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DETERMINATION OF SURFACE ROUGHNESS PARAMETER THROUGH AERIAL IMAGES IN WIND POWER PLANT INSTALLATION

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Abstract

The surface roughness parameter is an important parameter in the installation of a wind energy power plant and it varies depending on the dimensions and the distribution of the roughness elements on the land. Before the installation roughness maps indicate roughness of the surface has to be drawn. In today's applications, these maps are drawn approximately by WAsP software using the information obtained from the terrestrial observations belongs to experts. But this application is costly and time consuming and the assessment is based on limited land observations. In this study the surface roughness parameter is determined by digital image processing techniques from the digital images taken over aerial field. Thus it gives the opportunity to consider whole power plant surface into account with lower cost and time requirements over the traditional methods. Images used in the study are obtained from the Map General Command and MATLAB software platform is used. The study is based on the determination of the closure rates on the land by image segmentation method such as OTSU algorithm, fuzzy c-means and k-means algorithms. In order to evaluate the consistency of the results images are evaluated with ERDAS software. Obtained results showed the effectiveness of the study.

Keywords: Renewable Energy Sources; Wind Power; Wind Power Plant; Surface Roughness Parameter; Digital Image Processing.

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1. Introduction

The energy defined as the ability to do business is the basic input for all kinds of production, especially in the industrial sector. Energy production means, in other words, the conversion of energy into transferring energy from one form to another and doing business there. Today, the negative effects of traditional energy production methods on human and environment have

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reached serious dimensions. For this reason, the need for clean energy resources [1] is increasing day by day. Many countries in the world give priority to encouraging policies to increase the use of renewable energy sources and to develop energy production methods accordingly.

The wind, which is free and abundant in nature, is the most preferred energy source among alternative energy sources as a clean energy source and it is a promising energy source, especially in coastal areas and other wind fields [2-4]. For this reason, the most widely used renewable energy sources and technology is the fastest developing. Because wind energy is caused by differences in temperature and pressure caused by different heatings of the earth and the atmosphere by the sun, there will be winds as long as there are sun rays. Wind energy is more preferred than other renewable energy sources, and in addition to being abundant in nature, there are other advantages. These are the low cost of installation and operation of wind farms, the rest of the area can be used for agricultural activities and after the lifespan of the wind farms turbines can easily be reinstated to compete with other power plants. Beside all of these advantages it has some disadvantages, such as being noisy, causing bird deaths, and causing interference in radio and TV receivers. The choice of where the wind farms will be built is very important. Once the location of the wind farms has been established, the wind characteristics of the zone must be defined and solutions for energy production must be made.

For this purpose, various points that can represent the region should be determined and the necessary measurements should be made for at least one year. In addition to these measurements, the surface roughness factor, which represents the vegetation cover or high structure that will affect the wind profile in the land, is important. The surface roughness, which represents the plant height differences and the density of the structures, has different effects on the wind flow direction. The roughness unit is used to calculate these differences. The roughness length can be calculated by measuring the wind taken at a certain height from the surface. Today, WAsP software is used to determine the surface roughness parameter of wind park installation sites [5]. In order to find this parameter the information obtained by terrestrial observations made in the areas that can be reached by roads by specialists in a few km areas around the area where the wind park will be installed is transferred to the WAsP programme. However, there are some disadvantages to obtaining the surface roughness parameter in this way. The most important one of these disadvantages, it is not always possible to reflect the real terrain as a result of the fact that the information obtained by the terrestrial transportation does not cover places that cannot be reached by land on the region. Besides, it takes time for people to travel on an individual area, to have time for intensive labor, security and transportation problems. In this case, the results obtained by the conventional method cannot reflect the reality, but approximate results can be obtained.

In this study, a method is presented to obtain the surface roughness parameter of the site where the wind power plant installation will be by using digital image processing techniques over aerial images to avoid the disadvantages of conventional methods. In the study high resolution aerial images taken from the General Command of Mapping are used. As the digital image processing method, three different methods such as OTSU algorithm, fuzzy c-means and k-means algorithms are used and the results are given comparatively. For the performance analysis of the obtained results, images were also evaluated with ERDAS Imagine software, a simple and useful

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tool for visualizing and manipulating geographic imaging data [6], and comparative results were given.

