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RESEARCH PAPER

The Relationship between Physiognomic Characteristics of *Tamarix Aphylla* and *Seidlitzia Rosmarinus* and Morphometric Parameters of Khour Va Biabanak County Nebkhas using Regression Methods and Artificial Neural Network

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Abstract
As a series of desert features, nebkha is formed as a result of the accumulation of sediments around plants. On account of different characteristics of plants, which create nebkha, there is a structural difference between them and other forms of sandy features. Adequate information about nebkha would help efficiently and manage wind erosion-prone lands to identify appropriate wind erosion programs. This study aimed to compare regression methods and artificial neural networks to investigate the relationship between the quantitative characteristics of *Tamarix aphylla* and *Seidlitzia rosmarinus* plant species and quantitative parameters of nebkha. The regression methods used in this study included PCR (Principal Component Regression), PLS (Partial Least Squares regression), and OLS (Ordinary Least Squares regression**)**. Herein, the plant characteristics used were plant height, length, width, and type, and the morphometric characteristics included nebkha length, height, slope, and width. The number of sampling points in this study was 80, which were randomly selected from nebkha in Khour va Biabanak County. 70% of the data was used for training the network and 30% for validation. According to the results, the highest R^2 between nebkha length and *Seidlitzia rosmarinus* plant characteristics was observed using the OLS method ($R^2 = 0.8$), followed by nebkha area and width, which were lower in the neural network ($R^2 = 0.76$). For *Tamarix aphylla*, the highest R^2 was related to the characteristics of the plant with nebkha length ($R^2 = 0.797$), followed by nebkha area and width; in the neural network method, R^2 was 0.78. Moreover, the evaluation results of different predictive models revealed the superiority of the OLS model over the other models.

Keywords: Nebkha, Morphometric parameters, *Tamarix aphylla*, *Seidlitzia rosmarinus*, ANN, Regression methods

Introduction

It is necessary to study the characteristics of different wind erosion forms and their relationship with other landforms and environmental phenomena since it is an important criterion for assessing the conditions of natural resources, particularly in areas with high sensitivity to erosion. The use of some morphometric properties in the study of the characteristics of different wind erosion shapes can provide us with highly important information about the behavior of these shapes in different environments (Kargaran et al., 2017).

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Nebkha, are sand dunes that form around vegetation. They are a function of the common wind regime in the region, the amount of sediment loads available, and the type of vegetation. The sand accumulates at the base of the plant, leading to the formation of a sand dune around the plant over time and the formation of nebkha (Tazeh et al., 2018). Nebkhas may also be called phytogenic dunes because they are usually formed as a result of aeolian deposits accumulated at the base of shrubs and bushes in desert areas (Ruz et al., 2017).

These phenomena are mainly caused on smooth surfaces, where the amount of sand is moderate and there is enough moisture for vegetation survival. The shape of nebkha depends on the plant species, height, and plant cover of the host plant. Their height varies between a few decimeters to a few meters and their length ranges from 1 meter to several meters (Danin, 1996). In fact, they are a collection of suspended sands that surround plants (Wang et al., 2003). It could be stated that a nebkha is a series of features formed by vegetation (Li et al., 2018).

It is worth noting that individual plants should have a height of over 10-15 cm to be able to control the sand. If the sand grains that form the nebkha lack adhesion, clay, or silt elements, the size and volume of the nebkha dunes will change with the changes in wind speed (Hugenholtz et al., 2005). Different plant species show different levels of resistance against the burial of loess and can affect the dune by selective transport and burial (Maun et al., 1999).

With an increase in the sedimentation rate, the plant continues to grow until the plant's roots are connected to the groundwater level. However, where groundwater levels fall, the connection is impaired and nebkha begins to decay, leading to nebkha death eventually. (Nickling et al., 1994; Hesp, 2002).

A few studies have been conducted on nebkha and the factors affecting their shape.
Plant growth and characteristics affect the formation of these dunes (Necsoiu et al., 2014). Identifying nebkha, we can determine the amount of soil surface roughness (Afrasiabi et al., 2019). Nebkhas usually exist in areas with more degraded soil, where human activity-associated factors have exacerbated soil degradation and vegetation (Li et al., 2018). In a study on nebkhas, Tengberg (1995) concluded that nebkha is a good indicator of soil degradation in an area.

To date, there has been increasing discussion about identifying appropriate indicators for the rapid assessment of the severity and extent of destruction in arid areas (Tazeh et al., 2015; Khosravi et al., 2020). On the other hand, geomorphological indicators are of great importance owing to their low computability and direct relationship with erosion and sedimentation processes (Vali et al., 2008).

