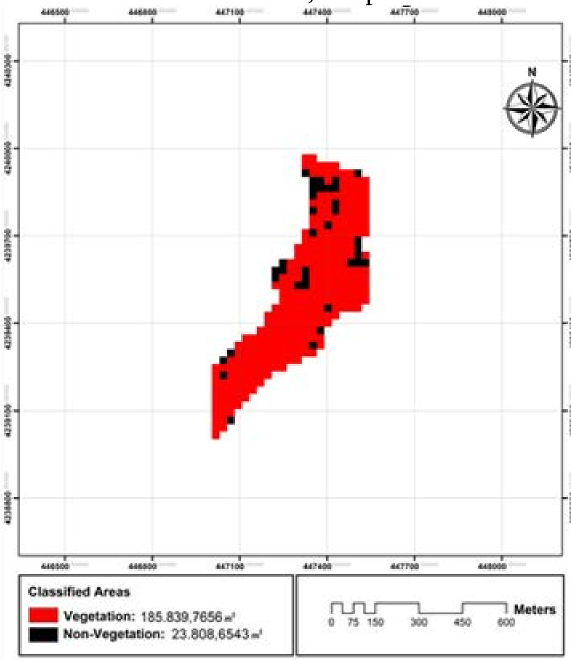


Figure 9. NDVI field sizes of SPOT satellite image (excluding the health protection area) (June 1996)

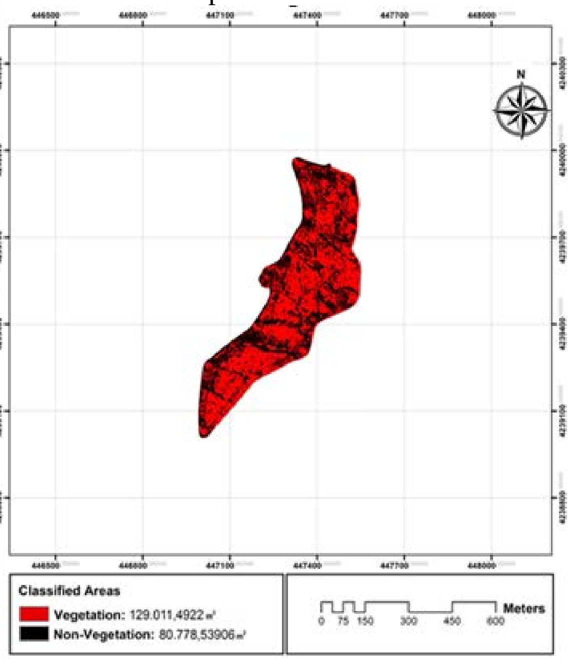


Figure 10. NDVI field sizes of Pleiades Satellite View (excluding the health protection area) (June 2014)

Analyzes and field studies on satellite images were evaluated within the scope of the research findings.

According to the work done on the satellite image; The comparison of NDVI values on satellite images of June 1996 and June 2014 resulted as following:

- Excluding the health protection area, 185.839 m^2 of plant area was detected in June 1996 as a result of NDVI calculation, which covers 88.6% of this area.
- In the same way, excluding the health protection area, 129.011 m^2 of plant area is detected according to the result of NDVI calculation for June 2014, which covers 61.5% of this area.
- Including the health protection area, according to the result of NDVI calculation, 734.761 m^2 of plant area was detected in June 1996, which covers 58.5% of the whole study area.
- Similarly including the health protection area, 746.045 m^2 of plant area was determined as the result of NDVI calculation for June 2014, which covers 59.8% of the whole work area.
- On the basis of the whole research area, including the health protection area, it was found that the presence of plant increased by 1.3% between 1996 and 2014. Among the growth factors of plant cover are the effects of vegetative growth and agricultural activities, which might be increasing over time in the health protection area.
- Excluding the health protection area, the amount of vegetation cover of the wind power plant decreased by 27.1% between 1996 and 2014. Wind turbines, business buildings, power plant units and roads that have been established are among the significant factors of plant cover decrease.
- As a result of field studies and satellite imagery reviews, no other adverse effect of wind turbines directly on the vegetation has been found. At the same time, there was no evidence that wind turbines caused bird deaths. Apart from this, it has been observed that bees and similar insects reach very close distances of the turbines.

Conclusion

It is important for sustainable ecosystems to prepare and apply a landscape reclamation plan in the project area of the wind power plants. To increase the vegetation quantity and growth within the boundaries of the health protection area may help to decrease the effects of vegetation reducing factors, which in the long term could be helpful to sustain the ecosystem of the area.

It is considered that landscape reclamation works to be carried out on wind power plants are also effective in reducing negative visual effects, one of the most significant negative effects, as well as functioning ecologically.

The support of wind energy plants that's environmental effects are less than conventional methods is important for sustainability. However, the development of wind energy plants should be wisely planned for both the environment and the energy need.

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