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Area and depth investigation of Anzali pond using satellite imageries and group method of data handling neural network

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Abstract: Analysis of changes in natural resources is one of the fundamental issues in remote sensing. Several research studies regarding the process of changes in natural resources using satellite imageries and image processing techniques have been done. Anzali pond is one of the important ecosystems in Iran that under the impact of some factors such as drought has the gradual drying trend over the last years. This study measures the area of basin surface and predicts the process of changes in the climate of the pond neighborhood during the next years, using GMDH neural network. Satellite imagery and meteorological data is used for this analysis. The final results represent reduction in area from 82 km^2 in 1998 to 51 km^2 in 2010. The average depth of the pond decreased to less than 4m in 2010 from 9m in 1998. The main reason for this reduction is diversion of rivers, sediment entering and changes in land use around the pond. If this trend continues, the amount of pollutants and toxins will reach to warning and this is a serious threat for animals and pond dwellers.

Keywords: Anzali Pond, Remote Sensing, Image Processing, GMDH Neural Network

1. Introduction

Investigating the conditions of natural ecosystems such as ponds, forests, grasslands and lakes is one of the significant issues in every country which is usually performed by remote sensing technology. Assessment or evaluation of land use changes and developments are a process that leads to understanding of how humans interact with the environment. A fundamental issue in pond evaluation is to consider changes in terms of area and depth [1].

The depth of the pond depends on the area of it. Therefore, calculation of area for forecasting the depth is essential. Several studies have been conducted about the Urmia lake in Iran about determination of influential factors on the reduction of volume and area of the Urmia Lake using visual analysis of satellite imageries and meteorological data [2]. In similar research studies, the environmental risk is determined through characterization of texture of the lake using image processing techniques [3]. In 2007, a study was done on the pond that utilized satellite imageries for estimating the masses collected on the pond surface [4]. In another work, changes in appearance of the pond, using satellite imageries and texture sampling were identified [5].

A pond is a shallow body of water separated from a sea by a low sand bank or reefs that have many advantages including flood control, water quality maintenance, wildlife habitat and erosion control. Anzali pond is one of the most important ecosystems in the north of Iran and in terms of ecological and economical sustainability has regional and international significance. Therefore, evaluation of the pond changes is essential. The Anzali pond lies in a location about 40 km from the north of Rasht in the southwest Caspian Sea.

The similarity in the texture of the pond margin is one of the most substantial issues such as the similarity between canebrake, rice cultivated land and aquatic plants, that makes it difficult to calculate the area. In this study, reaching to an appropriate formula, first, the solid part is separated from the aqueous part. Next, the area of the pond is calculated between1991 to 2010. By measuring the area and having influential factors such as sediment entering, input rivers, amount of rainfall as well as evaporation. The table of affecting factors on the pond is created and finally, using neural networks, an appropriate estimation for the future conditions of the pond according to changes in the area and depth, is estimated.

The structure of this paper is as follow:

In section 2, some primary definitions are expressed. The third section includes the proposed method and the method of calculating the area from satellite images. Next, changes in the depth and area in the future years is forecasted using neural network. Finally, in section 4 the final results are discussed.

2. Definitions and Procedures

2.1. Remote Sensing

Natural phenomena of the earth surface changes rapidly and these changes during the human life are very salient. In recent decades, using remote sensing technology for detection of these alteration, have aroused researchers' interest. Monitoring and evaluating regions such as coastal areas like the lakes and ponds as the ecological environments have been focused. Evaluating these regions is one of the essential issues in national development and natural resources management. In recent years, evaluating and detecting changes in the lakes, ponds and shorelines/coastlines became one of the important issues. Due to dynamic nature of shorelines managing this kind of ecologic environment needs correct information during specific time intervals. In this situation remote sensing technology plays a substantial role for obtaining information from phenomena on the earth surface. Multi-spectral satellite imageries have many advantages such as numeral interpretation and availability.

2.2. GMDH Neural Network

Group method of data handling (GMDH) algorithm is a self-organizing approach by which gradually complicated models are generated based on the evaluation of their performances on a set of multi-input-single-output data pairs (x_i,y_i) (*i=1, 2, ... M*). The GMDH was firstly developed by Ivakhnenko [6] as a multivariate analysis method for complex systems modeling and identification.

GMDH can be used to model complex systems without having specific knowledge of the systems. The main idea of GMDH is to build an analytical function in a feed forward network based on a quadratic node transfer function [7] whose coefficients are obtained using regression technique. In recent years, the use of such self-organizing network leads to successful application of the GMDH type algorithm in a broad range area in engineering, science, and economics.

