RESEARCH ARTICLE OPEN ACCESS

# Assessment on the Ecosystem Service Functions of Nansi Lake in China

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**ABSTRACT**
The assessment of ecosystem service functions is one of the focused area in modern ecological and environmental research. As a typical shallow macrophytic lake in China, Nansi Lake is selected as the study area. Based the indicator system and assessment models established in this research, the ecosystem service functions of Nansi Lake are assessed. The results show that the ecosystem service function of drinking water source area/aquatic product supply/ecological habitat/entertainment and landscape/ water purification function of the lakeside zone for Nansi Lake is assessed as medium (2.2)/good (3.5)/medium (3)/medium (2.55)/medium (3), and the overall ecosystem service function of Nansi Lake can be considered as "Medium". The eutrophication control and ecological restoration of lakeside wetland need to be enhanced in the future.
***Keywords –*** Assessment, Ecosystem function, Ecosystem service, Ecosystem, Nansi Lake

## I. INTRODUCTION

Ecosystem services are the resources and environmental conditions for human survival and development. The raw materials for the industrial and agricultural production can be obtained from ecosystems which also provide ecological functions including water conservation, environmental purification, regulation of atmospheric etc. [1, 2]. These functions and services safeguard the sustainable development of human society. The costs should be very large if the development intensity is larger than the threshold value of ecosystem. Holdren (1974) and Ehrlich (1981) pointed out that alternations of the lost ecological function must be expensive and will be defeated in the long run[3,4].

Many ecosystems degraded since people grabbed too many resources of market value or directly use value and ignored the other ecological functions of natural ecosystems [5]. With the various ecological functions of natural ecosystem were realized, people attempted to assessment the functions and the values of the ecosystem services for different natural ecosystems [6]. Such assessment connected the economic, society with the environment, and can provide comprehensive understandings on the ecosystem services of lake ecosystem, based on which, the environmental protection policies can be formulated and implemented correctly [7]. Nansi Lake, which was constructed during the major south-to-north water diversion project of China, serves as an important water transportation channel. The lake is eutrophic, due to excess nitrogen (N), phosphorus (P) and suspended solids, with these elements causing serious degradation [8]. As a result, the lake is now classified as an ecologically fragile region, due to high N loss [9, 10].

In this research, an indicator system and corresponding assessment models are established based on the regional basic situation of Nansi Lake. With the indicator system and assessment model, the ecosystem service functions of Nansi Lake are assessed. The results of the research may improve the comprehensive understanding of ecological assessment and provide some guidance for the sustainable formulation and implementation of local environmental policies.

## II. STUDY AREA

Nansi Lake which is the largest freshwater lake in the north of China locates at the southern part of Shandong Province. Nansi Lake is a typical shallow macrophytic lake with an average water depth of


Fig.1 Geographical location of NansiLake

1.5m, a length of 120km, a water area of 1226km$^2$ and a water storage of 1.93*10$^9$m$^3$. The Nansi Lake and its surrounding areas were once home to 106 species of birds and 78 kinds of fish. And more than 150,000 local people lived on the lake. However, in recent years, the lake and its surroundings suffered serious eutrophication and environmental disruption. Even worse, the local ecosystem was damaged. Since 2002, a series of policies for environmental/ecological protection and restoration were implemented by state and local governments.

## III. ASSESSMENT INDICATORS AND MODELS

### 3.1 Ecosystem service functions of Nansi Lake

For shallow macrophytic lakes in China, the most typical ecosystem service functions are (1) product supply function: providing drinking water for local people and ecological habitat for aquatic animals and plants; (2) environmental regulation function: flood control, climate regulation, water quality purification, etc.; (3) cultural service function: providing recreational and leisure site for local people, as well as scientific value for researchers in the field.

Based on the overall objectives of lake ecological security due to human activities, the ecosystem service functions of drinking water source area, aquatic product supply, ecological habitat, entertainment and landscape, water purification of the lakeside zone, as well as the entertainment and landscape are selected to assess the situation and change of Nansi Lake in recent years.

