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Quantification of eco-compensations based on a bidirectional compensation scheme in a water environment: a case study in the Jiangsu Province, China

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Abstract

This study delineates adjustments to the eco-compensation pilot work of the Taihu Lake Basin and the Huaihe River Basin. The number and location of original compensation sites were adjusted based on the characteristics of the river network and of the water pollution status. A bidirectional eco-compensation system based on water quality exceeding multiple was then implemented. Under this scheme, the eco-compensation payments of each city under three different compensation standards were calculated. A suitable unified short-term compensation standard for the whole province is determined among several compensation payment schemes. The results obtained after implementing the most relevant scheme reveal that (1) the bidirectional eco-compensation system is highly flexible and is viable economically, as the payment of fiscal expenditures used to pay eco-compensation is reasonable. (2) In the southern Jiangsu Province, the ratio of pollutant flux at each compensation site to the total regional flux is relatively high and may, therefore, accurately reflect the water quality condition of the main rivers flowing into the Taihu Lake. (3) The ratio of pollutant flux in the northern Jiangsu Province is low, which highlights the need for further improving the number and location of eco-compensation sites, as well as the compensation methods and standards.

Keywords: Bidirectional eco-compensation; Jiangsu Province; Pollutant flux ratio; Standard excess; Water quality

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1. Introduction

Eco-compensation focuses on optimizing the management of environmental resources to achieve environmental protection as well as sustainable use of these resources and has become a popular topic in the field of environmental protection over the past few years (Gouyon, 2003; Yuan & Zhou, 2014). The study of eco-compensation abroad mainly involves the definition of compensation quota (Murray & Robert, 2001; Johst *et al*., 2002), the degree to which relevant interest groups (protector, destroyer, beneficiary, and injured person) participate in the eco-compensation policy (Williams *et al*., 2006; Aschwanden *et al*., 2007; Ibarra, 2007), and the evaluation of the performance of an eco-compensation policy after its implementation (Cuperus *et al*., 2002; Herzog *et al*., 2005). Eco-compensation in China mainly involves the following discussions: the necessity of watershed eco-compensation, principle and object definition, compensation standard, and compensation mode (Liu *et al*., 2016). The determination of the compensation standard is a key link in the watershed eco-compensation scheme, which directly affects the operational effects of eco-compensation. Recently, results in defining the compensation standard have been achieved as many research works focused on the range, method, and basis of compensation (Peng *et al*., 2016; Chen & Ma, 2017; Ma, 2018). Overall, contemporary research has been estimating the watershed eco-compensation standard based on the ecosystem service value (Qiao *et al*., 2012; Zhou *et al*., 2015; Guan *et al*., 2016), the stakeholders' willingness to pay for the eco-compensation (Amigues *et al*., 2002; Morana *et al*., 2007; Xu *et al*., 2012), the ecological construction cost (He *et al*., 2016; Liu & Wang, 2017; Geng *et al*., 2018), and the ecological footprint (Xiao *et al*., 2015).

With regard to the watershed eco-compensation mode, the main scheme implemented in China is still emphasizing only on the pollution compensation, i.e., the single compensation of excess emissions from upstream to downstream, with the government mostly adopting a 'one-size-fits-all' approach. This kind of compensation leads to either too low or too high compensation to the extent that the regional compensation standard capabilities could be completely drained. Therefore, it cannot form an effective incentive and may even lead to the failure of the compensation mechanism. Therefore, in 2014, following the principle of 'whoever meets the standard will benefit, whoever exceeds the standard will compensate', the Jiangsu Provincial Government put forward the 'Implementation Measures of Regional Water Environment Compensation in Jiangsu Province (trial implementation)', proposing to establish an economic compensation scheme between the upper and lower reaches of the main water areas. This was a practical attempt at implementing a bidirectional eco-compensation mechanism. However, it lacked proper formulation for the compensation standards, and its implementation and operability were open to question. In view of this, this paper attempts to put forward a bidirectional compensation mechanism, which takes into consideration the river reciprocating flow as well as the stagnant flow. Such a mechanism could then be implemented in the near future. This mechanism is based on the principle that compensation depends on the amount (in multiples of the standard) by which water quality variables exceed an acceptable standard. The pollutant flux control rate is estimated by combining the water flow data of the main rivers in the province with the pollutant flux percentage at each compensated site. This study is expected to provide a reference for the continuous improvement and efficient operation of watershed eco-compensation mechanisms in China.

