Eco-environmental quality evaluation of Huaibei Plain

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Abstract In recent years, the destruction of the ecological environment in Huaibei Plain has limited the development of the economy. Doing research on eco-environment quality evaluation methods may be helpful to the recovery of the eco-environment in Huaibei Plain and the construction of ecological civilization. A new assessment system was introduced in this paper on the basis of a traditional eco-environmental evaluation method; the NPP index was used to replace biological abundance index and vegetation coverage index. This new method was used to evaluate the eco-environment quality of Huaibei Plain. Results indicate that: (a) the eco-environment of Huaibei Plain has been getting worse since 1990, but has improved since 2000; (b) the water-network density index is the key factor which affects the eco-environment of Huaibei Plain; (c) If human activities, pollution control, land degradation and urban area development are not taken into consideration, the eco-environment of Huaibei Plain in dry years will be serious.

Key words Huaibei Plain; eco-environmental quality evaluation; eco-environmental quality index; NPP

INTRODUCTION

Human survival is based on the eco-environment. In recent years, there have been serious environmental problems worldwide, such as environment pollution, deforestation and the scarcity of water resources. The damage of the eco-environment has become more and more serious since 1978 when China's reform and opening-up policies were launched. Eco-environmental problems have become increasingly outstanding in China (Wang *et al*., 1997), and there is an urgent need to construct water ecological civilization (Liu, 2013).

Eco-environmental quality, which is based on ecological theory can be used to estimate the quality of an ecosystem. The result indicates whether the ecosystem is sustainable to human survival and economic development during a period of time in a certain field. The results will show the status of the ecological environment and transition according to the requirement of people. Eco-environmental quality evaluation chooses typical and operable indexes to estimate the quality of the ecosystem environment according to specific purposes. A better eco-environment quality means less possibility of eco-system retrogression. We are able to judge whether the retrogression happens in the study area from this point of view. A further investigation should be done to determine the main factor if deterioration exists. Various methods have been employed to reveal the regional eco-environmental situation. There are some methods always used in research, such as the index evaluation method (Liu *et al.*, 2008), the analytic hierarchy process method (AHP) (Yu *et al*., 2002), fuzzy comprehensive evaluation method (Li *et al*., 2003), artificial neural network evaluation method (Li *et al*., 1995), and eco-environmental quality evaluation method (Zhu *et al*., 2012).

In this paper, the net primary productivity (NPP) has been introduced to replace the biological abundance index and vegetation coverage index. A new evaluation index system is established to evaluate eco-environmental quality. This paper utilizes this improved eco-environmental evaluation method to study the influence of LUCC on Huaibei Plain on the ecosystem. We are able to have a better understanding of the eco-environmental degree of Huaibei Plain. The results indicate that this new method is capable of reflecting the environmental quality effectively which will provide a sustainable development strategy for government.

MATERIAL AND METHODS

Study area

Huaibei Plain is located in the north of Anhui Province at 114º55′−118º10′E, 32º25′−34º35′N, with a total area of 37 437 km^2. Climate of the plain is characterized as subtropical continental monsoon. It is seriously affected by natural disasters, especially flood and drought. Because Huaibei Plain is located in the middle reach of the Huaihe River, its ecological status is very important for maintaining an ecological balance of the water system, and promoting healthy development of the society and economy in the middle and lower reaches of the Huaihe River.

However, in the recent 20 years, with the rapid development of socio-economics, some eco-environmental problems have appeared such as the degradation of biomass, water pollution caused by industry and land degradation. Therefore, the eco-environmental quality of the whole area has been damaged and even become one of the major factors restricting the sustainable development of the plain.

Data

The amount of solid waste discharge, COD emissions and SO_2 emissions are derived from the China Statistical Yearbook on Environment. The soil erosion area of Huaibei Plain is derived from Anhui Province Annual Communique on Soil and Water conservation monitoring. The land use of Huaibei Plain is obtained from remote sensing data (Fig. 1).