### 3.2 Indicators and models

#### 3.2.1 Drinking water source area

To evaluate the ecosystem service function of drinking water source area, the indicators contained in the drinking water quality criterion should be considered [11, 12]. In the drinking water source water quality standard (CJ3020-93) of China, the drinking water quality is divided into two levels (I-good, II-lightly polluted). Two common indicators of chemical oxygen demand ($COD_{Cr}$) and ammonia nitrogen ($NH_3$-N) which can well characterize the ecosystem service function of drinking water source area are selected. Secondly, the lake ecological security problem caused by eutrophication is one of the concerns in this research. To evaluate the influence of lake eutrophication on drinking water, the transparency, total nitrogen (TN) and total phosphorus (TP) are bring into the indicator system for the ecosystem service function of drinking water source area [13].

Above all, the selected indicators for the ecosystem service function of drinking water source area for Nansi Lake are:

- $COD_{Cr}$ (mg/l)
- $NH_3$-N (mg/l)
- Transparency (m)
- TN (mg/l)
- TP (mg/l)

The ecological index of the drinking water source area for Nansi Lake can be calculated with:

$$DS_{indx} = \frac{\sum_1^n DS_i}{n} \quad (1)$$

in which, $DS_{indx}$ is the ecological index of the drinking water source area function, $DS_i$ is the score for the $i$th indicator of drinking water source area function, n is the number of the indicators.

According to the obtained ecological index of the drinking water source area function, the situation of Nansi Lake for this ecological function can be assessment as Excellent ($DS_{indx}$>4), Good (3<$DS_{indx}$≤4), Medium (2<$DS_{indx}$≤3), Bad (1<$DS_{indx}$≤2) or Very bad ($DS_{indx}$≤ 1).

**3.2.2 Aquatic product supply**

Needless to say, the amount and quality of the aquatic product are important indicators to reflect the ecosystem service function of aquatic product supply. In this research, fishery yield is selected as the amount of aquatic product. On the other hand, the quality of aquatic product is multitudinous and the influence of pollution and eutrophication are considered and emphasized in the research.

As such, the selected indicators for the ecosystem service function of aquatic product supply for Nansi Lake are:

- The area of enclosed aquaculture
- Fishery output per unit area (kg/hm$^2$)

The ecological index of the aquatic product for Nansi Lake can be calculated with

$$FS_{indx} = \frac{\sum_1^n FS_i}{n} \quad (2)$$

in which, $FS_{indx}$ is the ecological index of the aquatic product function, $FS_i$ is the score for the $i$th indicator of aquatic product function.

According to the obtained ecological index of the aquatic product function, the situation of Nansi Lake for this ecological function can be assessment as Excellent ($FS_{indx}$>4), Good (3<$FS_{indx}$≤4), Medium (2<$FS_{indx}$≤3), Bad (1<$FS_{indx}$≤2) or Very bad ($FS_{indx}$≤ 1).

**3.2.3 Ecological habitat**

With the deterioration of water ecosystem, fish species and health changed significantly in China. The fish in polluted water are generally pathological such as rotten gills, skin ulcer, skeleton abnormal, hyperplasia of epidermis, etc., and the health of fish in the lake can therefore reflect the environmental quality of ecological habitat. In addition, such abnormal conditions can also threaten the health of birds, mammals and even human beings [15]. Therefore, the health of fish becomes common concern of people and governments. Secondly, the fish species and fish catches can reflect the changes of ecological habitat.

Based on the considerations above, the indictors for the ecosystem service function of habitat can be composed by

- The percentage of infected and abnormal fish (%)
- Added percentage of fish mortality in comparison with 5 years ago (%)
- Percentage of fish species numbers based on that of 1980s

The ecological index of the habitat function for Nansi Lake can be calculated with

$$HS_{indx} = \frac{\sum_1^n HS_i}{n} \quad (3)$$

in which, $HS_{indx}$ is the ecological index of the habitat function, $HS_i$ is the score for the $i$th indicator of habitat function.

