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Research Article

Evaluating the capability of using close-range photogrammetry in measuring desert pavement roughness

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A B S T R A C T

Background and objective: There are several methods of measuring desert pavement roughness. Among these methods, one can name laser and sonic rangefinder, 3D photography, and close-range photogrammetry. Remote sensing techniques need less and cheaper equipment than laser and sonic methods. In short-range photogrammetry, the quantitative amount of terrains can be obtained by processing the images of a digital camera using special methods of photography and camera calibration.

Materials and methods: This method can be introduced as an accurate and cost-effective measuring method to provide a digital model of complications and a three-dimensional model of objects. The present study aimed to evaluate the possibility of using close-range photogrammetry in measuring desert pavement roughness. In this research, first, the calibration parameter of the camera was calculated by taking photos of standard patterns. Then, the meshed samples of desert pavement were photographed and the photos were three-dimensionally simulated.

Results and conclusion: The results showed that since in this method the selected points have more effective height and uniform dispersion, the measurement of the average height of roughness is more accurate. It means that measuring the roughness of the soil surface is done with high accuracy in a short time.

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1. 1.Introduction

Since the surface roughness or microtopography is one of the most important and effective factors in preventing wind erosion and most of the methods in this field have been traditional, costly, and time-consuming, or special methods such as laser, methods require high technology and expensive tools. The purpose of this research is to achieve a method that Uses cameras and shooting with standard methods Soil surface roughness parameter values can be obtained (microtopography).

Photogrammetry with two aerial and close-range photogrammetry branches is the science of measuring and interpreting the desired object through images without direct contact with it. One of the applications of this method is the provision of the map using the non-metric digital camera (Zarei et al., 2021; Niazi et al., 2021). The necessity of using the cameras is the approximate determination of interior orientation parameters of them. Photographing in close-range photogrammetry is different from aerial photogrammetry. In the close-range photogrammetry is not necessary to observe the stereoscopy prominent principles, and it is possible to take the image from the desired angles by considering a geometric strength. In most cases, feature extraction does not occur in form of stereo, and the measurements of the points and the drawing of the features are done in multi-image form (more than two images) (Zehtabian et al., 2017). Close-range photogrammetry can be used as a precise and inexpensive measurement method to provide a map of the small structures, facades of buildings, and so on. Despite the advances made in the production of close-range photogrammetric software, it is possible to use non-metric digital cameras (personal digital cameras) to produce a 3D map of small objects with a millimetric precision.

Surface roughness is a key factor in the recognition of soil and earth properties in the fields of micro-meteorology, agriculture, hydrology, and planetary science (Kargaran et al., 2017). For example, in the field of cultivation, it is a very good indicator of the soil's sensitivity to wind erosion. Roughness affects the water penetration, runoff, water storage, and radiation distribution; as a result, it indirectly affects moisture, temperature, and soil aeration (Bretar et al., 2013). Wind erosion and the process of soil degradation are of central importance in semi-arid regions (Dastorani et al., 2008). The uncultivated soil is deeply affected by wind erosion compared to under cultivated soil. The soil roughness caused by tillage is one of the important features that affects wind erosion (Zhang et al., 2004). The dust caused by the wind blows changes atmospheric composition and weather conditions, which is one of the most dangerous environmental issues (Azad et al., 2021). Wind erosion also leads to the reduction of soil fertility, filling water channels and water reservoirs with wind deposits (Nordstrom & Hotta, 2004). The amount of sand and gravel transport varies among the soil surfaces with various roughnesses, because the required threshold speed for the movement of sand is changed by roughness. Roughness length (Z0) is the key parameter of this aerodynamic process. This parameter is equal to the height from the surface at which the wind speed falls to zero (Vulfson et al., 2012; He et al., 2021).

