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# The Hybrid Model Named CSEI to Evaluate The Water Resource

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**Abstract:** The regionalization of the assessment to rationally utilize and develop water resources and planning for the amelioration of the water scarcity status is very important and has practical significance. Motivated to evaluate the water resource situation of a region more accurately, a hybrid model and a set of appropriate metrics are proposed.

the hybrid model named CSEI can be applied to evaluate the water resource situation of a region effectively. Based on the cuckoo search (CS) algorithm, the parameters of traditional evaluation index are optimized, which lays more emphasis on inner links between different indicators, and the proposed CSEI can take kinds of indexes into consideration, including dynamic nature of the factors that affect both supply and demand in one region. Moreover, by assigning different weights, this model can provide an effective measure of the ability of a region to provide clean water to meet the needs of its population.

the region we chose locates in Liao River Basin of China, which covers eight cities: Yingkou, Panjin, Anshan, Liaoyang, Benxi, Shenyang, Fushun and Tieling. By analysing both physical indexes and economic indexes of this region and comparing them with national average values, we find that there is no wonder to exist water scarcity here. Furthermore, specific reasons of water scarcity in this region was concluded, like natural characteristics of water resources inconsistent with water needs, rapid industrialization and urbanization associated with a large population and poor water resource management.

## 1. Introduction

According to the United Nations, 1.6 billion people (one quarter of the world's population) experience water scarcity. Two primary causes for water scarcity are physical scarcity and economic scarcity. It is urgent to address the water scarcity issue in many parts of the world nowadays[1].

Take the Liao River basin for example; hundreds of thousands of people are short of drinking water in northeast China's Liaoning Province as it suffers one of its most severe droughts in history. The provincial flood control and drought relief headquarters said that some 248,500 people and 25,700 heads of large farm animals are short of water. Eight cities were selected in the Liao River basin (21.9×104 km2), Shenyang, Anshan, Fushun, Benxi, Yingkou, Liaoyang, Panjin, Tieling, where water was moderately exploited according to the UN water scarcity map.

In order to address problems above, we conclude two sub-problems to tackle in our paper.

- Established an evaluation model of water resources carrying capacity.

- Explain both physical and economic scarcity in Liao River basin.

To tackle the first problem, we select six relative indicators[2] as evaluation factors, for example, Irrigation water consumption (IRW), industrial water consumption(INW), domestic water consumption(DW), discharge of sewage(DS), precipitation(PR), and population(PO). For the second question, we also explain why and how water is scarce in the Liao River basin.