According to the obtained ecological index of the habitat function, the situation of Nansi Lake for this ecological function can be assessment as Excellent ($HS_{indx}$>4), Good (3<$HS_{indx}$≤4), Medium (2<$HS_{indx}$≤3), Bad (1<$HS_{indx}$≤2) or Very bad ($HS_{indx}$≤ 1).

**3.2.4 Entertainment and landscape**

A lake is composed by basin, water, organic matters and aquatic organisms, etc. As the recreational area for travel, play, swimming, etc., natural lake has 6 aesthetic characteristics of shape, picture, sound, color, sweet and strange. In general, the relationship between water with pollutant, biology, climate, structures and so on are important factors affecting the quality of the site for entertainment. However, these indicators are difficult to measure. In this research, 12 environmental/travel/landscape experts in this field are invited to mark a score for the ecosystem service functions of entertainment and landscape for Nansi Lake.

The ecological index of the entertainment and landscape functions for Nansi Lake can be calculated with

$$RS_{indx} = \frac{\sum_1^n RS_i}{n}, \quad (4)$$

in which, $RS_{indx}$ is the ecological index of the entertainment function, $HS_i$ is the score marked by the $i$th expert.

According to the obtained ecological index of the entertainment function, the situation of Nansi Lake for this ecological function can be assessment as Excellent ($RS_{indx}$>4), Good (3<$RS_{indx}$≤4), Medium (2<$RS_{indx}$≤3), Bad (1<$RS_{indx}$≤2) or Very bad ($RS_{indx}$≤ 1).

**3.2.5 Water purification of the lakeside zone**

The function of water purification for lakeside zone can be characterized by the ecological situation and vegetation coverage. In general, a lakeside zone with good ecological situation and high vegetation coverage has strong function of water purification, and weak contrarily. In North America, the assessment methods for the function of wetland have

HEP (Habitat Evaluation Procedures) and HGM (Hydro-geomorphic Assessment Method). Although these two methods are different in many aspects, the change of wetland area is selected to reflect the loss rate of wetland function in both methods. Theoretically, for the non-point source pollutants, the interception and purification effects of the lakeside wetland can be obtained by multiplying the vegetation coverage area and purification rate per unit area for each vegetation species. The vegetation coverage area of natural wetland and artificial constructed wetland in the lakeside zone are selected as the indicators to reflect the ecosystem service function of water purification of the lakeside zone.

Another indicator to assess the water purification function of the lakeside zone is the situation of the damaged lakeside zone due to human activities (construction, agricultural development, sewage disposal, aquatic breeding, etc.) and natural processes (sediment deposition, ecological succession, etc.) [14]. The score for this indicator can be obtained by inviting 12 experts to mark for it.

The indicators to assess the ecosystem service function of water purification for the lakeside zone of Nansi Lake are:

As such, the selected indicators for the ecosystem service function of aquatic product supply for Nansi Lake are:

- The situation of the damaged lakeside zone
- The vegetation coverage area of natural wetland ($km^2$)
- The area of artificial constructed wetland ($km^2$)

The ecological index of the water purification function for Nansi Lake can be calculated with

$$LS_{indx} = \frac{\sum_1^n LS_i}{n} \quad (5)$$

in which, $LS_{indx}$ is the ecological index of the water purification function, $LS_i$ is the score for the $i$th indicator of the water purification function.

According to the obtained ecological index of the water purification function, the situation of Nansi Lake for this ecological function can be assessment as Excellent ($LS_{indx}$>4), Good (3<$LS_{indx}$≤4), Medium (2<$LS_{indx}$≤3), Bad (1<$LS_{indx}$≤2) or Very bad ($LS_{indx}$≤ 1).

### 3.3 The overall assessment method of the ecosystem service functions for Nansi Lake

Based on the assessments of the ecosystem service functions for Nansi Lake, the overall assessment can be conducted to realize the ecological situation of the lake. The ecosystem service functions provided by disparate lakes should be different according to the lake characteristics such as water depth, size of the lake basin, situation of substrate, nutriture, chemical properties, geographic location, climatic characters and so on. That means the weights of different ecosystem service functions for Nansi Lake are different and need to be determined. As the weights determined, the overall assessment can be conducted.