2. Surface Roughness Parameter

In order to utilize wind power plants efficiently and profitably, the wind potential analysis of the region where the wind power plant will be installed is of great importance. In this analysis, important features that need to be considered in the wind field installation are wind characteristics, wind gauges, anemometer, wind speed, turbine placement, wake effect, turbulence, peak effect, tunnel effect, wind obstacles and surface roughness parameters. Since the surface roughness parameter increases friction effect, it affects the wind speed seriously. While the wind speed at locations 1 km or more from the ground is reduced due to the lowering of the roughness parameter and it increases closer to the ground surface due to the increase of the surface roughness parameter. Today, there are various methods used to determine the surface roughness parameter. However, these methods have some disadvantages. In this paper, a new approach is presented using digital image processing techniques which will overcome the disadvantages of the conventional methods used to determine the surface roughness parameter.

It is generally accepted that the surface roughness parameter at a surface distance of about 100 times the height of the turbine around the turbine, in the region where the turbines will be installed, affects the wind potential of the region. For example; If a turbine with a height of 75 m is to be used, at least 7,5 km of the surface area around this turbine should be examined and surface roughness map should be determined However, if there are roughness elements that will seriously affect the wind, a few km outside the boundaries of the roughness map, they should be analyzed and included in the roughness map [7].

Traditionally, two methods have been used to determine the surface roughness of the zone where the plant will be installed. The first of these is the creation of a hand-drawn roughness map representing the roughness of the region in the light of information obtained after the first local observations and the second is the drawing of a roughness map by using online resources. In manual drawings, maps and satellite images can be used together. In addition, field trips are required. The notes taken on the field trips and the roughness of the images to be taken are important and are of great importance for achieving more realistic results. However, field trips are limited to only a few km, but they have disadvantages such as difficult and unsafe conditions. The wind roughness maps that can be accessed online are usually obtained by matching the maps obtained from the Geographic Information Systems to the roughness classes that can be seen in Fig. 1 WindPro software and WAsP program, which are frequently used in wind analysis, are used in roughness analysis, but attention should be paid to the resolution of the maps and the roughness maps they match. Pairing with a different plant cover that does not have roughness matching can result in erroneous results that will seriously affect the wind power plant installation. For example, if a classification is made such that a zone with frequent forests has dwarf and sparse trees, the wind flow conditions will give the wrong results in a big way. As the wind flow is most important around a few kilometers of the turbine, it is necessary to go out to the field trips in the roughness map obtained from the online sources and to take images and take notes and get more detailed information.

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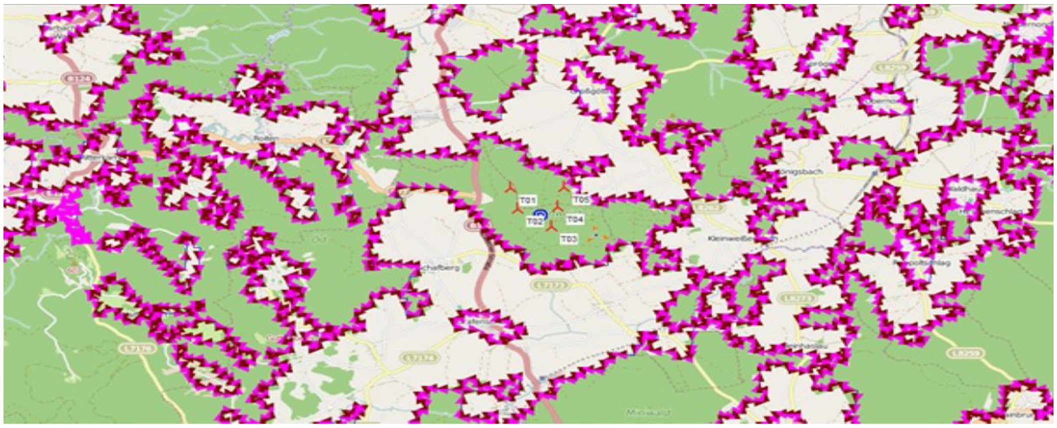

Figure 1: Online surface roughness map [8]

In today's applications, the surface roughness of the area where the plant will be installed is defined by the distribution and dimensions of the surface roughness elements in this area. Main surface roughness elements can be defined as vegetation cover, lakes and settlements. When the roughness condition of a region in the wind sector is examined, it is realized that the roughness class is determined by a prepared table depending on the roughness length. There are traditionally five types of wind roughness classifications in wind potential studies (Table 1). The roughness of the material is denoted by z_0 and the roughness length is assumed to vary between 0.0002 and 1.5. Water surfaces are shown with 0.0002, while dense settlements are shown with 1.5. These roughness length values can be found in the table of the WAsP program as well as in the following equation.