Some researchers have studied the geomorphological characteristics of nebkha (Khalaf, 1989; Tengberg et al., 1998; Hesp et al., 2000). However, Brown and Porembski (1997) and Bornkamm et al. (1999) further investigated the effects of plant parameters.

To control desertification as much as possible and to conduct accurate assessments in this field, it is critically important to identify nebkha and the factors influencing its formation.

Nebkha and the plant that creates it together form a system. Intra-system relationships could be identified through a variety of models. A model is a behavioral scheme or a perception method used specifically in induction systems to predict the results of a series of activities. Therefore, modeling is considered as a beneficial tool for understanding communication (Fathizad et al., 2017; Azad et al., 2021).

To investigate the relationship between nebkha and the vegetation that forms it, we could assess the morphometric parameters of nebkha (nebkha length and slope), which is generally wind direction, nebkha height above the ground level, nebkha width, vegetation widths (plant morphological parameters, plant length, width, and height from the nebkha surface), and the type of plant.

The present study aimed to investigate the effect of length, width, and height of *Tamarix* and *Seidlitzia rosmarinus* species on the morphometric characteristics of nebkha. To this end, we compared OLS/PCR/PLS regression models to artificial neural networks so that the most appropriate method could be identified.

Materials and Methods

Area of Study

Khour va Biabanak County is a desert located in the southwest of Dasht-e Kavir (Kavir-e Namak and the Great Salt Desert), Isfahan, Iran. It is located in the latitude range of 32° 58′ to 33° 46′ north and longitude 54° 57′ to 55° 5′ east, with an altitude of 836 m. Nebkha is one of the most obvious and common forms of sand dunes in the study area (Figure 1).