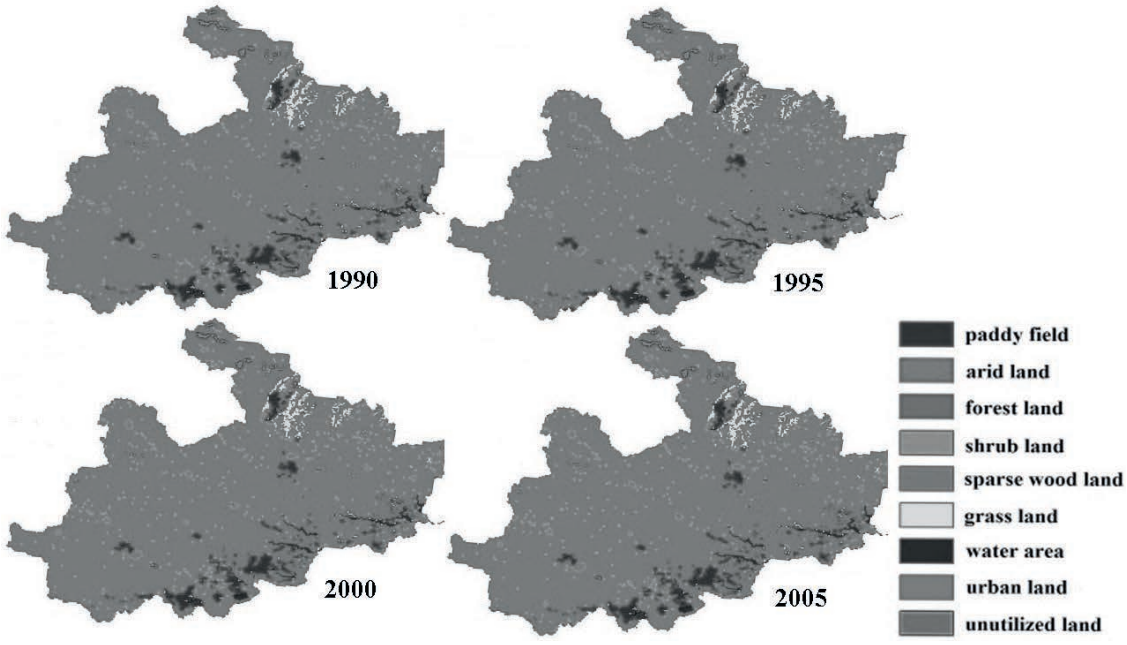

Fig. 1 The distribution of land use/land cover on Huaibei Plain.

Methodology

Establishment of the evaluation index system The index selection in this paper follows six principles proposed by Wan Bentai (Zhu *et al*., 2012). NPP has been utilized to instead biological abundance index and vegetation coverage index. NPP is short for net primary productivity, which means that a higher NPP value represents a better eco-environmental system. A better eco-environmental system means the biodiversity is greater and vegetation coverage is larger. Thus, NPP is chosen as a new index for the evaluation. This paper selects NPP, water-network density, land retrogression and pollution load as the eco-environmental evaluation indexes.

The calculation of NPP index To calculate the NPP index in Huaibei Plain, score values of different types of vegetation have been derived (He *et al*., 2005). We consider the ecosystem of tropical rain forest is the best, and its NPP score value is 1. The NPP score values of other vegetation are obtained on the basis of the NPP score value of tropical rain forest. The vegetation score values are shown in Table 1.

Total NPP value of Huaibei Plain is calculated based on the area of different vegetation:

$$NPP_{total} = \sum(S_i \times \overline{NPP_i}) \quad (1)$$

where NPP_{total} (g/year), S_i (m^2), and $\overline{NPP_i}$ (g/(m^2·year) are total NPP value of Huaibei Plain, area of each classified vegetation in Huaibei Plain, corresponding average NPP value, respectively.

Average NPP value of Huaibei Plain is obtained by following equation:

$$\overline{NPP} = \frac{NPP_{total}}{S} \quad (2)$$

where $\overline{NPP}$ (g/(m^2·year)) is the average NPP value of Huaibei Plain and S (m^2) is the total area of Huaibei Plain.

Finally, we obtain the NPP index using the NPP value of tropical rain forest as reference.

$$NPP = \frac{\overline{NPP}}{\overline{NPP_{trop}}} \quad (3)$$

where $\overline{NPP_{trop}}$ (g/(m^2·year) is the average NPP value of tropical rain forest.

Table 1 Score values of different vegetation.

Classification	Score value	Classification	Score value
Tropical rain forest	1	Grassland	0.26
Deciduous broad leaved forest	0.57	Sparse shrubbery	0.17
Natural mixed forest	0.47	Bare soil	0
Evergreen coniferous forest	0.54	Crop	0.46
Coniferous forest	0.38	Water	0
Ground cover broadleaf forest	0.72	Total	0.38

The calculation of other indexes

(a) Water-network density index

$$WDI = River\ length/S + Lake\ area/S + Water\ quantity/S \quad (4)$$

(b) Land retrogression index. The weight of land retrogression is shown in Table 2.

