Multi-resources data based environment assessment of the Grand Canal in Beijing with CEAI model

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Abstract

The Grand Canal was more than 3,500 km long, going through 2500 years in China history. It plays an important role in the field of navigation, military affairs, political affairs and culture. Until now, the part of the canal from Jining city to Hangzhou city is still being used. But the current situation of the environment along the canal is disgusting and valuation standards are not uniform. For the case of Beijing, based on GIS and RS, RS image data of Peking was interpreted and raster database of land use/vegetation coverage was made with SPOT5 remote sensing image data of September in the year 2006. With the heritage parameters as well as the ecological parameters along the canal, an environment assessment model was constructed to evaluate the environment along the canal under ArcGIS 9.3. Results showed that the general environment along the canal was usual, and the area under middle level takes 34% of the whole. Synthesis value of environment, which correlated with natural condition, economic development and human environment, decreased from the suburb to the urban area in spatial distribution. This environment assessment system is also useful for the ecological and human environment assessment of the area along the Grand Canal in other provinces for its planning, protection, management, application for the world heritage as well as its sustainable development.

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Key words: The Grand Canal; GIS; Remote Sensing; Environment assessment

1. Introduction

Comprehensive environment assessment can provide basis and strategy making for the regional environment protection and sustainable development [1]. There are several standards for the value

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assessment of the Grand Canal, such as, the world heritage committee [2] thought high of its historical, cultural, scientific and art values; Yu (2008) etc [3] proposed its heritage, economic, ecology, basic facility, scenery and channel values. These qualitative valuations focused on the view of humanistic and economic, lacking of ecological environment factors. For the special heritage, the Grand Canal, a Comprehensive qualitative environment assessment model was proposed which includes both humanistic and ecological factors. Based on RS and GIS, SPOT5 image data in the year 2006 was interpreted to get land use data and forest coverage data. With these data, both Comprehensive index assessment and analytic hierarchy process was used to evaluate the area 2 km within the Huitong canal and the North canal of the Grand Canal in Beijing, China to provide basis for its management, protection, sustainable development as well as its World heritage application.

2. Study area

The length of the Grand Canal is 3500km, being the longest and the biggest as well as the earliest in the world. It is 10 times long of the Suez Canal, and 20 times long of the Panama Canal. It goes through 8 provinces (Beijing, Tianjin, Hebei, Henan, Anhui, Shandong, Jiangsu and Zhejiang province), connecting five rivers (Hai River, the Yellow river, the Huai River, the Yangtze River, the Qiangtang River) and many lakes, passing through 35 important cities in eastern China along the seashore, including 12 famous cultural cities. It is divided into 7 periods: the Tonghui River (from Keking to Tongzhou), the North Canal (from Tongzhou to Tianjing), the South Canal (from Tianjing to Liaocheng in Shandong province), the Middle Canal (from Xuzhou to Huaian in Jiangsu province), Li Canal, from (Huaian to Yangzhou in Jiangsu province), and the South Canal (from Zhengjiang to Yangzhou in Zhejiang province). Precipitation varied from 500mm in Hai River to 1300mm in Tai lake. It also connects Chinese political capital to the Hebei plain, Shangdong hills, the developed Triangular area of the Yangtze River as well as important cities along the seashore in Jiangsu and Zhejiang province. Cities along the Grand Canal share convenient traffic facilities, but differ quietly in economics.
Beijing lies in the north west of the north China plain, belonging to the temperate continental climate [4]. It connects north China, North West China and northeast China as well as the middle China. The Grand Canal in Beijing period was dug in the year 1293. It includes two periods: the Tonghui River (from Beijing to Tongzhou) and the North Canal (from Tongzhou to Tianjin) with river area 4.4 km². In the year 2006, the Grand Canal was added to the world heritage candidate, inspiring the management department of cultural relics and water conservancy making plan about the canal at national scale, provincial as well as prefectural scale. The area of this environment assessment keeps the rules for the protection of the canal stipulated by the management department. It includes the Canal and within 2 km along the canal (Fig.2).