Wind erosion control requires quantifying the surface characteristics and estimating the erosion rate. Processes such as storing moisture in the soil, stresses, and contact friction caused by wind blowing or falling raindrops, and sediment transport are affected by roughness (Jester & Klik; 2005, Taghizadeh et al., 2016). Soil roughness measurements using roughness can be classified into two large classes: 1- Contact methods: in this method, mechanical tools (such as rods that are mounted on a mold with a similar distance) directly contact with soil. One of the disadvantages of the method is the change of the soil surface by device contact, the required time for collecting data, and accuracy; 2: Noncontact methods: The measuring tools are far from the surface of the soil and do not touch the soil surface (Afrasiyabi et al., 2019; Zehtabian et al., 2013). The first description of roughness was presented by Koperz in 1975, where the roughness surface is assumed as a set of points. According to this definition, the standard deviation of the point height is considered the roughness index. Romkens and Wang (1986) introduced small topographies based on frequency and area occupied by the level. Vulfson (2012) proposed a chain application method for measuring ground roughness. He measured the soil surface roughness by this method and compared it with the results of laser scanning and showed a significant correlation between the results of these two methods. In this method, the ratio of the chain length in the real and the horizontal image of the chain on the roughness surface were compared and its roughness index was estimated. Allmaras et al. (1996) introduced the concept introduced by Koperz as a random roughness index. Random roughness includes the topographies caused by the deposition of aggregates and other components of the soil surface, and the roughness caused by the topographies of the planting rows are not considered. Ewins and Pilgrim (1997) suggested that although roughness indexes such as the mean height or SD of the height of points provide some of the scientific needs for assessing the effect of roughness on wind erosion, none of these indexes fully provides the required information.

Several studies have been carried out in the field of photogrammetry and the use of Photomodeler software. Some of these studies are briefly mentioned here. Ewins and Pilgrim (1997), evaluated the Photomodeler for submersible use and indicated that the study of three-dimensional evolution is necessary for ancient sites. While, there are some good techniques for underwater work, which are generally difficult, time-consuming, expensive, and limited to a certain depth of diving. The Photomodeler system requires the use of several photographs of an object in different directions with only one camera. The results of the evaluation of the Photomodeler system for underwater work showed that this package is suitable for this task, although very few values of error should be accepted. Gomes et al. (2003) carried out the "Photogrammetry Project in Brazil: Using the Photomodeler software". The project aimed to find a technique for recording and measuring the Brazilian architectural heritage at an affordable cost. Among the common photogrammetry methods, Photomodeler was the cost-effective method.

In other research, Zhang et al. (2004) evaluated the effective factors on the accuracy of nonmetric analysis of 3D photogrammetry using Photomodeler. Besides, they investigated the special variables that affected the accuracy of 3D, non-metric, and analytic photogrammetry using Photomodeler software. They also evaluated the camera properties, a method of photo production, the use of labeling, and the number of control points to determine their relative effects of them on coordinate accuracy (Afrasiabi et al., 2019). Among the studied parameters, the number of control points and the number of photos had the highest effect on accuracy. Fathizad et al. (2017) investigated the identification of face photos using Photomodeler and stated that since criminals can be photographed by CCTV cameras from different angles, the set of photos can be used in face 3D interpretation (Switzer & Candrlic, 1999). The results showed a high accuracy among 15 cases so that 14 out of 15 cases were performed correctly.

Since field operations and ground measurements of desert pavement are time-consuming processes, in the present study we aimed at using automatic and semi-automatic digital methods to evaluate and measure desert pavement.

A review and summary of studies performed in this field shows Most of these studies have been in the field of agriculture and for example plowing is referred to as microtopography. Which has larger dimensions than the microtopography created by desert pavement. In other words, none of these studies has examined the microtopographies created by desert pavement or roughness from the view of wind erosion and this is one of the main approaches of the present study.

2. Study Area

Ashkzar County is one of the cities of Yazd province in central Iran. Ashkzar city is the center of this county. Ashkzar County with an area of 5644 KM^2 is located in the northwest of the province, It is located 20 km northwest of Yazd city and it is located between 53◦ to 54◦ 29′ 31" longitude and 31◦ 35′ 32" north latitude (Fig. 1).