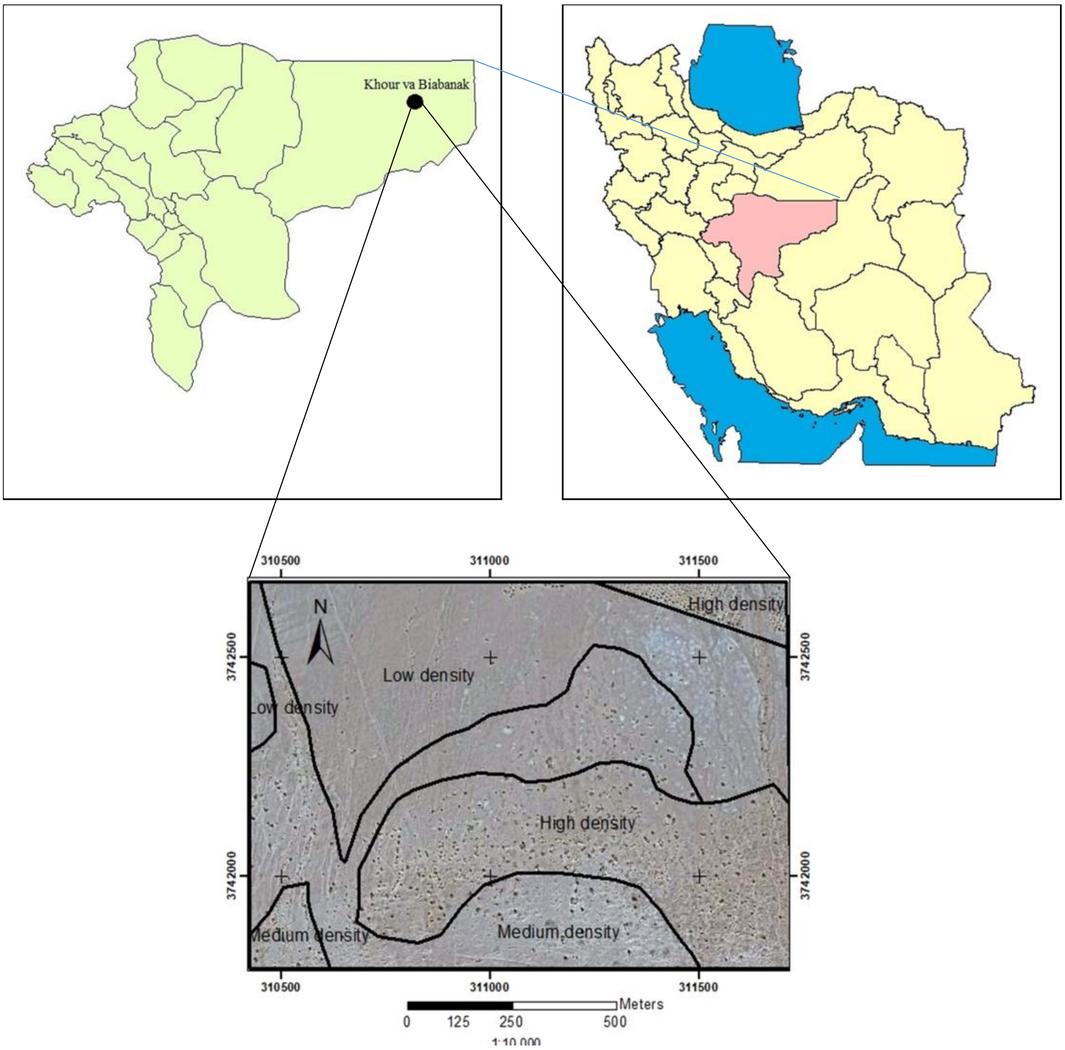


Figure 1. Geographical location of the study area

In this area, *Seidlitzia rosmarinus* and *Tamarix* predominate. A big proportion of the area lacks vegetation due to severely limited salinity and alkalinity. *Amygdalus scoparia* and *Pistacia khinjuk* are found scattered on low mountains in the southern part of the region. In the southeastern part of the region, there is vegetation containing *Haloxylon* spp and *stipagrostis pennata*.

To carry out this research project, the scope of nebkha development was identified using satellite imagery and field studies. Subsequently, the number of sampling points was determined using the Cochran formula.

$$n = \frac{NZ^2pq}{Nd^2+Z^2pq} \tag{1}$$

where n is the minimum sample size, Z is the value of the distribution function (you can calculate this value for alpha that equals to 1.96), pq =0.5, and d is the acceptable standard error.

Accordingly, the total number of sampling points was 80. Figure 2 represents the distribution of the sampling points.

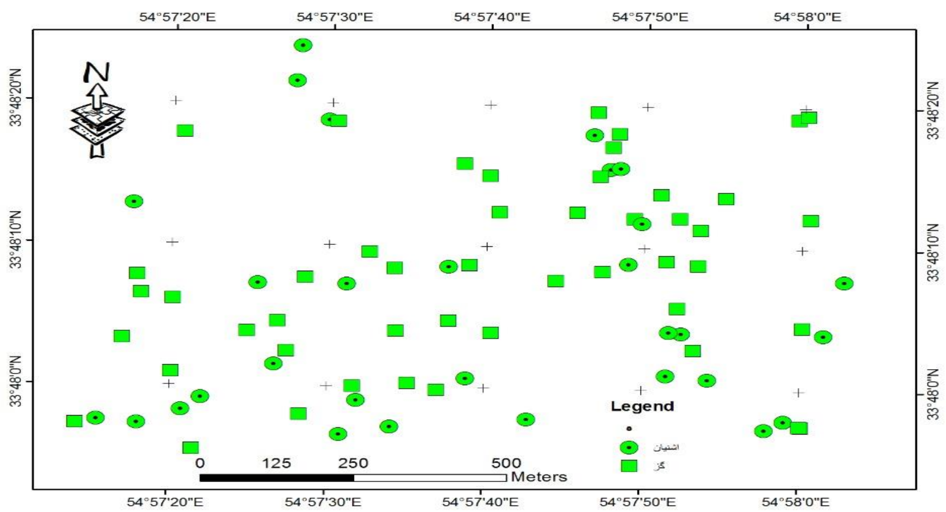


Figure 2. Distribution of the sampling points

In the next step, we arrived in the area and took the necessary measurements on the nebkha and the plants located on them.

Various parameters were measured, including plant length, width, and height, and nebkha slope, length, width, and height parameters (Fig. 3). The measured values were analyzed using different regression and data mining methods.

Figure 3. Image of the measured variables at the field

In this study, OLS / PCR / PLS regression models and artificial neural networks were performed via each of the nebkha morphometric parameters (slope, length, width, and height) as a dependent variable and plant characteristics (length, width, and height) as an independent variable.

Regression Methods

One of the predictive modeling techniques, which examines the relationship between independent and dependent variables, is regression analysis. Identifying the relationships between the variables and predictions could be done using this technique. OLS, PCR, and PLS are among the regression models.

Ordinary Least Squares (OLS)

Ordinary least squares (OLS) is the most frequently utilized method for linear regression models, also called simple linear or multiple linear regression, depending on the number of variables.

This method is based on the assumption that the model coefficients are the values closest to the observation. Furthermore, the coefficients must be estimated in order to reach the minimum of the sum of squares.

Depending on the number of variables, OLS is also called simple or multiple linear regression.

Principal Component Regression (PCR)

For estimating the unknown regression coefficients in a standard linear regression model, used regression analysis technique, that is based on principal component analysis. This technique is called principal component regression (PCR).