The overall index of ecological assessment on the ecosystem service function of Nansi Lake can be calculated by

$$TLES_{indx} = \frac{20 * \sum_1^n LES_i Q_i}{n} \quad (6)$$

in which, $TLES_{indx}$ is the overall assessment index of the lake ecosystem service function, $LES_i$ is the score for the $i$th ecosystem service function, $Q_i$ is the weight of the $i$th ecosystem service function and $n$ is the number of the ecosystem service functions assessed in this research.

According to the calculated results, the ecosystem service function of Nansi Lake can be ranked as Excellent ($TLES_{indx}$>90), Good (70<$TLES_{indx}$≤90), Medium (55<$TLES_{indx}$≤70), Bad (40<$TLES_{indx}$≤55) or Very bad ($TLES_{indx}$≤40).

## IV. ASSESSMENT RESULTS AND DISCUSSION

### 4.1 Drinking water source area

In the assessment method for the drinking water source area, there are 5 indicators. Combining the data from <Report of Ecological and Environmental Monitoring and Quality Evaluation of Fishery in Nansi Lake (2011)> and <Bulletin of Water Resources Monitoring in Nansi Lake (2011)>, the measured values of 5 indicators including transparency, $NH_3$-N, TN, TP and $COD_{Cr}$ are found. Based on these data, the ecological function of drinking water source area for Nansi Lake is assessed. The measured values of these indicators and the assessment results are listed in Table 1

**Table 1**. Measured values of water quality indicators and assessment values for Nansi Lake

| No. | Indicator | Value | Score |
|---|---|---|---|
| 1 | Transparency (m) | 0.63 | 2 |
| 2 | $NH_3$-N (mg/L) | 0.3 | 4 |
| 3 | TN (mg/L) | 1.04 | 1 |
| 4 | TP (mg/L) | 0.085 | 1 |
| 5 | $COD_{Cr}$ (mg/L) | 24.24 | 3 |

Based on the scores in Table 1, the ecological index of the drinking water can be calculated with Eq. (1), $DS_{indx}$=2.2. As such, the ecological function of drinking water source area for Nansi Lake can be assessed as "Medium". This assessment is based on the annual average data, the situation of this service function may different with the change of seasons.

**4.2 Aquatic product supply**

For the assessment of the aquatic product supply function, 2 indicators are set. Based on the data from <Report of Ecological and Environmental Monitoring and Quality Evaluation of Fishery in Nansi Lake (2006 and 2011)>, the area of enclosed aquaculture and fishery output per unit area are listed in Table 2. The assessment scores for each indicator can therefore be calculated and also shown in Table 2.

**Table 2.** Surveyed values and assessment scores of the aquatic product supply function for Nansi Lake

| No. | Indicator | Value | Score |
|---|---|---|---|
| 1 | Area of enclosed aquaculture ($km^2$) | 159.5 | 2 |
| 2 | Fishery output per unit area ($kg/hm^2$) | 151.3 | 5 |

Based on the assessment scores in Table 2, the index of aquatic product supply function for Nansi Lake can be obtained with Eq. (2), $FS_{indx}$=3.5. According to the index and standard, the situation of the aquatic product supply function for Nansi Lake can be assessed as "Good". As the fishery output per unit area was seasonally changing, the ecosystem service function of aquatic product supply may be different to different seasons.

In addition, the indicators for the assessment on the function of aquatic product need to increase for more rational, credible and comprehensive assessment results, for example, the indicator of smelly substance, algal toxin, heavy metal, pesticide and so on.

**4.3 Ecological habitat**

There are 3 indictors settled for the assessment on the ecological habitat function of Nansi Lake. However, the percentage of infected and abnormal fish and the added percentage of fish mortality in comparison with 5 years ago couldn't be found in the available data. The assessment on the ecological habitat function of Nansi Lake is therefore conducted with the only indicator of the percentage of fish species numbers based on that of 1980s.