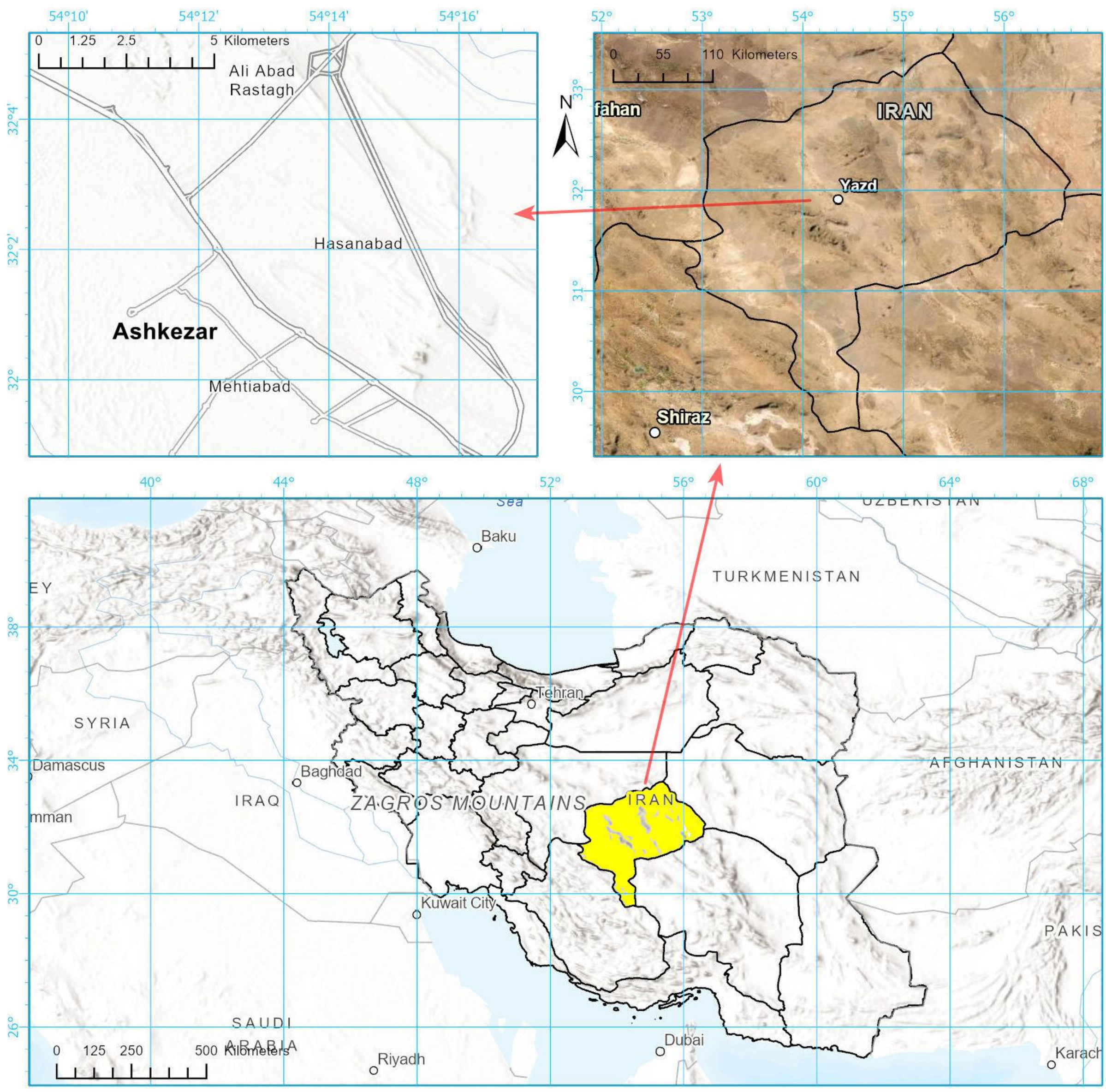

Fig. 1- Study area in Yazd Province in Iran

2. Material and methods

2.1. Camera calibration

In recent years, the image sensor in digital cameras has created a unique advantage in taking and processing photos. Today, the digital camera is used by everyone and has many applications in many fields such as photogrammetry, archaeological research, medical research, plant protection, and crop growth ((Jester & Klik; 2005, Khosravi et al., 2020). In this study, the Nikon D3200 camera was used. First, the camera was calibrated and the calibration parameters were determined. For this purpose, Photomodeler software was used. Accordingly, the basic photos in the guideline of the software were printed on 12 sheets of paper and their photos were taken from different angles.