In this method, the principal components of the explanatory variables are used as regresses and the dependent variable does not change directly to the explanatory variables.

Partial Least Squares (PLS)

Partial least square regression can fit the effects of independent variables on the dependent variable, as a regression model or structural model. This method is used once the effects of several independent variables on one or more dependent variables are examined. The PLS method does not require any default.

Artificial Neural Networks (ANN)

A neural network is a data processing system that assigns the processing data task to a large number of small processors operating side by side as a continuous and parallel network to solve a problem (Taghizadeh et al., 2016). The main idea of such networks is to an extent inspired by the data processing mechanism used by biological and nervous systems for learning and knowledge creation (Zehtabian et al. 2017; Zarei et al., 2021). Each of these layers contains a group of neurons generally associated with all the neurons in the other layers unless the user restricts communication between the neurons. Nevertheless, the neurons in each layer are not related to the other neurons in the same layer. Since ANNs fall in the black box model class, there is no need to get through the details about the internal information of system performance to identify the relationship between the inputs and outputs.

In this method, there is no need to know the internal information and details because it is a black box model (Fathizad et al., 2017).

Model Performance Criteria

To compare the validity or efficiency of the models, the following criteria were used to compare their results:

Coefficient of Determination

Coefficient of determination (R2) represents the variance percentage of the dependent variable determined by the independent variable(s). In other words, by calculating this coefficient, we could say that the independent variable(s) can explain the percentage of the total variance Y. The numerical value of this coefficient is variable between 0 and 1. Zero means that the use of the independent variable(s) has no roles in estimating the dependent variable and 1 means that the independent variable(s) can estimate the variance of the dependent variable by 100%. If the standard deviation of the variables X and Y are SX and Sy, respectively, and their covariance is shown with the symbol Covy, x, then
R^2 could be calculated using the following equation:

$$R^2=S^2_{XY}/S_{XX}\,S_{YY} \qquad (2)$$

Evaluation Indicators

There are numerous techniques to measure predictive accuracy. This study used Mean Absolute Error (MAE), Root means squared error (RMSE), and mean absolute percentage error (MAPE). Their functions are presented below.

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}(\tilde{y}_t - y_t) \qquad (3)$$

$$\mathrm{RMSE} = \sqrt[n]{\frac{1}{n}\sum_{i=1}^{n}(\tilde{y}_t - y_t)\,2} \qquad (4)$$

$$\mathrm{MAPE} = \frac{1}{n}\sum_{i=1}^{n}(\tilde{y}_t - y_t) * 100 \qquad (5)$$

Results

Tables 1 to 3 depict the relationship between the plant and morphometric traits of nabkha using different regression methods and data mining. Table 3 shows this relationship for *Seidlitzia rosmarinus* and Table 2 for *Tamarix aphylla*.

According to Table 1, among various regression methods employed in this study, OLS had the highest R^2 values among vegetation parameters with nebkha characteristics. Furthermore, this method had the lowest values of estimation error for *Seidlitzia rosmarinus* species. In this method, the highest R^2 (0.799) belonged to the nebkha length. Thus, it could be concluded that the nebkha created by *Seidlitzia rosmarinus* had the greatest relationship between Physiognomic Characteristics of vegetation and nebkha length, followed by the nebkha area (R^2 = 0.728) and nebkha width (R^2 = 0.65), with the highest R^2 values. In this paper, the slope and height of the nebkha were least affected by the vegetation characteristics of *Seidlitzia rosmarinus*.

Table 1. Summary of evaluation indicators of the models (*Seidlitzia rosmarinus* nebkha)

Regression methods	Variable	R^2	MSE	RMSE	MAPE	Equation of the model
OLS	nebkha slope	0.513	22.098	4.701	23.911	nebkha slope = -27.74-14.35a+37.91b+47.57c-34.67d
	nebkha Area	0.728	0.368	0.606	18.726	nebkha Area = -3.18+9.24-02a+3.08b+4.51c-2.16d
	nebkha width	0.650	0.052	0.228	12.587	nebkha width = -0.39+5.18-02a+0.81b+1.48c-0.61d
	nebkha length	0.799	0.041	0.204	8.694	nebkha length = -0.73+0.11a+1.53b+1.89c-1.07d
	nebkha height	0.290	0.011	0.103	15.013	nebkha height = 0.75-0.26a+3.87-02b-0.41c+0.13d
PCR	nebkha slope	0.365	24.922	4.992	26.335	nebkha slope = -7.34-12.3a+18.19b+22.78c-13.3d
	nebkha Area	0.701	0.394	0.628	19.362	nebkha Area = -2.98+0.21a+2.94b+4.14c-1.98d
	nebkha width	0.675	0.049	0.222	12.134	nebkha width = -0.46-1.31-02a+0.87b+1.61c-0.68d
	nebkha length	0.783	0.041	0.204	8.511	nebkha length = -0.76+0.1a+1.56b+1.91c-1.09d
	nebkha height	0.217	0.012	0.111	16.592	nebkha height = 0.81-0.29a-7.62-02b-0.32c+0.16d
PLS	nebkha slope	0.258	30.820	5.552	-----	nebkha slope = 6.56+0.98a+2.47b+3.15c+1.42d
	nebkha Area	0.181	1.049	1.024	-----	nebkha Area = 1.13+0.15a+0.3b+0.43c+0.26d
	nebkha width	0.197	0.114	0.338	-----	nebkha width = 0.87+9.79-0.2a+9.58-0.2b+0.16c+8.65-0.2d
	nebkha length	0.266	0.120	0.346	-----	nebkha length = 1.1+0.17a+0.13b+0.17c+0.1d
	nebkha height	0.119	0.012	0.109	-----	nebkha height = 0.63-0.17a-1.3-02b-0.04c-9.03-03d