Based on the < Survey Report for the Fishery Resources of Nansi Lake (1981) by the Environmental Protection Agency of Jining City>, the number of fish species for Nansi Lake is 78 in 1981. From the <Investigation and Assessment Report of Biological Status in Nansi Lake (2011)> Nansi lake biological status quo investigation and assessment report, the fish species of Nansi Lake can be numbered as 52. And the percentage of fish species numbers based on that of 1980s can be determined as 67%. The assessment score is 3 and the function of ecological habitat for Nansi Lake can be ranked as "Medium". However, to get rational assessment results, more indicators reflecting the health condition of fish catches are need to add.

**4.4 Entertainment and landscape**

According to the factors of aesthetics, landscape, travel, etc. 12 experts in the environmental/travel/landscape field are invited to evaluate the ecological functions of entertainment and landscape for Nansi Lake. Based on the waste situation, algae growth, water transparency, crowdedness degree (extent of human activities), travel attraction, landscape value, recreational value and so on, 12 experts marked for the entertainment and landscape functions of Nansi Lake, respectively. The results showed the consistency, which means that the differences among score values are not very large. Based on these scores, the assessment index of the entertainment and landscape functions for Nansi Lake is 2.55, which is calculated with Eq. (4). And the situation of the entertainment and landscape functions for Nansi Lake can be assessed as "Medium".

**4.5 Water purification of the lakeside zone**

In the assessment method for the water purification function of the lakeside zone for Nansi Lake, 3 indicators are settled. The vegetation coverage area of natural wetland and artificial constructed wetland can be calculated through the satellite imagery in ArcGIS. Based on the situations of human activities (levee constructions, agricultural development, sewage disposal, estate development, fishery breeding etc.) and natural process (sediment deposition, ecological succession, etc.), 12 experts marked to evaluate the situation of the damaged lakeside zone in Nansi Lake. Table 3 shows the vegetation coverage area of natural wetland and artificial constructed wetland (2011), as well as the average score for the situation of the damaged lakeside zone

**Table 3**. The vegetation coverage area of natural, artificial wetland and the average score for the situation of damaged lakeside zone in Nansi Lake

| No. | Indicator | Value | Score |
|---|---|---|---|
| 1 | The situation of damaged lakeside zone | — | 2 |
| 2 | The vegetation coverage area of natural wetland ($km^2$) | 111.2 | 4 |
| 3 | The area of artificial constructed wetland ($km^2$) | 11.7 | 3 |

Based on Table 3, the ecological index of the water purification function for Nansi Lake can be calculated as $LS_{indx}$=3 with Eq. (5). As such, the situations of the water purification function of lakeside zone. in Nansi Lake can be considered as "Medium"

### 4.6 The overall assessment of the ecosystem service functions for Nansi Lake

Based on the assessment results for the ecosystem service functions of drinking water source area, aquatic product supply, ecological habitat, water purification of the lakeside zone, as well as the entertainment and landscape, the situation of each indicators are shown in Table 5, in which, different colors represent different situation: Excellent (Dark Green), Good (Light Green), Medium (Yellow), Bad (Orange) and Very bad (Red).

As can be seen in the table, for the function of drinking water source area in Nansi Lake, the transparency is "Bad", the $NH_3$-N is "Good", TN and TP are Very Bad, $COD_{Cr}$ is "Medium". In the indicators assessing the aquatic product supply function, the area of enclosed aquaculture is "Bad" and the fishery output per unit area is "Excellent". The service functions of ecological habitat, as well as the entertainment and landscape are evaluated as "Medium". For the function of water purification of the lakeside zone, the situation of damaged lakeside zone is "Bad", the vegetation coverage area of natural wetland is "Good" and the area of artificial constructed wetland is "Medium".

Based on the assessment results of the subitems, the overall situation of the ecosystem service functions for Nansi Lake can be conducted. As indicated above, the weights for different ecosystem service functions should be determined before the overall assessment. The weights for the ecosystem service functions of drinking water source area, aquatic product supply, ecological habitat, water pollution purification of the lakeside zone, as well as the entertainment and landscape are determined according to the suggestions from these 12 experts. These weights are shown in Table 4.