2. Theory and methods

2.1. Research area

Jiangsu Province is located in the middle part of the eastern coast of China (between 30°45′N, 116°18′E–35°20′N, 121°57′E) and is characterized by a flat terrain, numerous rivers and lakes, and a dense water network. Both the Yangtze River and the Huaihe River Basin cross the province. The Yangtze River is the largest river in China, its length and water volume being ranked third in the world. The main stream of the Yangtze River in the Jiangsu Province is 418 km long, flowing through Nanjing, Zhenjiang, Yangzhou, Taizhou, Changzhou, Wuxi, Suzhou, and Nantong, all of which are prefecture-level cities. The Taihu Lake Basin belongs to the Yangtze River system and covers a total area of 36,900 km^2 of which about 19,200 km^2 are located in the Jiangsu Province, involving the four following prefecture-level sites: Suzhou, Wuxi, Changzhou, and Zhenjiang. The main stream of the Huaihe River is 1,000 km long, covering a basin area of 187,000 km^2, including 39,400 km^2 in Jiangsu Province. Most of the rivers in the province communicate with each other, with the Grand Canal flowing from north to south across the province (Figure 1).

2.2. Eco-compensation model

In this study, the permanganate index (COD_{Mn}), ammonia nitrogen (NH_4^+-N), and total phosphorus (TP) measured concentration values at each control cross section of the Jiangsu Province in 2013 are used to estimate the compensation payment. Automatic monitoring stations provided daily data, whereas data were collected four times a month at other (manual) monitoring sites.

2.2.1. Bidirectional compensation management mechanism. The bidirectional compensation model is implemented at cross sections along river segments separating two cities. When the water quality at the cross section exceeds the standard, the upstream city compensates the downstream city; when the water quality meets the standard, the downstream compensates the upstream. Lastly, in the case of stagnant flow, no compensation is made by either city.

A different model is adopted at key control cross sections whose downstream directly flows either into the sea or in the Taihu Lake or the Yangtze River, or in clear water corridors, or out of Jiangsu Province. In this case, under normal down-flow conditions, if the water quality at the cross section exceeds the standard, the upstream city compensates the provincial finance; if the water quality reaches the standard, the provincial finance compensates the upstream city. In the case where a stagnant flow occurs due to the closing of a dam's gate or other reasons, if the water quality exceeds the standard, then the upstream city compensates the provincial finance at a rate of 70%, compared to the normal down-flow condition. No compensation exists for a countercurrent condition. Among all the cross sections, the control sections on the 'South-to-North Water Transfer Project' river route are considered as positive flow during water transfer. All compensation payments shall be turned over to the provincial finance, which also allocates annual funding. All special funds must be earmarked for local water environment protection.

2.2.2. Model formulation. The compensation amount is calculated once a month following the principle of multiplying the amount excessing the standard (in multiple of the standard) by a compensation coefficient.