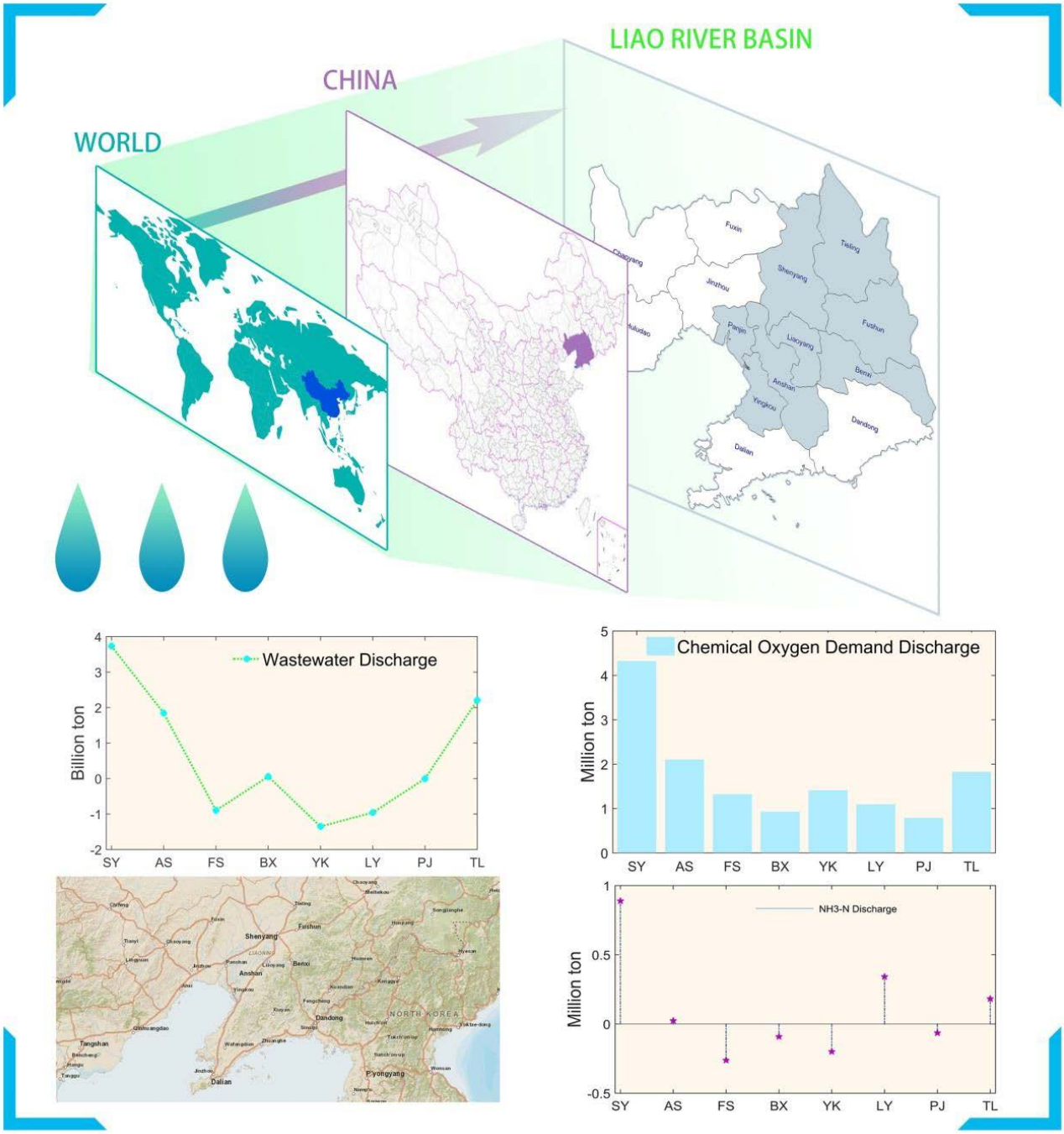


**Fig 1.** Trend of wastewater, chemical oxygen demand, $NH_3$-N discharges in Liao River Basin. Data source: SEPA (1991–2007) and SEPA (1995–2006).

## 2. Construction of evaluation model: CSEI

### 2.1 Methodology introduction

We introduced cuckoo search (CS) algorithm and an universal index formula for evaluating the ability: EI.

#### 2.1.1 Cuckoo search (CS) algorithm

The CS algorithm was recently developed by Yang and Deb. In comparison with other meta-heuristic search algorithms, the CS algorithm is a new and efficient population-based heuristic evolutionary algorithm for solving optimization problems with the advantages of simple implement and few control parameters. This algorithm is based on the obligate brood parasitic behavior of some cuckoo species combined with the Lévy flight behavior of some birds and fruit flies.

#### 2.1.2 An universal index formula for evaluating the ability: EI

**Defination1:** $I_i$ is the *ith* single index, which represents a measure of the *ith* water supply index.

**Defination2:** *EI* represents comprehensive index value to evaluate water supply capacity, which reflects the measure of the ability of a region to provide clean water[3].
According to above definitions, the universal *EI* indices can be stated as following:

$$\begin{cases} EI = \alpha(\sum_{i=1}^{n} w_i * I_i)^{\beta} \\ \sum_{i=1}^{n} w_i = 1 \end{cases}$$

Where $n$ is the single index number, and $w_i$ represents the weight value of $I_i$. $\alpha, \beta \in [0,10]$, whose values changes in the light of different problems.

