ATLANTIS PRESS

Advances in Engineering Research, volume 112

4th International Conference on Renewable Energy and Environmental Technology (ICREET 2016)

The New Evaluation Mechanism of Water Scarcity

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Keywords: Water scarcity, Neutral Network Model, Grey Forecasting Model

Abstract. This paper examines water scarcity from both social and environmental perspectives in arrange of 6 factors. 3 social factors and 3 environmental factors are used to analyse both physical and economic water scarcity. After collecting all above factors of 176 countries or regions, a rating mechanism is developed by dividing each variable into 3 to 5 levels to present a neural network model. Then further improve our initial network model into a hybrid model by incorporating grey forecasting model.

Shandong Province of China is chosen to explain, where water resources are heavily exploited. After analysing its water scarcity condition comprehensively from the perspectives of society and environment，The results are: a) It suffers from physical water scarcity more than economic. b) In 15 years, with the growth of GDP, water shortage situation of Shandong has been improved. c) To release water stress, the government should expand its budget deficit moderately.

Introduction

According to the UN-water, over 80% of the world's population lives in area where water is scare[1] . Water scarcity is either the lack of enough water or lack of access to clean water.

To solve the problem of the access to clean water, neural network model is used to recognize the effect of different factors. Then for a chosen area, assess the water sources situation by using social and ecological indexes such as GDP, population, precipitation and fresh water per capita. Based on above factors, after correlating with grey forecasting algorithm, model could forecast water situation of the given area in 15 years. For the improvement of clean water availability, intervention is designed to change the value of social and environmental variables. ***Figure 1*** shows algorithm to perform water scarcity dynamic analysis.

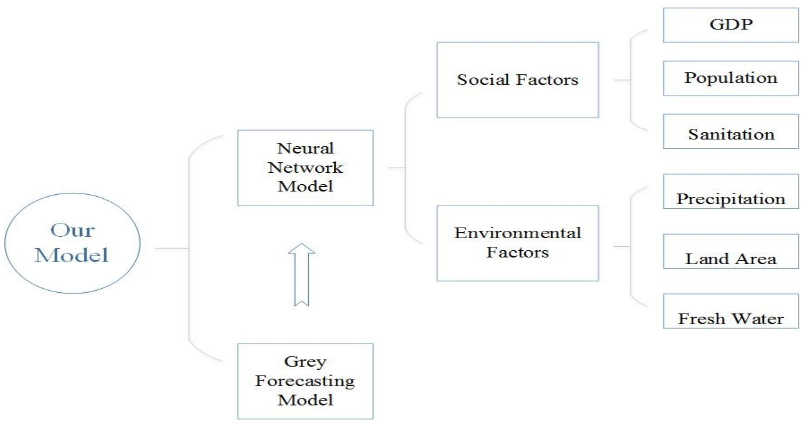

Fig. 1 – Flow chart of water scarcity analysis

Basic models

Factors

In order to measure water availability of an area, six variables are used in rating. Each variable can be categorized into 3 to 5 levels based on previous statistics data from World Bank and The United Nations[2]. It includes three social indexes and three ecological factors:

- Social factors: GDP , population, investment, sanitation facilities

- Ecological factors: precipitation, land area, fresh water per capita

Table 1 – Classification method of factors

Social factors	**Criteria**	**Rank**
GDP (2014 US$ billion)	>1000	1
	100-1000	2
	<100	3
Population (2014 million)	>100	1
	10-100	2
	<10	3
Improved sanitation (% of population with access)	75-100	1
	50-75	2
	25-50	3
	0-25	4

Environmental factors	**Criteria**	**Rank**
Precipitation (mm per year)	>2000	1
	1000-2000	2
	500-1000	3
	200-500	4
	0-200	5
Land area (10 million km^2)	>20	1
	5-20	2
	<5	3
Fresh water per capita (1000 m^3)	>10	1
	5-10	2
	1-5	3
	<1	4

Grey Forecasting model

On the basis that the neural network model is hard to explain the effects of time-varying changes, model is optimized by combining with grey forecasting model. Assume that this is an original data sequence:

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)) \quad (1)$$

The equation (3) is called the basic form of GM (1, 1) model:

$$\frac{dx^{(1)}}{dt} + ax^{(1)}(t) = b \quad (2)$$

The equation (4) is called the time response equation.

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - \frac{\hat{b}}{\hat{a}})e^{-\hat{a}k} + \frac{\hat{b}}{\hat{a}}, k = 0, 1, \cdots, n-1, \cdots \quad (3)$$

Then the future projection value is:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1, 2, \cdots, n-1, \cdots \quad (4)$$

By using this model, movement of a system's variables could be correlated with time-varying changes. Once enough previous data is put into our system, then the prediction could be made.[3]

Neural network model

Warren McCulloch and Walter Pitts created a computational model for neural networks. Like other systems that can learn from data, neural network model has been used to solve a wide variety of tasks involving a large quantity of inputs, while the function is unknown.[4] The results of this analysis are shown in *Figure 2.*