a= plant height, b= Plant length, c= Plant width, d= Plant Area

Table 2. Summary of evaluation indicators of the models (*Tamarix aphylla* nebkha)

Regression methods	Variable	R^2	MSE	RMSE	MAPE	Equation of the model
OLS	nebkha slope	0.236	44.827	6.695	36.494	nebkha slope = 39.84 +0.21a+ 3.015b -36.63c +9.09d
	nebkha Area	0.686	0.959	0.979	18.327	nebkha Area = -1.48+1.13a+2.84b-0.6c+4.91-02d
	nebkha width	0.618	0.080	0.283	12.251	nebkha width = 0.30+0.27a+0.71b-6.69-02c-5.68-03d
	nebkha length	0.797	0.032	0.180	6.233	nebkha length = 0.73+0.259a+0.77b-4.84-02c-0.04d
	nebkha height	0.166	0.041	0.203	33.832	nebkha height = 0.74-0.22a5.6-0.2b-0.1c+6.57E-02d
PCR	nebkha slope	0.239	45.489	6.745	37.370	nebkha slope = 38.66+0.75a+3.57b-36.99c+8.95d
	nebkha Area	0.682	0.939	0.969	18.136	nebkha Area = -1.22+1.12a+2.96b-1.22c+0.20d
	nebkha width	0.627	0.083	0.288	12.669	nebkha width = 0.19+0.27a+0.72b+2.74-02c-0.02d
	nebkha length	0.787	0.032	0.180	6.233	nebkha width = 0.19+0.27a+0.72b+2.74-0.2c-0.02d
	nebkha height	0.165	0.041	0.203	33.638	nebkha length = 0.73a +0.77b-4.84-02c-4.28-0.2d
PLS	nebkha slope	0.018	50.713	7.121	-----	nebkha height = 0.64-0.24a+0.08b+3.87-0.2c+1.75-0.2d
	nebkha Area	0.594	1.056	1.028	-----	nebkha Area = -0.21 +0.73a +0.93b +0.91c+0.28d
	nebkha width	0.578	0.085	0.292		nebkha width = 0.58+0.19a+0.24b+0.25c+7.59-0.2d
	nebkha length	0.633	0.050	0.224	-----	nebkha length = 1.24+0.16a+0.21b+0.21 c+6.51-0.2 d
	nebkha height	0.171	0.036	0.191	-----	nebkha height = 0.74-0.22a+5.77-02b-0.1c+6.58-02d

a= plant height, b= Plant length, c= Plant width, d= Plant Area

Table 3. Descriptive statics of the variables (ANN)