3. Materials and methods

3.1. Land use data

Landsat-ETM of Beijing with 30m resolution in the year 2006 was used as well as part of RS data from spot 5 of which panchromatic wave band was 2.5m×2.5m, and multispectral image was 10m×10m resolution. Based on the 1:2,500,000 topographic map, integrated with the 1:5 and 1:1 basic geographic data to correct the interpretation error of RS data, land use data and plant coverage data was reached. Then ERDAS was used to interpret the land use file. Processed with ArcGIS, land use change information was made (Fig.3). The total area of this study, the canal and 2 km away from the canal, is 266.36 km².

3.2. Plant index

Under ArcGIS, from the RS image data (ETM, TM), the multispectral image data was transformed into values signifying plant index with Eq.(1)

$$VI = (IR - R) / (IR + R)$$

(1)

Where VI is the plant index, IR is the lightness value of the near-infrared waveband and R is that of the visible red wave band.
3.3. Land deterioration data

Soil erosion type was divided into light erosion, middle and intensive erosion. For Beijing, there were only light erosion and middle erosion. Land deterioration data was obtained from the Beijing forestry department and Beijing water conservancy department.

3.4. Water resource and precipitation

Water resource and precipitation, SO2 and COD data was obtained from the annual statistical year book of the year 2006.

3.5. Heritage data

The heritage data was obtained from national scientific support project “application of the spatial information technology in the protection of the heritage—in the case of the Grand Canal in Beijing” [5].

3.6. Economic data

Economic data including average GDP, navigation, tourism and population density data was obtained from the annual statistical year book of the year 2006.

Fig.3 Land use map of the Grand Canal in Beijing
4. A model for comprehensive assessment of environment

The Grand Canal still has the function of shipping, irrigation, so it is called “living heritage” [6]. It is a successful model for the development of wetland and lakes in eastern China, a big artery of Chinese history development, as well as a Chinese great ecological cultural engineering [7]. It is great water conservancy project in the world history, with plenty of heritages along its long line, improving the communication between the north and the south China by interacting with the natural geography. It also stands for the peak level of hydrological plan and engineering before the industry revolution. In the research, with a comprehensive corridor heritage idea, the nature, culture, ecology and scenery were included to construct a CEA (Comprehensive Environment Assessment) model of the Grand Canal including two index, the $EEAI$ (Ecological Environment Assessment Index) and the $HEAI$ (Humanistic Environment Assessment Index) with (Eq.2).

$$CEAI = \sum_{i=1}^{n} EEAI_i \times W_i + \sum_{j=1}^{m} HEAI_j \times W_j$$ (2)

Where the $CEAI$ is the Comprehensive Environment Assessment Index, $EEAI_i$ is the index of the i factor, $W_i$ is the weight of the i factor, $HEAI_j$ is the environment assessment index of the j factor, $W_j$ is the weight of the j factor.

According to the “Technical specification of ecological environmental assessment (Trial implementation)” (HJ/T192—2006) stipulated by the Chinese National Environmental Protection Agency, the BR (Bio Richness) index, PC (Plant Coverage) index, RN (River net) index, LD (Land deterioration) index, EQ (Environment quality) index, EE (Ecological environment) index were selected as sub-factors in the EEAI. EEAI was calculated with Eq. (3) and the other sub-factors was calculated with Eq. (4) to Eq. (8):

$$EEAI = 0.25 \times BRI + 0.2 \times PCI + 0.2 \times WNI + 0.2 \times LDJ + 0.15 \times EQI$$ (3)

$$BRI = A_{bio} \times (0.35 \times A_f + 0.21 \times A_g + 0.28 \times A_w + 0.11 \times A_j + 0.04 \times A_e + 0.01 \times A_b) / A$$ (4)

$$PCI = A_{reg} \times (0.38 \times A_f + 0.34 \times A_g + 0.19 \times A_a + 0.07 \times A_e + 0.02 \times A_b) / A$$ (5)