Table1: Roughness class-roughness length according to WAsP program.

WAsP Surface Roughness Classification	Roughness length	Roughness class
Offshore surface	0.0002	0
Distant from the sea, sparse	0.030	1
Areas with low building density, around 1000m between tree communities	0.100	2
Area with high building density and frequent tree groups	0.400	3
Cities with dense and high buildings	1.5	4

3. Materials and Methods

Materials: Aerial imaging is a bird's-eye view of a region drawn by special cameras mounted on air vehicles such as airplanes and helicopters for various purposes. Aerial images are used especially in cartography, in forests, in military areas, in agriculture and in control applications such as urban development, vegetation cover (Fig.2).

Figure 2: An aerial imaging.

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The aerial images are taken in a certain system with the aid of the cameras mounted on the aircraft. There is a certain flight speed and flight schedule which varies according to the purpose of shooting. Shooting is done at even intervals throughout the flight and different films and filters can be used in shooting. According to the purpose of use, black and white or color images can be taken. Air photographers who can measure for a good aerial image, high resolution films, and low speed aircraft should be used. In addition to the flight team consisting of well-trained and experienced pilots, navigators and photo operators on board, appropriate specialists for shooting purposes should also be included.

In this study, surface roughness analysis was done by using digital image processing techniques on images taken from air of the region where the wind power plant will be installed (Fig.3). The aerial images of the zone were purchased from the General Command of the Map. In addition to these aerial images, orientation parameters and camera calibration information were also taken. Features of these photos are they are taken from flights in 2011, 1/60000 scale and 3 Band (Red-Green-Blue) + Color Infrared (CIR) 30 cm resolution.

Figure 3: A sample of aerial image from the field

Methods:

- **OTSU Algorithm**

In this study, OTSU algorithm, K-means clustering method and fuzzy C-means clustering methods are used as image processing method. The two-dimensional function f (x, y) defined in spatial coordinates such as x and y is defined as a digital image. The amplitude value at any (x,y) point of the function f (x, y) is called the density value of the digital image. Digital image processing means that digital images are processed in various levels on a computer. Digital image processing generally consists of three levels. First level image processing is used to improve the image for human and computer perception, which can be called pre-processing. At this level, the process is also the image the output is the image again. The second level is called intermediate level and it includes operations such as object analysis, object segmentation, and so on. At this level, the input is the image, while the output is the property of the process. The third

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and final stage is the level in which cognitive functions such as object recognition are applied, called high-level image processing. At this level, also the output is the application-dependent properties while the input is image.

The Otsu method, a statistical image thresholding method, was first proposed by Nobuyoki Otsu in 1979 [9]. The Otsu method is based on the statistical properties of the image and distinguishes the images according to the variance of the class and the maximum variance between the classes. The pseudo code for this algorithm is given in Table 2.

Table 2: Pseudo code for OTSU algorithm

1. Reading of the image
2. RGB to Gray level image conversion
3. Finding the optimum threshold level
4. Applying threshold levels to the image
5. Retrieving only the areas with trees
6. Finding tree areas, total area and percentages
7. Drawing tree circles on the original image

- **K-Means and Fuzzy C-Means Clustering Algorithms**

The purpose of classifying digital images is to distinguish objects with similar values by grouping pixels. Classification, which has an important place in remote sensing and image analysis, is a decision-making mechanism. Classification is done by dividing each pixel into different groups according to its spectral characteristics and finding the cluster that belongs to the image. The classification process is divided into pixel-based and object-based. The pixel-based classification process is also divided into two categories, supervised and unsupervised.

In the supervised classification method, a sufficient number of sample areas are selected on the terrain image, and the spectral properties defined files are created for each object to be classified. By applying these generated files to the original data of the view, each pixel in the image is automatically assigned the most similar class from the calculated classes. There are three approaches, the largest similarity, the parallelism and the smallest distance, in the training classification. In the unsupervised classification, there is no prior knowledge about the classes. These classes to be created are the process of dividing the number of grubs as desired in accordance with the characteristics of the available data. This process can also be called clustering.