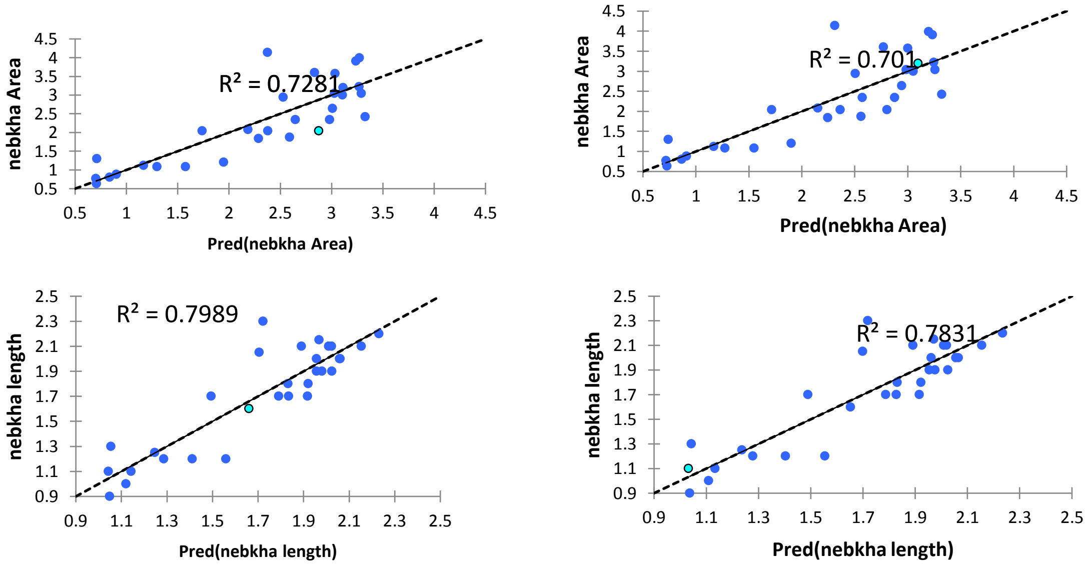
Plant	Variable	R^2	RMSE
Tamarix aphylla	nebkha slope	0.172	6.817
	nebkha Area	0.636	0.818
	nebkha width	0.682	0.258
	nebkha length	0.777	0.222
	nebkha height	0.190	0.83
Seidlitzia rosmarinus	nebkha slope	0.132	5.802
	nebkha Area	0.421	0.820
	nebkha width	0.567	0.251
	nebkha length	0.763	0.194
	nebkha height	0.256	0.094

According to Table 3, the study of nebkha on *Tamarix* using an artificial neural network indicated a higher correlation between nebkha length and Physiognomic Characteristics of Tamarix. . R^2 of this parameter was estimated to be 0.777, followed by nebkha width and the area with correlation coefficients of 0.682 and 0.636, respectively. Moreover, there was the least correlation between the plant and nebkha slope (R^2 = 0.172).

Furthermore, artificial neural network-based analyses on *Seidlitzia rosmarinus* showed a nebkha length superiority with a correlation coefficient of 0.763. This plant had the lowest correlation with the nebkha slope (R^2 = 0.132).

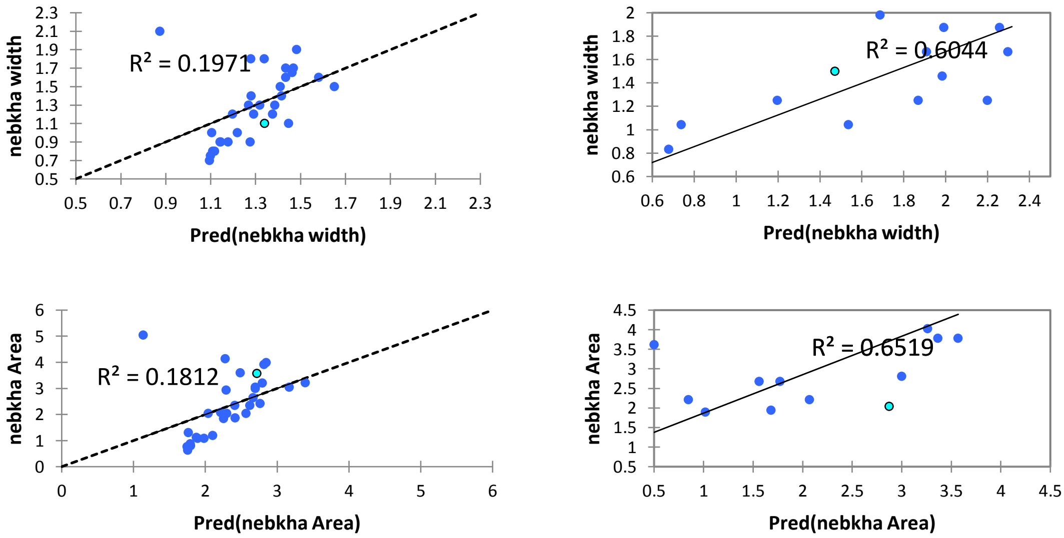
Based on the above tables and analyses, it could be concluded that the highest correlation between the studied parameters was observed between *Seidlitzia rosmarinus* nebkha and nebkha length. This information was obtained utilizing the OLS method.

When comparing these models in terms of efficiency, the more consistent the predictive results are, the more ideally efficient the model is in terms of the results observed. Figures. 4 to 6 show the differences between the estimated values and the actual values for different models for *Seidlitzia rosmarinus*. These shapes reveal the visual recognition of the performance of different estimation models.