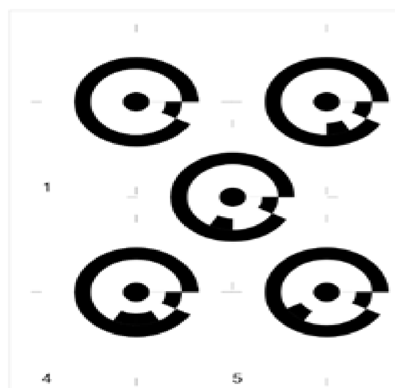

Fig. 2- Photomodeler calibration points network.

To take photos of calibration points, the camera was mounted on a tripod and the printed sheets of paper were placed on a 1m2 area surface with determined intervals, and shooting was done in three steps (Fig. 2). In the first step, the camera was positioned to create a 45-degree angle with a points network, and photographs were taken from the four sides of the surface of the paper in the clockwise direction. In the next step, the camera should be rotated to the left, and the shooting was done from the four sides of the screen. When the camera was rotated right, the same process was done for the third time. In each photo, the proper coverage of the points network screen should be obtained and the height of the tripod should be 170 cm (Fig. 3-5).

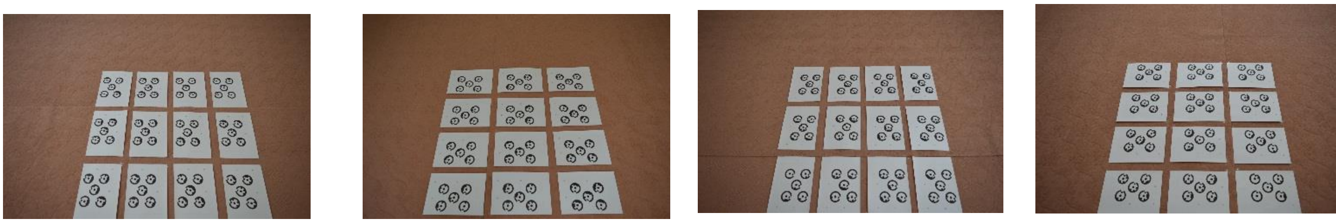

Fig. 3- The view of provided photos (the camera has 90° angle with the surface)