### 2.2 An Evaluation Model of Water Supply Capacity: CSEI

According to the after mentioned theory, $\alpha$ and $\beta$ have a significant impact on the evaluation results in *EI*. Therefore, cuckoo search (CS) algorithm is applied to optimize the two parameters, which produces the Evaluation Model of Water Supply Capacity (CSEI). Details of this new model are expressed as follows:

**Step1:** The number of choosing the single indices $I_i$. Herein, in order to measure the ability, to provide clean water, the different indices $I_i$ chosen should reflect the water supply capacity from different angles as much as possible. On the other hand, different values of $I_i$ represent the difference in the providing water.

**Step2:** Optimization. The objective function of CSO algorithm is given as follows:

$$f_{objective} = \frac{1}{K}\sum_{k=1}^{K}\left(EI_k - EI_{k0}\right)^2$$

Where K is the number of providing water levels, and $EI_k$ is the *k*th level calculated by the above Eq

$EI_{k0}$ is the kth standard, which is set by a proportion. In general, $EI_{k0} \in (0,1)$ may be divided into K levels according to problems. The optimized algorithm terminates if it reaches the maximum iterations.

**Step3:** Evaluation. The best $(\alpha,\beta)$ obtained by CSO algorithm is set to be the final parameters in the Eq the ability of providing clean water is assessed by $EI_k$ calculated by the Eq compared with $EI_{k0}$.

## 3. Why and how water is scarce

### 3.1 Causes of water scarcity

Many factors contribute to water scarcity in Liao River Basin of China. Naturally, the spatio-temporal distribution of water resources is inconsistent with socio-economic needs for water. This inconsistency could cause a conflict between water supply and demand, and this conflict is intensifies by economic development, population growth, and urbanization. To make the situation worse, water resource management has been poor, increasing the vulnerability of this region with serious social and environmental consequences.

### 3.2 Gray correlation analysis

Grey correlation analysis represents if the sample data column reflects the two factors of the situation are basically similar, they will have a larger degree of correlation, and vice versa[4].

#### 3.2.1 Gray theory

Gray correlation analysis is developed from the gray system theory, an analysis of the geometric proximity between different discrete sequences within a system. The proximity is described by the gray relational degree, which is a measure of the similarities of discrete data that can be arranged in sequential order.

Consider the reference sequence $Y = \{y(1), y(2),..., y(n)\}$. Then, consider a p data series $X = \{x(1), x(2),..., x(n)\}$ $(i = 1,2,..., p)$ as the comparison sequences. Then the gray relational degree is defined as follows:

$$r(Y, X_i) = \frac{1}{n}\sum_{k=1}^{n} \frac{\min_i \min_i |y(k) - x_i(k)| + \rho \max_i \max_k |y(k) - x_i(k)|}{|y(k) - x_i(k)| + \rho \max_i \max_k |y(k) - x_i(k)|}$$

## 4. Conclusions

To quantitatively or numerically identify the prime factors affecting the rate of water scarcity, in this sector, Irrigation water consumption(IRW), industrial water consumption(INW), domestic water consumption(DW), discharge of sewage(DS), precipitation(PR), and population(PO) are regarded as the main indices affecting the rate of water scarcity. The gray relational degree and the relational order of the reference datasets (the rate of water scarcity) of each comparison dataset were calculated (see Table 1).

The gray relational degree are 0.5633, 0.4846, 0.4964, 0.7341, 0.5698, and 0.6054, respectively, with the gray relational order DS>PO>PR >IRW>DW>INW. It can be obtained that the discharge of sewage and population are the main factors giving rise to water scarcity.

Table 1 Grey relation degree and the relation order

| Reference variable | Comparison variables | | | | | |
|---|---|---|---|---|---|---|
| | IRW | INW | DW | DS | PR | PO |
| The rate of water scarcity | 0.5633 | 0.4846 | 0.4964 | 0.7341 | 0.5698 | 0.6053 |
| | Grey relational order: DS>PO>PR>IRW>DW>INW. | | | | | |

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