K-means clustering algorithm is a non-hierarchical clustering method that targets the data in the database split into K prespecified clusters based on similarity. The pseudo code for this algorithm is given in Table 3.

The Fuzzy C-means algorithm is a clustering algorithm developed by Bezdek in 1981, defined by Dunn in 1973 [10]. The basic approach is that each value in the data takes a membership value between fuzzy logic principles (0, 1). It is decided what proportion of each value in the data is included in which cluster. The value is considered to be the element of the cluster that is closer to the higher rate. With a goal function, the function is minimized until a final decision is made. It means that the optimum clustering has been achieved when the final decision is made.

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Table 3: Pseudo code for K-Means clustering algorithm

1. Assigning K data centers for the dataset
2. Calculation of distances to assigned cluster centers for each data value
3. Assigning each data point to the nearest cluster center
4. Go to the Second Step
5. Stop if the previous data assignments and the next data assignments do not change in terms of cluster centers.

4. Experimental Studies

In this work, high resolution aerial images purchased from the General Command of Map were used. The images were taken in 1/60000 scale and color with Ultra Cam X brand camera. By using these high-resolution images, 9 trees with 750 * 750 matrix size were selected and segmentation of the forested areas was performed with OTSU, fuzzy c-means and k-means algorithms in MATLAB environment. In order to show the effectiveness of the algorithms results ERDAS IMAGINE, an image processing and geographic information system package, software is also applied to the images and comparative results are given as the "gold standard".

Through the aerial images, the boundaries of the surface roughness elements inside the land were determined and the surface roughness of the land was analyzed as a percentage. For this, three different algorithms are used as OTSU algorithm, K-means algorithms and fuzzy C-means algorithms. The application was carried out on nine images. Since the images are colored, they are first converted to gray level images. Then, clustering of the pixels on the images was performed for the three algorithms. From the cluster pixels only the labels of the trees were taken and the other regions were accepted as background and discarded from the image. The gray level images were then converted into binary images and the areas of the white pixels on the image were calculated by MATLAB and divided by the total number of pixels in the image to calculate the percentage of the white areas on the image. At the same time, the boundary pixel coordinates of each object in the binary image can be calculated by using MATLAB image processing tools. Below are the results of the application for each of the three algorithms for the same aerial image.

The same processing steps are used for all three algorithms. The pseudo code for this processing is given in Table 4. In Fig.4,5,6 the processed image samples for the same aerial image (Fig. 3) can be seen which belong OTSU, K-Means and Fuzzy C-Mean algorithms respectively.

Table 4: Pseudo code for processing

1. Convert RGB image into gray level image
2. Apply clustering algorithm so as to label the regions covered with tress other regions are discarded.
3. Convert gray level image into binary image so as to trees are white
4. Compute the percentage of white pixel region

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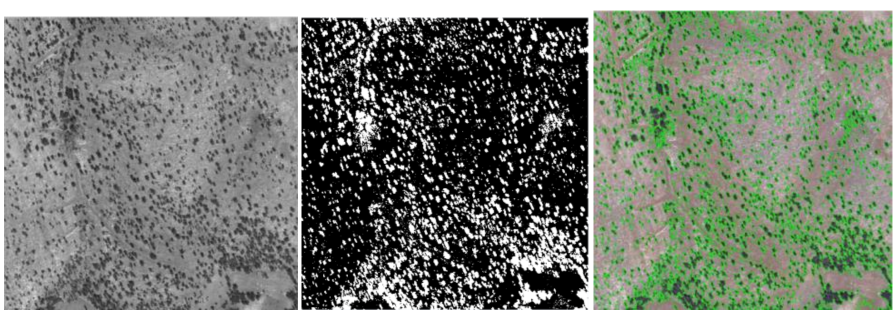
(a) (b) (c)

Figure 4: A sample processed image with OTSU. (a) gray level image, (b) binary image, (c) trees are labelled

(a) (b) (c)

Figure 5: A sample processed image with K-Means (a) gray level image, (b) binary image, (c) trees are labelled



(a) (b) (c)

Figure 6: A sample processed image with Fuzzy C-Means (a) gray level image, (b) binary image, (c) trees are labelled

In Table 5, 6, 7 set numbers, fields covered with trees and their percentages are given for OTSU, K-Means and Fuzzy C-Means respectively.