OLS PCR

Figure 4. The relationship between the observed and predicted values via OLS and PCR in *Seidlitzia rosmarinus*

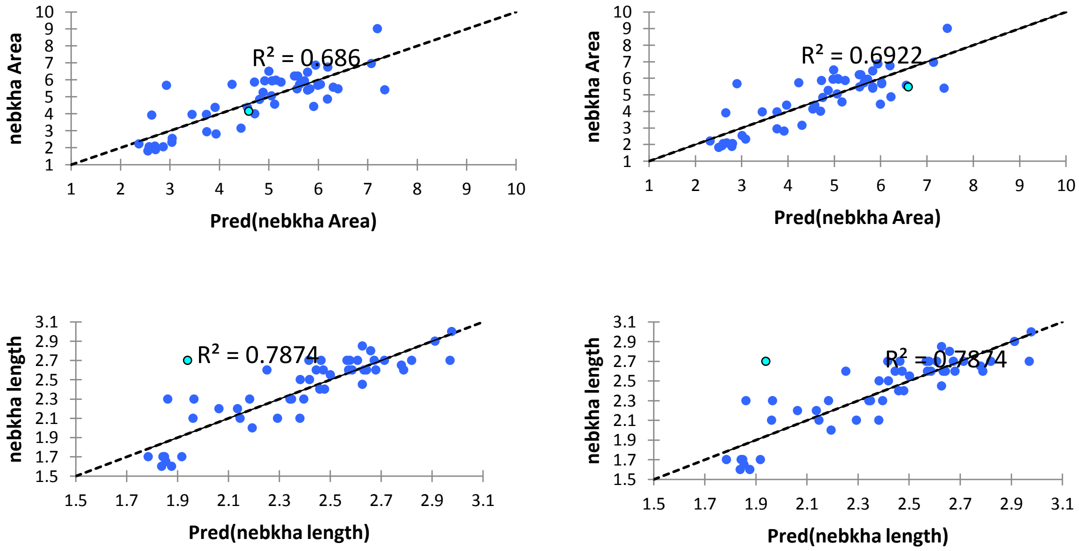


PLS ANN

Figure 5. The relationship between the observed and predicted values via ANN and PLS in *Seidlitzia rosmarinus*

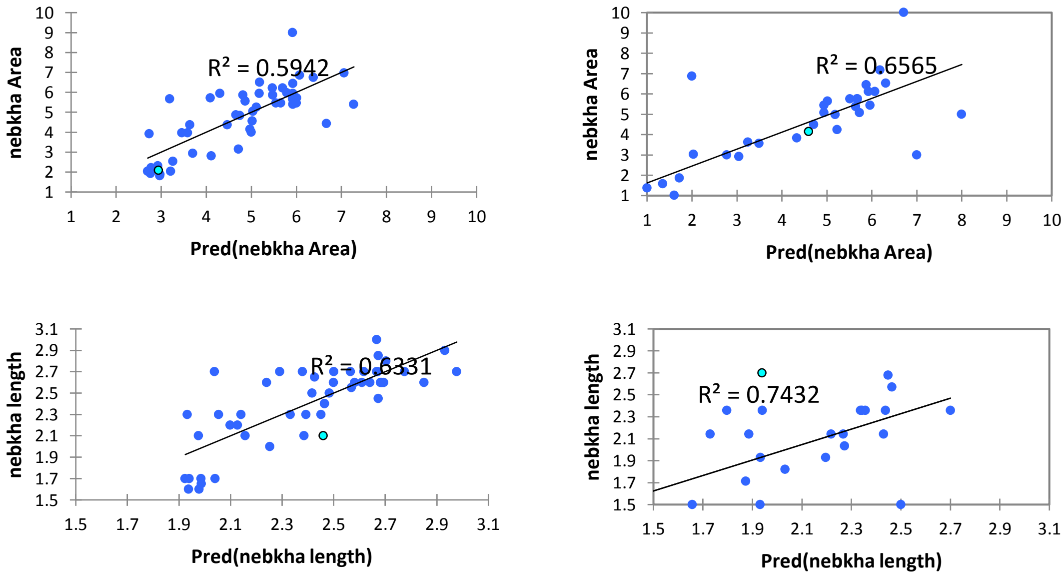
According to Figure 4, the highest correlation between the predicted results and the observed results was obtained through OLS for nebkha length (R^2 = 0.798). Using plant data, the best predictions will be made for the nebkha length through the OLS method, followed by the PLS regression method (R^2 = 0.783).

Analyses of the models and the study of these forms generally indicate the predictive performance of the OLS ideals.