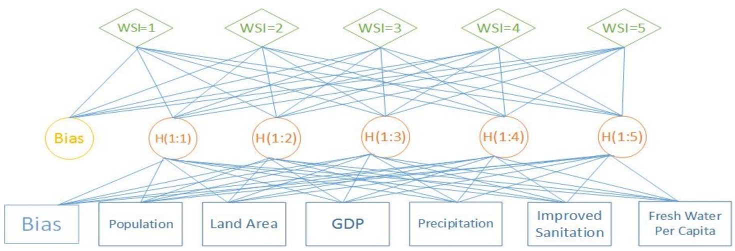

Fig. 2 – Neural network of rating index

Solutions

3.1 Chosen region

Shandong Province is chosen from UN water scarcity map, because its uniform distribution of water shortage. From ranking system, description of Shandong shows in ***Table 2.***

Table 2 – Descriptive statistics of Shandong province

	Population	Land area	GDP	Precipitation	Improved Sanitation	Fresh Water Per capita	WSI
Shandong	3	3	3	3	1	3	4

Why water is scare

Figure 3 shows that under the same water scarcity situation, the percentage of other countries which share better factors than the given one. Taking fresh water per capita as an example, it means there are 42% countries or regions around the world that enjoy more fresh water than Shandong Province. Comparing to other countries, Shandong has advantage in the factor of improved sanitation and fresh water per capita, but has disadvantage in other factors.

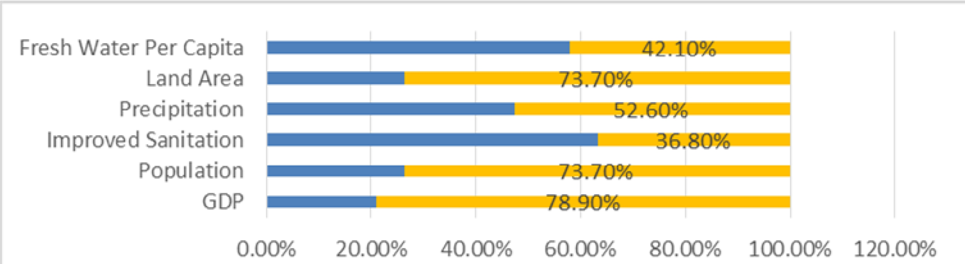

Fig. 3 – With same WSI, the percentage of which shares better factors

Predicted value

By using grey forecasting model, create the expression correlating with time variables.

$$\text{GDP: } y = 552.047e^{0.0737325t} - 521.847 \tag{6}$$

$$\text{Population: } y = -5624.11e^{-0.00170333t} + 5633.77 \tag{7}$$

$$\text{Fresh Water Per Capita: } y = 158301e^{0.0230208t} - 154660 \tag{8}$$

Predictive value shows in *Figure 5*. And how changed of those factors influence water scarcity is showed in ***Table 3.*** As a result, water scarcity situation will be improved in 15 years.

Table 3 – Water scarcity situation comparison

	Population	Land Area	GDP	Precipitation	Improved Sanitation	Fresh Water Per Capita	WSI
Before	3	3	3	3	1	3	4
After	3	3	2	3	1	2	2

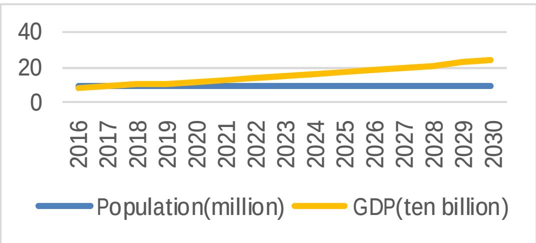

Fig. 4 – Predictive value in 15 years

Intervention Plan

Both the development of technology and infrastructure needs more investment. Therefore, our intervention plan is increasing the fiscal deficit, which can be performed through the following three procedures.

- Expand government expenditure
- Issue government bonds
- Implement the structural tax reduction

In 15 years, the water scarcity situation of Shandong will change from medium to less reflecting by WSI changing from 4 to 3. That could influence the indicator of GDP and Fresh water per capita. Compared with prediction of 15 years, as it shows in ***Table 3***, after the intervention, GDP will change from rank 3 to rank 2, while fresh water per capita will change from rank 3 to rank 2.***Table 4*** shows the effect of our intervention.

Table 4 – Effect of intervention

	Population	Land Area	GDP	Precipitation	Improved Sanitation	Fresh Water Per Capita	WSI
Before	3	3	3	3	1	3	4
After	3	3	2	3	1	2	2

Conclusions

To improve the access to clean and fresh water, we prevent a hybrid neural network model using 6 factors from social and environmental perspectives, including data of 176 countries or regions. Besides that, Shandong Province is taken to explain how the change of variables will affect water sources situation. In addition, sensitivity analysis is carried out to validate our model. With further discussion, this model could be extended into other aspects in society.

References

[1]Fawcett T, An introduction to ROC analysis, J. Pattern recognition letters. 27(2006): 861-874.

[2] Hopfield J, Neurons with graded response have collective computational properties like those of two-state neurons, J. Proceedings of the national academy of sciences. 81(1984): 3088-3092.

[3] Xie N M, Liu S F. The parallel and uniform properties of several relational models, J. Systems Engineering, 25(2007): 98-103.

[4] Xijing S, Shoukui S, Shurong T. The image hiding algorithm based on the mask matrix and dct transform[C] Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC), 2011 2nd International Conference on. IEEE, 2011: 765-767.