3. The Proposed Procedure

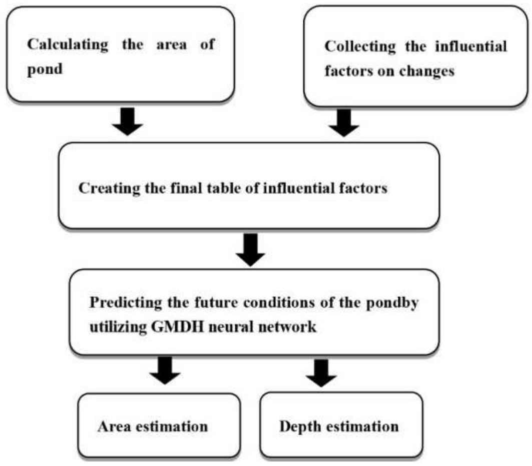

Figure 1. *The flowchart of proposed procedures*

As shown in Figure 1, first the area of pond has been calculated by using image processing techniques. Next, the table of influential factors was created according to meteorological data. In the next step, GMDH neural network was used in order to predict the future conditions of the pond's depth and area calculated based on these input data.

3.1. Measuring the Area of the Pond by Using Image Processing Techniques

Calculating the area was performed by using remote sensing and image processing techniques. In this study, the Quick bird satellite imageries were applied. In some images, noise caused some errors in calculation of the area where image processing techniques solved this problem. Next, in segmentation part, the area of the pond was separated from the ground. Finally, the area is measured by counting the pixels of pond surface and considering the image scale. For classifying pixels into two classes of water and ground, this study used spectral features of water. It means that by considering the water spectrum and taking into account the image spectral bands, through allocating precise image coefficients, the water part can be separated from the ground part. Then by counting the number of pixels in water part, area of the pond is measured.

In this method, the area is measured by dividing the number of pond pixels in $1km^2$to the total number of pixels in the same part. This method is a type of unsupervised classification and this strategy is relevant to determination of changes in the pond.

Furthermore, the pixels were classified into water and ground classes, applying the following Equation 1. In this equation B_2, B_4 , and B_5 are second, fourth and fifth band, respectively.

If ((B4 > B2) and (B5> B2))

Then 0 else 255

Figure 2 depicts the separation of water part from ground in 1991.

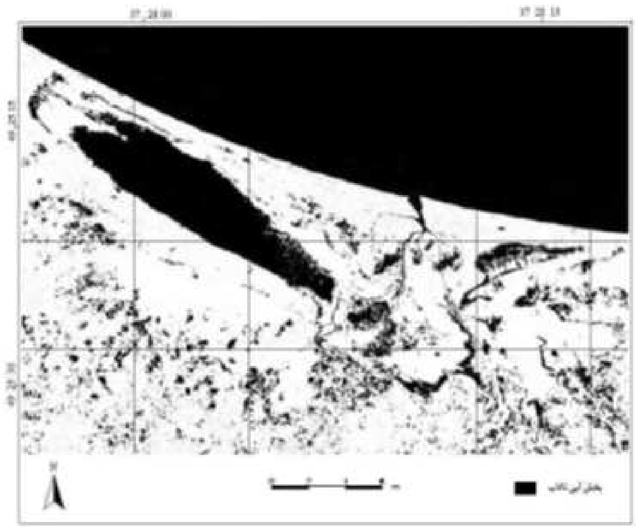

Fig. 2. Separation of water part from ground in 1991.

3.2. Modeling Using GMDH-Type Networks

The classical GMDH algorithm can be represented as set of neurons in which different pairs of them in each layer are connected through a quadratic polynomial and thus produce new neurons in the next layer. Such representation can be used in modeling map inputs to outputs. The formal definition of the identification problem is to find a function *f*, so that it can be approximately used instead of actual one, *f*, in order to predict output *y*ˆ for a given input vector

$$(x_1,\ x_2, x_3, \ldots,\ x_n\ ) \qquad (1)$$

close as possible to its actual output *y* . Therefore, given *M* observation of multi-input-single-output data pairs so that

$$Y_i = \text{f}\ (x_{i1}, x_{i2}, x_{i3}, \ldots, x_{i4}) \qquad (2)$$

It is now possible to train a GMDH-type neural network to predict the output values

The problem is now to determine a GMDH-type neural network so that the square of difference between the actual output and the predicted one is minimized, that is

$$\sum_{i=1}^{M} (y_i^2 - y_i)^2 \rightarrow minimization \qquad (3)$$

General connection between inputs and output variables can be expressed by a complicated polynomial of the form

$$Y_i = \alpha_0 + \sum_{i=1}^{n} \alpha_i x_i + \sum_{i=1}^{n} \sum_{i=1}^{n} \alpha_{ij} x_i x_j + \sum_{i=1}^{n} \sum_{i=1}^{n} \sum_{i=1}^{n} \alpha_i x_i x_j x_k \qquad (4)$$