OLS PCR

Figure 6. The relationship between the observed and predicted values via OLS and PCR in *Tmarix aphylla*



PLS ANN

Figure 7. The relationship between the observed and predicted values via ANN and PLS in *Tamarix aphylla*

For *Tamarix*, the results of predictions made by different models are presented in Figures. 6 and 7. As demonstrated, the highest correlation exists between nebkha length and Physiognomic Characteristics of *Tamarix aphylla*. obtained by the OLS regression model with $R^2 = 0.787$.

A greater consistency could be obviously seen between the observed and predicted results in the OLS model regarding this plant compared to the other models, indicating its higher efficiency compared to the other models.

Discussion

Despite the importance of predictive data, as well as the management of desertification and wind erosion, a few studies have addressed this issue. This paper sought to identify the effect of different plant parameters on nebkha morphometric properties using different models and to identify the best model for predicting these characteristics for more informed management decisions. The obtained results revealed that OLS excelled in achieving these goals.

Studies have shown that the OLS method allows the highest level of compliance between the data observed and predicted by the model. The highest correlation is related to the length of nebkha (Figure 8).

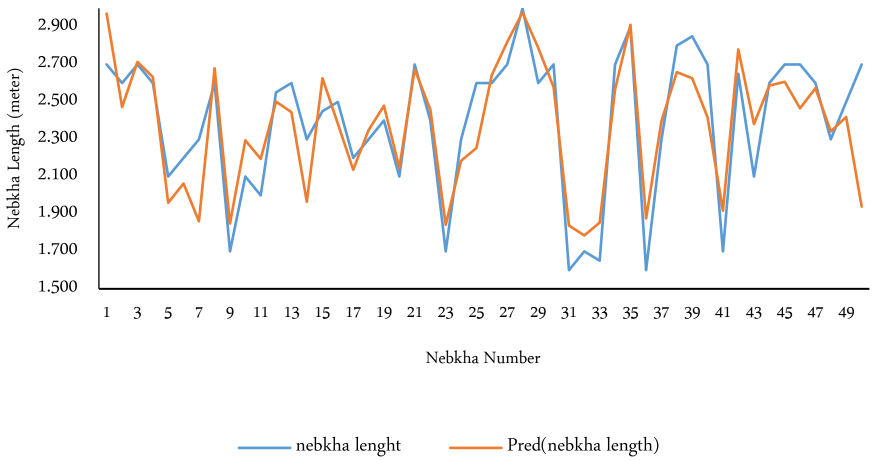


Figure 8. The relationship between the observed and predicted values of nebkha length via OLS

Moreover, thanks to its predictive power, the OLS model took precedence over the other methods.

This study also implied that nebkha length had the highest correlation and nebkha slope/height has the lowest correlation with plant parameters when estimating the correlation between the parameters of different plant species through different methods for both species and all the methods in the study area.

Li et al. (2014) examined *Tamarix* nabkhas located in Hotan County, China. They reported a correlation between plant parameters and nebkha characteristics, which is consistent with the results of the present study.

In their study on the characteristics of nebkha, li et al. (2019) found that morphometric parameters of nebkha varies due to the effect of vegetation on nebkha, indicating that these results are consistent with those of our research.

Thomas and Dougil (2001), having studied the South African region, concluded that Acacia nebkhas had a higher correlation with nebkha parameters owing to the morphology of the plant. This research also confirms the results of our work.

Furthermore, Hesp et al. (2013) examined the dynamics of nebkhas using the Monte Carlo (Cellular Automata) model. Their results showed the ability of this model to distribute the size of sand grains in each time stage in the total volume and the distribution of compression in each time stage in the total volume of sediments.

Generally speaking, according to the results of the current study, the plant characteristics of *Seidlitzia rosmarinus* have a higher correlation with nabkha parameters compared to the Tamarix phylum. It seems to be attributed to the vegetative form of these species. *Seidlitzia rosmarinus* is a plant species with a greater impact on the nebkha characteristics formed on it owing to a denser canopy and its proximity to the earth's surface. Meanwhile, the *Tamarix* phylum is a shrub with a height of 6 m, whose canopy features have less of an effect on the slope, length, width, and height of its nebkha. In general, in all the methods studied, the plant characteristics of both *Tamarix* phylum and *Seidlitzia rosmarinus* had the greatest effect on nebkha length, area, and width, and had the least effect on nebkha slope and height. This could be attributed to the characteristics of the plant and their effect on reducing wind speed and increasing sedimentation alongside plants, as a strong determinant in nebkha shape parameters determination.

Compared to different regression methods, OLS had the highest R^2 values, followed by PCR. In both cases, PLS had low R^2 s, indicating that this method was not appropriate.

In a general comparison between regression methods and artificial neural network methods, OLS and PCR regression methods had higher R^2 values compared to artificial neural network methods for both plants.

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