Table 5: Clustering results for OTSU

Image Number	**Set Number**	**Woodland Area**	**Woodland Area (%)**
1	2	129890	23.09
2	3	121731	21.64
3	3	82391	14.65
4	2	108569	19.32

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5	3	45055	8.01
6	4	52068	9.26
7	3	143003	25.42
8	3	73229	13.02
9	4	54246	9.64

Table 6: Clustering results for K-Means

Image Number	**Set Number**	**Woodland Area**	**Woodland Area (%)**
1	2	127558	22.68
2	2	140573	24.99
3	2	101435	18.03
4	2	108659	19.32
5	2	268193	47.68
6	2	70081	12.46
7	2	178778	31.78
8	2	106672	18.96
9	2	241717	42.97

Table 7: Clustering results for fuzzy C-Means

Image Number	**Set Number**	**Woodland Area**	**Woodland Area (%)**
1	2	132270	**23.51**
2	3	121731	**21.64**
3	3	81097	**14.42**
4	2	108659	**19.32**
5	3	45055	**8.01**
6	4	56373	**10.02**
7	3	140686	**25.01**
8	3	73229	**13.02**
9	4	54246	**9.64**

For the comparison purposes all the images are also applied to ERDAS Imagine software. For the sample image in Fig 3, the resulted clustered image using ERDAS Imagine software is given in Fig. 7 and ERDAS Imagine software results for set numbers, woodland area and woodland percentages are given in Table 8.

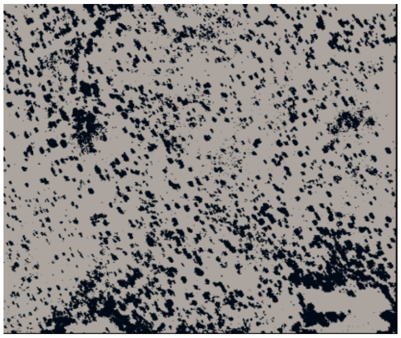

Figure 7: A sample processed image with ERDAS Imagine software

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Table 8: ERDAS Imagine clustering results

Image Number	Set Number	Woodland Area	Woodland Area (%)
1	2	126527	**22.49**
2	2	121449	**21.59**
3	2	65665	**11.67**
4	2	113008	**20.09**
5	2	43214	**7.68**
6	2	60673	**10.79**
7	2	142257	**25.29**
8	2	72274	**12.85**
9	2	70950	**12.61**

5. Results and Discussion

Digital image processing techniques have been used to create roughness maps used in surface roughness analysis, which is an important parameter in wind power plant installation. In this study, aerial images taken from the Map General Command and the MATLAB program were used. Image segmentation is the preferred in order to obtain the percentage of the field covered with trees. Experiments are performed using three different algorithms such as OTSU algorithm, k-means and fuzzy c-means. The comparative results for these algorithms are given in Table 9.

The classification accuracy method was used to find the convenience of the three algorithms to ERDAS Imagine. For this, the pixel values of the three algorithms for each image are compared with the pixel values of the individual ERDAS program, and the success rate of the algorithm is determined by taking the arithmetic mean of the found accuracy percentages (Table 10). According to these results, Otsu 96.43%, Fuzzy 96.47% and K-Means 96.27% has classification success.

Table 9: Results for OTSU, K-Means and fuzzy C-means with ERDAS Imagine

Image Number	OTSU (%)	K-Means (%)	Fuzzy C-Means (%)	ERDAS Imagine (%)
1	23.09	22.68	23.51	22.49
2	21.64	24.99	21.64	21.59
3	14.65	18.03	14.42	11.67
4	19.32	19.32	19.32	20.09
5	8.01	47.68	8.01	7.68
6	9.26	12.46	10.02	10.79
7	25.42	31.78	25.01	25.29
8	13.02	18.96	13.02	12.85
9	9.64	42.97	9.64	12.61

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Table 10: Comparative results for OTSU, K-Means and fuzzy C-means with ERDAS Imagin***e***

Image Number	ERDAS-OTSU (%)	ERDAS-FUZZY C-MEANS (%)	ERDAS-K-MEANS (%)
1	95,08249	94,94204	94,94204
2	97,02507	97,02507	96,816
3	96,00996	96,14329	95,34916
4	96,34151	96,34151	96,34151
5	99,128	99,128	98,77173
6	97,99413	98,2944	98,20924
7	91,76853	91,87716	91,54311
8	98,73227	98,73227	98,55147
9	95,81191	95,81191	95,83733
Average	96.43	96.47	96.26

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