**Table 4**. Weights for the ecosystem service functions for Nansi Lake

| | Drinking water source area | Aquatic product supply | Ecological habitat | Entertainment and landscape | Water purification of the lakeside zone |
|---|---|---|---|---|---|
| Weight (%) | 35 | 20 | 15 | 10 | 20 |
| Index | 2.2 | 3.5 | 3 | 2.55 | 3 |

As the weights determined, the overall assessment index of the lake ecosystem service functions can be calculated with Eq. (6). The result shows that $TLES_{indx}$=55.5, which means the overall ecosystem service functions of Nansi Lake are at the "Medium" condition. This result is also shown in Table. 5.

Above all, the ecological function of drinking water source area, ecological habitat, entertainment and landscape and po purification function of the lakeside zone are "Medium", while the aquatic product supply function is "Good". The overall conclusion is that the ecosystem service function of Nansi Lake is "Medium". As N, P and COD are the ecological problems due to eutrophication [16], the problems endangering the ecological security of Nansi Lake are therefore the eutrophication and the damage of the lakeside wetland. As such, the eutrophication control and ecological restoration of lakeside wetland should be placed at very important positions. Although there are some results on the ecological assessment of lake ecosystem, more work need to pay on such research as the ecosystem is complex [17].

## V. CONCLUSIONS

In this research, Nansi Lake which is a typical shallow macrophytic lake in China is selected as the study area. According to the local situation of Nansi Lake, an indicator system and corresponding assessment models are established to evaluate the ecosystem service functions of Nansi Lake. With these indicators and models, the ecological assessment on Nansi Lake is conducted. The results of the research reveal that:

(1) Due to the assessment values for the indicators of transparency (2), $NH_3$-N (4), TN(1), TP (1)and $COD_{Cr}$ (3), the ecological function of drinking water source area for Nansi Lake is evaluated as "Medium " as the ecological index can be calculated as $DS_{indx}$=2.2.

(2) The assessment scores of the indicators for the aquatic product supply function are 2 and 5 corresponding to the area of enclosed aquaculture and the fishery output per unit area. The aquatic product supply function of Nansi Lake is "Good" with an ecological index of $FS_{indx}$=3.5.

(3) The function of ecological habitat for Nansi Lake can be ranked as "Medium" with $HS_{indx}$=3.

(4) Based on the scores marked by 12 experts, the assessment index $RS_{indx}$=2.55 and the ecosystem

service function of entertainment and landscape functions for Nansi Lake is therefore "Medium".

(5) Although the lakeside zone damage in Nansi Lake is relatively serious; the vegetation growth in wetland is not bad. The water purification of lakeside zone for Nansi Lake is therefore "Medium" with $LS_{indx}$=3.

**Table 5**. Health report card of the ecosystem service functions in Nansi Lake

| Function | Indicator | Situation |
|---|---|---|
| **Drinking water source area** | Transparency; $NH_3$-N; TN; TP; $COD_{Cr}$ | **Medium** |
| **Aquatic product supply** | Enclosed aquaculture; Fishery output | **Good** |
| **Ecological habitat** | Ecological habitat | **Medium** |
| **Entertainment and landscape** | Entertainment and landscape | **Medium** |
| **Water purification of the lakeside zone** | Damaged lakeside; Natural wetland; Artificial wetland | **Medium** |
| Overall | | **Medium** |

With the overall assessment on the ecosystem service function of Nansi Lake, the final overall result is "Medium". Although the assessment is not very comprehensive and more indicators are deed to add, the problems endangering the ecological security of Nansi Lake are found as the eutrophication and the damage of the lakeside wetland. This may give some guidance for the local government to enhance the eutrophication control and ecological restoration of lakeside wetland.

## Acknowledgements

The authors acknowledge with great appreciation for the support provided by the Chinese National Special Water Programs (No. 2015ZX07203-011, No. 2015ZX07204-007), Department of Environmental Protection of Shandong Province (SDHBPJ-ZB-08).

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