Table 2 The weight of land retrogression.

Classification of land retrogression	Mild	Moderate	Severe
Weight	0.05	0.25	0.7

$$LRI = (0.05 \times Mild\ retrogression\ area + 0.25 \times Moderate\ retrogression\ area + 0.7 \times Severe\ retrogression\ area)/S \quad (5)$$

(c) Pollution load index. The weight of different pollution index is shown in Table 3.

Table 3 The weight of different pollution index.

Pollution index	SO_2	COD	Solid waste
Weight	0.4	0.4	0.2

$$PLI = 0.4 \times SO_2\ emission + 0.2 \times Soild\ waste\ emission/S + 0.4 \times COD\ emission/precipitation \quad (6)$$

The calculation of eco-environmental quality index The weight of each evaluation index is based on the eco-environmental evaluation method proposed by Wan Bentai. We add the weight of the biological abundance index and vegetation coverage index to give the weight of NPP index. The weights of other indexes are not changed (Table 4).

Table 4 Weight of each evaluation index.

Index	NPP	Water-network density	Land retrogression	Pollution load
weight	0.5	0.25	0.15	0.1

The eco-environmental quality index has been denoted as ecological index (EI) in this paper, which ranges between 0 and 100. It can be summarized by the following equation:

$$EI = 0.5 \times NPP + 0.25 \times WDI + 0.15 \times (1 - LRI) + 0.1 \times (1 - PLI) \quad (7)$$

where *NPP*, *WDI*, *LRI*, *PLI* represent separately the net primary productivity, water-network density, land retrogression and pollution load.

To compare the eco-environmental quality of Huaibei Plain, EI was divided into five levels in this paper (Table 5).

Table 5 Classification of eco-environmental quality in Huaibei Plain.

Classification	EI	Eco-system retrogression degree
Best	≥75	No retrogression
Good	55–75	Slight retrogression
Normal	35–55	Normal retrogression
Pool	20–35	Strong retrogression
Pooler	<20	Complete retrogression

RESULTS

(a) The NPP index falls during the study period, which was mainly caused by the dynamic change of land use (Fig. 2(a)). From 1990 to 2005, the areas of agricultural land decreased by 178 km^2. But the areas of construction land increased year by year during the same period, at an increasing rate of 26.84%.

(b) Water-network density index is highly affected by the climate. The annual variation of precipitation is obvious in Huaibei Plain (Fig. 2(b)). Thus, no obvious tendency could be observed. The index is lowest in 2000 due to drought in the spring at that year. The index is highest in 2005 because the precipitation was abundant in that year.

(c) Land retrogression has intensified since 1995 (Fig. 2(c)). The major factor is that the Huaibei Plain has a lime concretion black soil. The structure of this calcareous black soil is fragile and it is easily eroded. At the same time, the vegetation cover has decreased and area of bare soil has increased.

(d) Pollution load index has increased since 1990a for several reasons (Fig. 2(d)). The main reason is the rapid growth of industry in Huaibei Plain. Many factories have been built. However, the pollution from these factories has not been well controlled. Higher levels of industrialization may attract more people to work here. Higher population density is another factor raising the pollution load index.

(e) To sum up, the eco-environmental quality of Huaibei Plain was in a good state during the study period except in 2000 (Fig. 2(e)). The eco-environment quality improved slightly from 1990 to 1995 when the index was 55.38 and 56.87, respectively. In 2000, the eco-environmental index was the lowest because the water-network density was the lowest. The eco-environmental quality in 2005 was the highest with 59.01.