The coefficient α_i in Equation 5 are calculated using regression techniques [7, 8] so that the difference between actual output, *y,* and the calculated one, *y*ˆ, for each pair ofx_i, $x_j$as input variables isminimized. Indeed, it can be seen that a tree ofpolynomials is constructed using the quadratic form given in Equation 5 whose coefficients are obtained in a least-squares sense. In this way, coefficients of each quadratic function $G_i$are obtained optimally fit the output in the whole set of input-output data pair, that is

$$\frac{\sum_{i=1}^{M} (y_i - g_i)^2}{Mn} \rightarrow Minmization \qquad (5)$$

By using GMDH and the relevant values, the formulas of every regression related to the factors are calculated according to the Table 1.

3.2.1. Calculation of Changes in Depth of Pond

Table 1. *Function obtained from GMDH on each of the influential factors from 1991 to 2010*

Influential factors on water changes	Linear regression formula
The area	y = -0.071x + 206.34
Amount of rainfall	y = -8.6803x + 18587
Water entering	y = -6.705x + 15350
Sediment entering	y=35543x+18.339
evaporation	y=19198x+9.12543

Table 2. *Dependent and independent values for implementation of neural network in order to predicting the height of water in pond.*

Meteorological data	constants	variables
Rainfall- independent	B1	X1
Water entering- independent	B2	X2
Temperature- independent	B3	X3
Sediment- independent	B4	X4
Height- dependent	Y	

Y=1298.19+0.00033X1+0.00011X2- 0.5904X3+2.6502X4

Table 3. *Data needed for GMDH neural network*

year	Sediment entering (ton)	Volume of water enteringMillion m^3	Rainfall (mm)	Evaporation(MM)	Area (Km^2)
1991	974.44	1600	1095	1100	57.84
1993	990.759	1700	1246	950	58
1998	1073.616	3100	1154	1020	81.87
2001	1175.728	1900	1324	900	66.9
2005	1273.572	1800	1257	850	66.5
2006	1273.189	1700	1425	800	66
2007	1273.158	2000	1326	900	64.5
2008	1272.214	1900	1411	800	62.09
2009	1271.144	1800	1324	1000	60.39
2010	1291.52	1700	1264	900	56.91

For predicting the depth, meteorological data and height of the pond are independent and dependent values. By investigating the data and values according to Table 3, the coefficients and equation are obtained. The determination coefficient is about 0.74.

3.2.2. Calculation of Changes in the Surface of Area

Table 4. *Dependent and independent values for implementation of neural network in order to predict the area of pond.*

Meteorological data	constants	variables
Rainfall- independent	B1	X1
Water entering- independent	B2	X2
Temperature- independent	B3	X3
Area- dependent	Y	

Y=3104.01+10.1X1+0.15X2-45.13X3

For predicting the area changes with GMDH method, meteorological data and area are considered as independent and dependent values. After investigating the data and values according to table IV, the appropriate equation and formula is reached. This coefficient is about 0.89.

4. Discussion & Conclusion

Determination of climate changes in natural ecosystems is one of the vital issues in remote sensing. Anzali pond is one of the important ecosystems in north of Iran that has have severe reduction in area and depth of pond.

This study used satellite imageries and meteorological data for evaluating the area and depth of Anzali pond during 1991 to 2010. A GMDH neural network method was applied for investigating these criterions. Climate changes especially in recent years lead it to be dried. If serious decisions are not made to prevent sediment entering and changes in land use of pond surrounding, the amount of pollutant and toxins will reach to warning phase. This situation can be end angered the aquatics and birds. The depth decreased between 4 and 5m and the area of the pond also has reduction about $25km^2$. It is suggested that for the future work, a better estimation of pond position can be achieved through combining image processing techniques with other textual features like GLCM features such as entropy and mean.

The results of this research indicate a decrease in the area of about 25 km^2 and the average depth reduced about 5m between 1991 and 2010. By examining the obtained coefficients, it is understood that the trend of reduction in depth and area has increased in recent years. The main reasons for this reduction are excessive entry of industrial and non-industrial sediments to the pond, land use changes and diversion of input rivers to the pond for irrigation of agricultural lands.

Maintaining this procedure can endanger the life of birds, fishes and animal spices with extinction. The increase in pollutants and toxins are serious threats for residents of the pond. Therefore some crucial decisions should be taken for resolving the crisis.

Generally, in this paper:

First, the soil part was separated from aqueous part by using image processing techniques on satellite images. Next, the area is calculated by counting the pixels of the pond surface. For measuring the depth of the pond, the table of influential factors on the pond changes was created. Finally, by utilizing GMDH neural network, an appropriate formula for estimating the area and depth changes was estimated.

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