Where $BRI$ is the Bio Richness index, $A_{bio}$ is the index of normalization coefficient of $BRI$, $A_f$ is the area of forestry, km$^2$; $A_g$ is the area of grass land, km$^2$; $A_w$ is the area of water, km$^2$; $A_a$ is the area of agriculture land, km$^2$; $A_e$ is the area of Construction land and km$^2$; $A_b$ is the area of the bare land, km$^2$; $A$ is the total area of the region, km$^2$;

$$WNI = N_{riv} \times l / A + N_{lak} \times A_{lak} / A + N_{lak} \times W_{res} / A$$ (6)
Where $N_{riv}$ is the index of normalization coefficient of river length, $l$ is the length of the river, km; $N_{lak}$ is index of normalization coefficient of lake area, $A_{lak}$ is the area of lake, km$^2$; $W_{lak}$ is index of normalization coefficient of water amount in lake and dam; $W_{res}$ is the water amount of the lake and dam.

\[
PLI = N_{ero} \times (0.05 \times A_l + 0.25 \times A_m + 0.7 \times A_s) / A
\]  

(7)

Where $N_{ero}$ is the index of normalization coefficient of land deterioration, $A_l$ is the area suffering from light erosion, $A_m$ is the area suffering from middle scale erosion, km$^2$; $A_s$ is the area suffering from serious scale erosion, km$^2$; $A$ is the total area of the region km$^2$;

\[
EQI = 0.4 \times (100 - N_{SO2} \times A_{SO2} / A) + 0.4 \times (100 - N_{COD} \times A_{COD} / P) + 0.2 \times (100 - N_{Sol} \times A_{sol} / A)
\]  

(8)

Where $N_{SO2}$ is the index of normalization coefficient of SO$_2$, $A_{SO2}$ the amount of SO$_2$, t; $N_{COD}$ is the index of normalization coefficient of COD; $A_{COD}$ is the annual discharge amount of COD, t; $P$ is the annual precipitation, mm; $N_{Sol}$ is the index of normalization coefficient of the amount of Solid wastage; $A_{sol}$ is the annual discharge amount of solid wastage, t.

The HEAI includes heritage (including history, culture, science and art) index, economic (including navigation, tourism, irrigation) index and the scenery (including heritage density, comfortability and humanistic integrity) index. The sub-factors in heritage values were made by experts and the economic database was obtained from the annals. The scenery sub-factor was calculated from interpreted database under ArcGIS.

Eq. (9) [9] is used to calculate the HEAI.

\[
HEAI = 0.4V_h + 0.35V_e + 0.25V_s
\]  

(9)

Where $V_h$ is the value of heritage, $V_e$ is the value of economic, $V_s$ is the value of scenery.

Due to the different characteristics of each type of data, it is necessary to normalize the various types’ data to evaluate at the same level. This research classifies, normalize and assign value to the factors according to the idea of experts as well as their contribution to the environment.

Eq. (10) is used to normalize the factors EEAI and HEAI.

\[
EEAI_j(HEAI_j) = \frac{x_j - x_{j_{min}}}{x_{j_{max}} - x_{j_{min}}} \times 10 \quad \text{EEAI}_j(HEAI_j) = (1 - \frac{x_j - x_{j_{min}}}{x_{j_{max}} - x_{j_{min}}}) \times 10
\]  

(10)

Where $x_j$ is the assessment index of the $j$ sub-factor, $x_{j_{min}}$ is the minimum value of the assessment index, $x_{j_{max}}$ is the maximum value of the assessment index.
5. Result

With the data introduced above, the weights of both ecological environmental and humanistic factors were valued (Table 1). Substituting the value of each environment factor into Eq. (3) to Eq. (8) and Eq. (10) Fig.4 was reached showing the EEAI of the area within 2 km along the Beijing Canal; Substituting the sub-index value of each humanistic factor into Eq. (9) Eq. (10) and Fig.5 was reached showing the HEAI of the area with 2 km along the Beijing Canal.