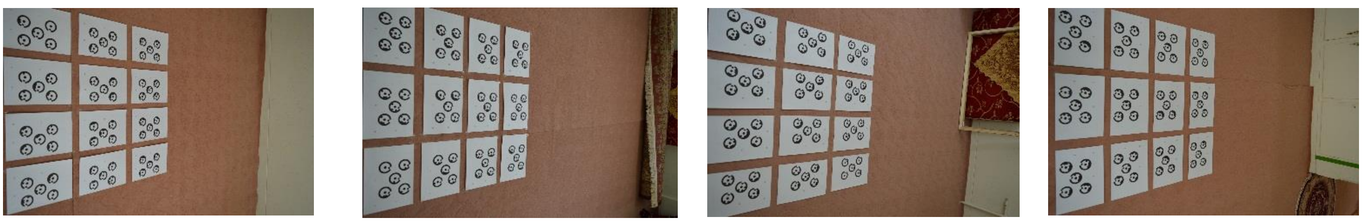

Fig. 4- The view of provided photos with the right-rotated camera

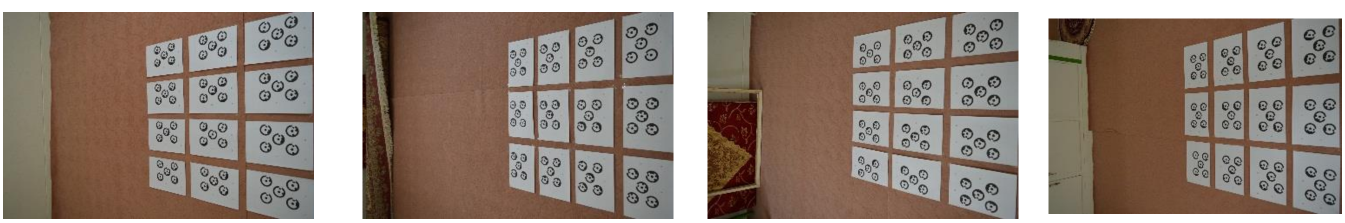

Fig. 5- The view of provided photos with the Left-rotated camera

After finishing photographing, 12 taken photos were entered into the Geomatica software. It should be noted that the photos should have compatible with the software. To provide a calibration file, the software determined some maximums to some parameters as follows:

1: Total Error/Last Error: 4

2: Quality/Point Marking Residuals/ Overall RMS: 0.5 pixels

3: Quality/Point Marking Residuals/Maximum: 2.0 pixels

4: Quality/Point Marking Residuals/Maximum RMS: 1.0 pixel

These parameters were determined after processing photos by software and then a file containing calibration parameters was created. Photomodeler is a Windows-based software for measuring and making a 3D model of objects and complications. In this software, a DSLR* camera can be used as an input device.

* Digital Single-Lens Reflex

Photomodeler software analyzes the taken photos in a short time and provides a calibrated file with details.

2.2. Sieving pavement samples

the desert pavement samples were collected and particles with different diameters were separated using a sieve and shaker device. In plain areas, the sizes of the particles varied from 2mm to over 4cm. In the present study, the results of a three-dimensional simulation of desert pavement with the actual values of the existing particles with a diameter less than or equal to 4 mm were used to test the results.

It should be noted that it is possible to use other particles in other sieves. Thus, in this study, all of the test particles were 4 mm in diameter and less. Then the particles were distributed in a plot of 1 m2 and the next step was carried out.

3.2. Photographing the particles in the plot and their analysis

After generating a calibration file and particle size separation, it is necessary to photograph the surface of the pavement. To do this, at first, a 1m2 plot was made with a minimum thickness and a width of 4 cm. In the next step, targets similar to calibration network targets were printed and installed on the plot (in calibration background was white and targets were black, but in-ground sampling, the background was black and targets were white). It is worth pointing out that the targets output was provided by Photomodeler software. Then, the plot was placed on a flat surface and two pairs of vertical photos and 4 photos from 4 sides of the plot were taken (Note: during taking a picture of the surface, be careful that the lens zoom is set to a minimum value).

In the next step, 8 taken photos were entered into software and processed, and then all plot targets were labeled. To perform calculations, the following steps were performed in order:

1- Coordinate System: At this stage, the dimensions of the plot, the location of the origin of the coordinates, and the axes X, Y, and Z on the platform are defined for the software.

2- Cut the working area, which is the same surface that is in the plot.

3- Creating a regular network of points that are specified for each point of X, Y, and Z parameters.

4.2. Providing output with text file format

The result of these steps is a three-column text file representing the values of x, y, and z. By processing the file in Excel software and sorting them, we can use them in the ArcGIS software to build DEM (Jamali et al., 2020). Hence the soil surface roughness was created digitally.

3. Results

In the first step, the calibration points saved in the Photomodeler software were used to find the calibration parameters by printing them on 12 sheets of paper. Then, the printed papers were placed on a 1m2 screen and 12 photos were taken from different angles (Table. 1). The provided photos were introduced to the software and the calibration process was done.

The values of the named parameters in the calibration report were assessed. For example, camera calibration parameters were presented in Table 2.

Table 1- The used values in the camera calibration of the present study

Name	Nikon D3200[18.00]
Format Size	W: 24.0069 H: 15.9574
Focal Length	18.8712

Table 2- the values of parameters in calibration file

Parameters		values
Total Error/Last Error		0.484
Quality/Point Marking Residuals	Overall RMS	0.062
	Maximum	0.310
	Maximum RMS	0.033

In the next step, the 1m2 plot was prepared and placed on the pavement. Then, 8 photos were taken (Fig. 6).