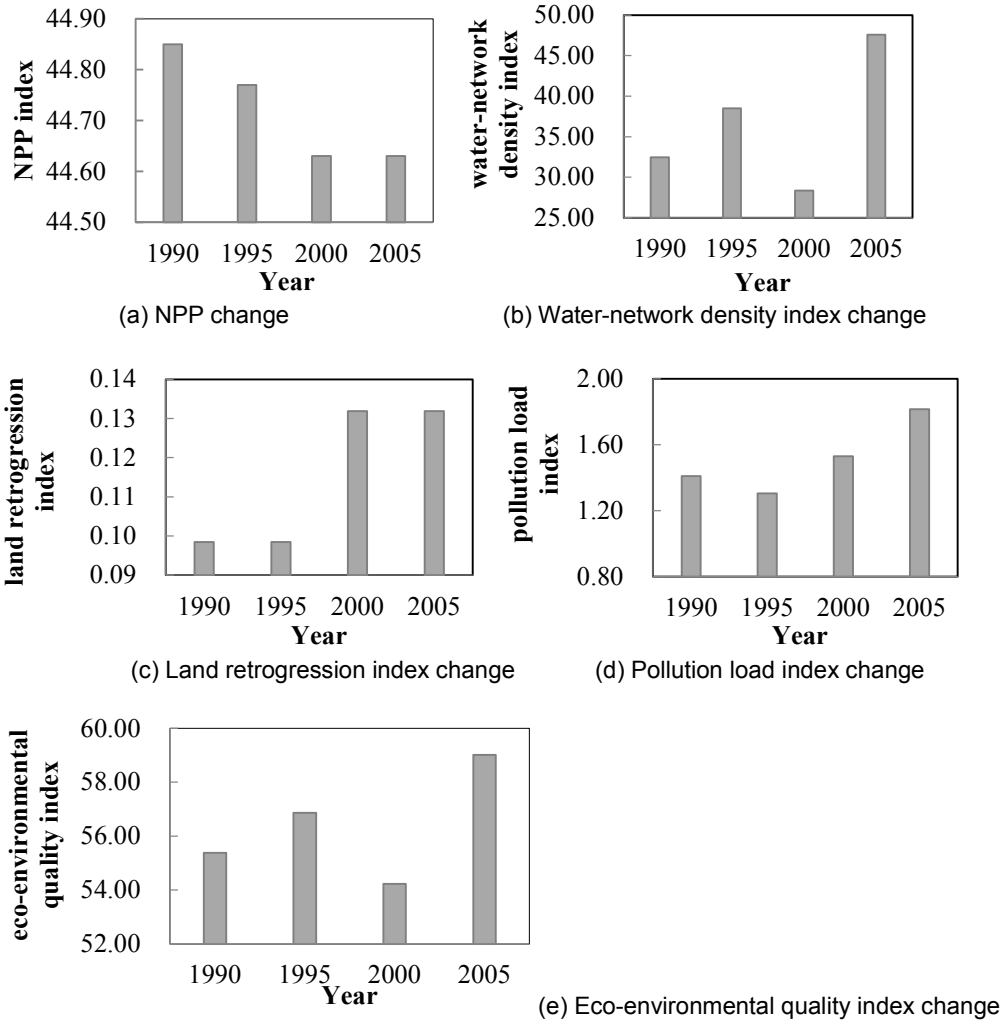

Fig. 2 The change of each index from 1990 to 2005.

The results of the improved eco-environmental quality evaluation method tally with the phenomena we have observed in Huaibei Plain (Fig. 3), which indicates this new method is credible. Also, the NPP index we have used in this paper has taken the spatial variation into consideration, and the result should be more accurate.

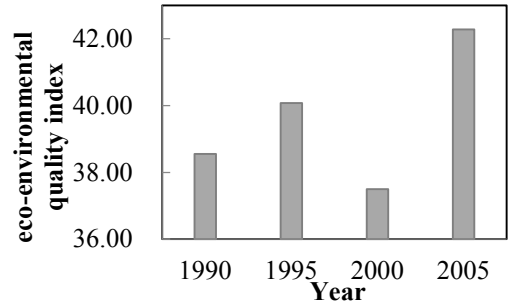

Fig. 3 the result of tradition eco-environment evaluation method

CONCLUSION

In this paper, NPP has been introduced to replace biological abundance index and vegetation coverage index. A new eco-environmental index is set up to evaluate the dynamic change of the

eco-environment of Huaibei Plain and gives a satisfactory result. The results show that the eco-environmental quality index is greatly affected by the water-network density index. Higher water-network density always leads to better eco-environmental quality. This will have a certain reference value for realizing the environment state and planning economic development.

In addition, this paper has some insufficiencies. For instance, because the dynamic change and influence factors of the eco-environment are complex and relative, the factors we select in this paper are not enough; Although we have chosen 1990 to 2005 as our study period, we just analyse the eco-environmental quality in 1990, 1995, 2000, 2005, which means further detailed analysis should be done in future research.

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