Table 1. Weight of the factors in the CEA model

| Ecological factors       | weight | Humanistic factors      | weight |
|--------------------------|--------|-------------------------|--------|
| Bio richness             | 0.25   | History                 | 0.11   |
| Plant coverage           | 0.2    | Culture                 | 0.10   |
| River net                | 0.2    | Art                     | 0.09   |
| Land deterioration       | 0.2    | scientific              | 0.1    |
| Environment quality      | 0.15   | navigation              | 0.12   |
|                          |        | tourism                 | 0.11   |
|                          |        | irrigation              | 0.12   |
|                          |        | heritage                | 0.10   |
|                          |        | scenery                 | 0.07   |
|                          |        | humanistic integrity    | 0.06   |
| Total                    | 1.0    |                         | 1.0    |

Table 2. Classification and evaluation results of environmental conditions

| Scale | Environment situation | Comprehensive assessment value | Area (%) |
|-------|------------------------|--------------------------------|----------|
| I     | excellent              | 15.1~20.0                      | 0        |
| II    | good                   | 11.1~15.0                      | 0        |
| III   | middle                 | 7.1~11.0                       | 66       |
| IV    | Light                  | 4.1~7.0                        | 34       |
| V     | bad                    | 0.0~4.0                        | 0        |

The EEAI (Environment Ecological Assessment Index) of the Grand Canal in Beijing is 4.44. The values of BRI, PCI and EQ varied between 2.86~5.25. The assessment result was IV, lower than the middle level, showing the general condition of the Grand Canal in Beijing is not so good with great environment pressure along the canal. The environment condition in Tongzhou is better than that in Beijing except the land deterioration index.

The HEAI (Humanistic Ecological Assessment Index) of the Grand Canal in Beijing is 2.72. The values of HI, EI and SV varied between 2.42~2.84. The assessment result was IV, showing the general condition of the Grand Canal in Beijing is also not so good. The Grand Canal originated in the Yuan dynasty, went through the Ming and Qin dynasty. There are many heritages of high value along the canal. But after 1960s, the canal in the north of Jining lost the function of navigation. The North canal can only be used as water transportation and irrigation during high water season. The Tonghui canal was almost dry during dry season and was almost a polluted water discharge canal. Due to lake of water and poor
situation of environment, the government paid little attention on the planning of the canal scenery and tourism development in Beijing. The water conservancy engineering in Tongzhou is better than those in Beijing and much attention had been paid on the canal scenery and tourism planning.

Fig. 4 the EEAI of the area 2 km away from the Beijing Canal Bio Richness (BR), Plant Coverage (PC), River net (RN), Land deterioration (LD), Environment quality (EQ), Ecological environment (EE)

Fig. 5 the HEAI of the area within 2 km along the Beijing Canal

With the obtained value of EEAI and HEAI, the CEAI in the urban area and Tongzhou of Beijing was calculated with Eq. (2) and shown in Fig. 6.

Fig. 6 showed that the average CEAI of the Grand Canal in Beijing is 7.16, varying from 5.28 ~ 8.09 during III and IV level. It takes 66% for the III level, and 34% for the IV level. In the view of spatial pattern, the CEAI in the east was higher than that in the west, that is, it is higher in the countryside than that in the city.
6. Conclusion

This research used GIS, RS data in Beijing to interpret land use data. A CEA model, which can decrease the objective factors in traditional method, is used to quantify the assessment of environment in Beijing. The following conclusions were reached:

(1) The environmental condition along the canal in Beijing is under the middle level. The CEA index decreases from the countryside in Tongzhou to the urban. Environment improving and scenery planning is strongly recommended for the government for the world heritage application, which is believed not only to improve the environment of the canal, but also the level of the whole city.

(2) The CEAI was calculated in the view of both ecology and humanistic by constructing a value system including ecological environment, heritage, economic and scenery etc, which showed the comprehensive environment situation of the heritage canal. Integrating the CEA model with GIS, RS data as well as field investigation, information of environment factors can be reached with high accuracy, improving the robust of the CEA model.

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