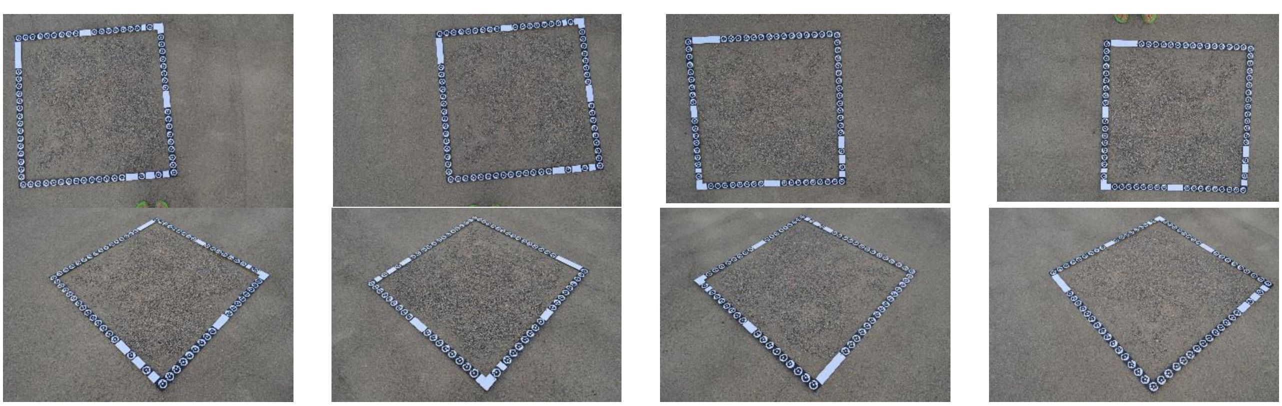

Fig. 6- the taken photo from the soil surface

The photos of the pavement were analyzed during the 4 described operations, and the file containing information related to the point was obtained. In the next step, the text file was arranged in the Excel software to prepare DEM in ArcGIS software. Finally, DEM was prepared in the Surfer software (Fig. 7).

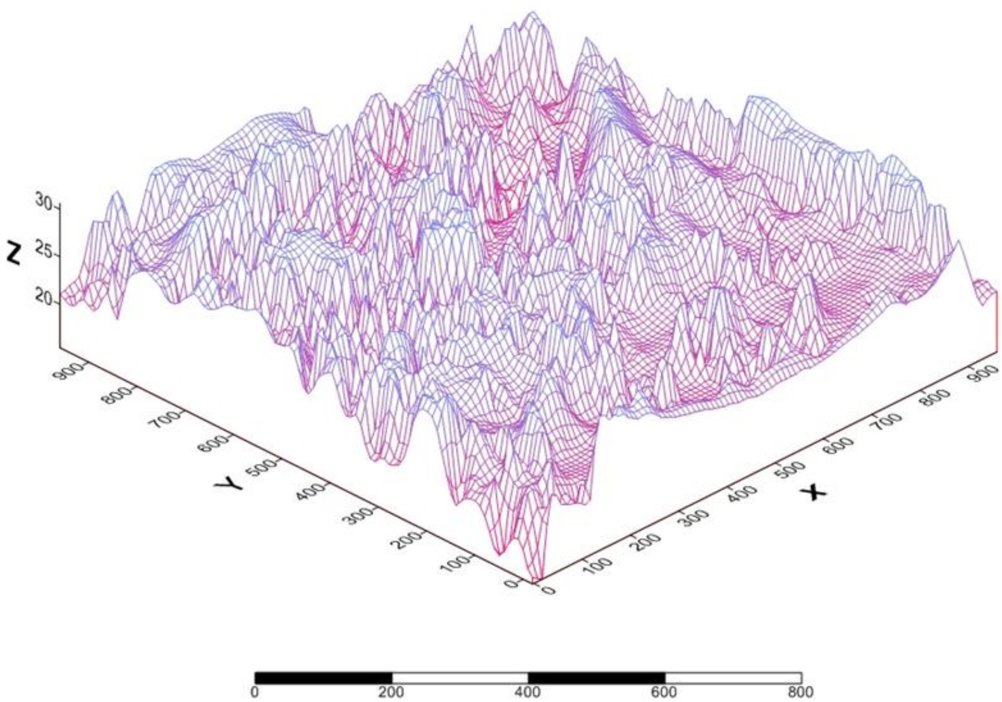

Fig. 7- DEM of pavement in surfer software

4. Discussion and conclusion

To compare the elevation values obtained from Photomodeler software and actual values, a T-test was used. The results were presented in Table 3 and Table 4. Table 3 provides descriptive statistics for the hypothesis test. The calculated numbers represent the number of data, mean, standard deviation, and Std. Error Mean, respectively. The results of the descriptive statistics test showed that the mean value of the sample (24.55) is more than 20, but this should be confirmed by inferential statistics (assumption test with a confidence interval).

Table 3- One-sample statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00008	2846	24.5536	6.52105	.12224

Table 4 shows inferential statistics and the results of the test. According to the Statistic value of t -25 / 37, the freedom degree of 2845, sig is zero.

Table 4- inferential statistics

One-Sample Test

	Test Value = 20					
	t	df	Sig. (2-tailed)	Mean Difference	99% Confidence Interval of the Difference	
					Lower	Upper
VAR00008	37.253	2845	.000	4.55362	4.2385	4.8687

The difference between the average of the sample and the value of the under test sample is 4.55 and the confidence interval of 99% is between 4.86 and 4.24. Considering the positive upper and lower limits, the average is greater than under the test sample. Besides, in this method, all points will be effective.

The pavement as a natural factor of soil protection against wind erosion is of central importance. This coverage causes roughness on the soil surface. The formed roughness of desert pavement is one of the wind erosion control factors.

The results of this research indicated that Photomodeler software can be used to estimate the camera calibration parameters, as well as the three-dimensioning process, and to extract the elevation information. Moreover, the software plays an effective role in decision-making in project management operations (Tazeh et al., 2018).

The traditional method of measuring soil roughness, although has high efficiency, it has low accuracy and all elements of pavement are not involved in the measuring average elevation. While, in this method, because of a regular network of selected points all elements of the pavement are involved in the measuring process. Therefore, spending less time and cost more accurate roughness value is obtained and it helps to provide an accurate model of surface and mean roughness of elevation.

The results of the present research were in agreement with those of Ewins and Pilgrim (1997) who designed a three-dimension model of the object underwater. Moreover, Gomes et al. (2003) aimed at finding a cost-effective method for a model object and selected Photomodeler software, which is in agreement with the results of the present study. Lynnerup et al. (2003) employed Photomodeler to model the face of criminals, which was recorded by CCTV cameras from different angles and its results were consistent with the present research.

Also, the results of this research are Correspond. with the results of Zhang 2010 in the use of digital cameras and the preparation of maps related to land surface features. Also, the results of this study are consistent with the results obtained from the study of Gomes in this project to the application of photogrammetry in Brazilian agricultural lands. Other studies were conducted by Vulfson 2012, in which the effect of photography angles on the studies and interpretation of 3D photographs is mentioned, which is Correspond with the calibration of photography parameters in this study.

Based on the results obtained in this study, the initial hypothesis was confirmed and it can be concluded that Desert pavement roughness can be measured using short-range photogrammetry.

The results of this research can be used by experts in various environmental sciences, including in topics related to wind erosion. It is suggested that the present study be carried out on other types of desert pavement with different granulations and in a larger number of areas so that it can be used operationally in executive projects.

Declarations

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Conflict of Interest /Competing interests (There are no conflicts of interest or competing interests to report.)

Availability of Data and Material (Data and software applications that support and underlie this study are publicly available sources.)

Consent to Publish (Authors consent to publishing)

Authors Contributions (All co-authors contributed to the manuscript)

Code availability (Not applicable)

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