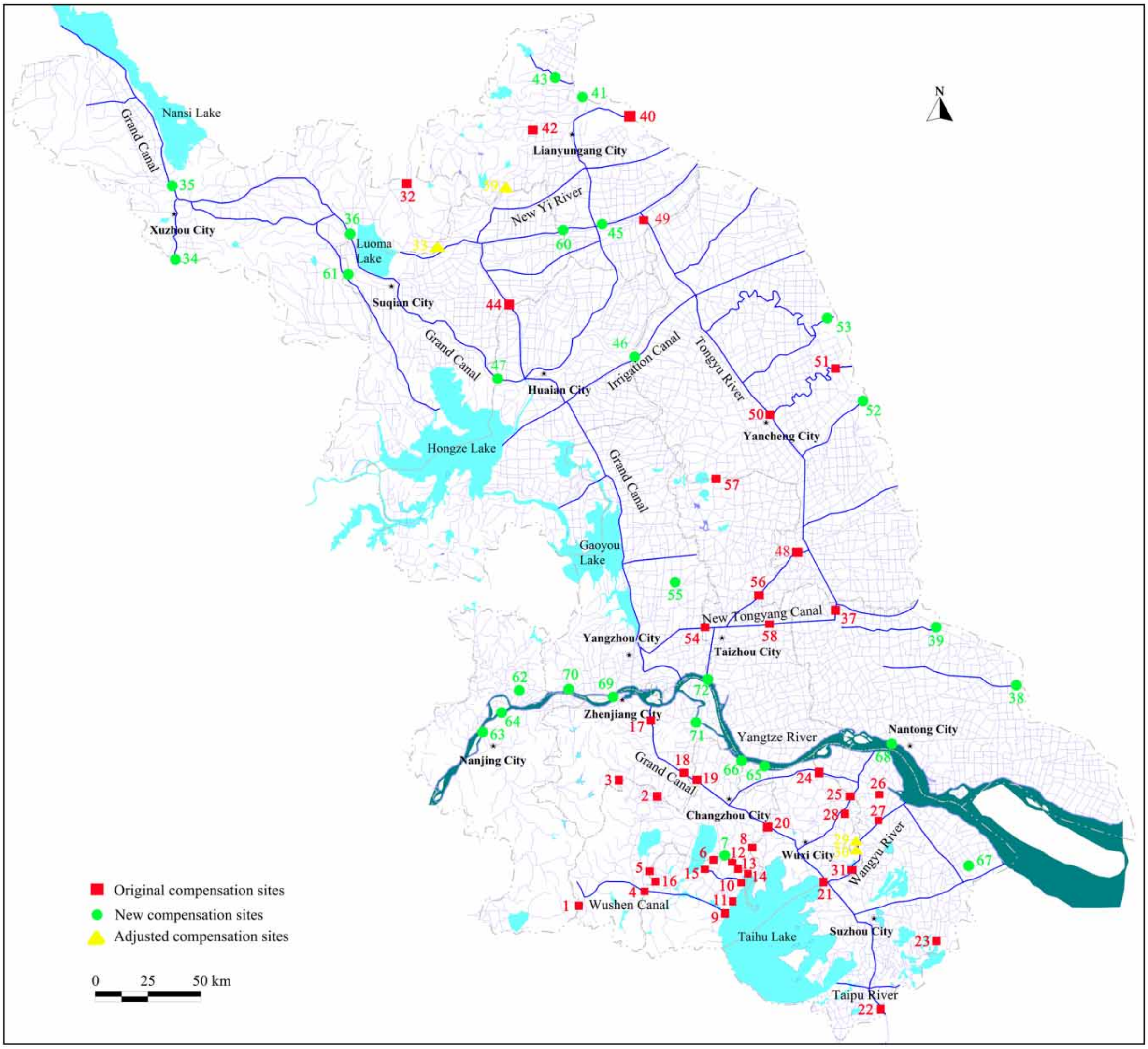

Fig. 1. Hydrographic network system and optimized water environment eco-compensation sites within the Jiangsu Province.

1. The compensation is positive (upstream compensates downstream) when the water quality at the cross section exceeds the standard. The calculation steps are as follows: (1) Estimation of the single payment M_i, i.e., the compensation payment amount of a certain site under the ith measurement order; (2) Calculation of the monthly average payment M_j, i.e., the average value of all M_i of a given site in the jth month; and (3) Calculation of the annual positive compensation payment M_f, i.e., the sum of all M_j at a given site during a whole year:

$$M_i = d \times (P_{\mathrm{COD}\cdot i} \times B + P_{\mathrm{NH_3-N}\cdot i} \times B + P_{\mathrm{TP}\cdot i} \times B) \tag{1}$$

$$M_j = \frac{\sum_{i=1}^{n} M_i}{n} \quad (2)$$

$$M_f = \sum_{j=1}^{12} M_j \quad (3)$$

where $P_{COD \cdot i}$, $P_{NH_3-N \cdot i}$, $P_{TP \cdot i}$ are the exceeding amounts (in multiple of the standard) of COD_{Mn}, NH_4^+-N, and TP, respectively, under the ith measurement order. P equals 0 when the standard is not exceeded; B is the positive compensation coefficient; d is the directional regulation coefficient, $d = 1$ for down-flow, $d = -1$ for counter-flow, and $d = 0$ when the flow is stagnant; and n is the number of measurements at a given site in the jth month.

2. The compensation is reversed (downstream compensates upstream) when all water quality assessment factors (COD_{Mn}, NH_4^+-N, and TP) of a certain site meet the standard during a whole month. Considering the economic development of Jiangsu Province at this stage, the reverse compensation coefficient of any given site is 0.2 million yuan per month. The annual reverse compensation payment M_r of any given site is calculated as follows:

$$M_r = 20 \times m \quad (4)$$

where m is the number of months in the whole year that all the assessment factors of water quality of this site reach the standard, $m = (0, 1, 2, \ldots\ldots, 10, 11, 12)$.

2.2.3. Compensation standard. Here, the compensation standard implemented in the Tongyu River Basin in 2010 is taken as a reference. Three different positive compensation standards are proposed in this paper: (1) Standard one: the compensation coefficients are 0.25 million yuan, 0.5 million yuan, and 1 million yuan when the water quality exceeds the standard by 0.5 times (including 0.5 times), 0.5 times–1 time (including 1 time), and more than 1 time, respectively; (2) Standard two: the compensation coefficients are 0.5 million yuan, 1 million yuan, and 1.5 million yuan, respectively; and (3) Standard three: the compensation coefficients are 0.15 million yuan, 0.25 million yuan, and 0.5 million yuan, respectively.

3. Results and discussion

3.1. Eco-compensation site adjustment

In the course of the previous pilot eco-compensation scheme in Jiangsu Province, 30 compensation sites had been designated in the Taihu River Basin, as well as 15 sites in the Huaihe River Basin. In view of the adjustment of the river network system, the construction of water conservancy projects, and the large discharge or poor water quality observed in recent field surveys, the number of sites has since been adjusted and increased. Meanwhile, new compensation sites have been set up in rivers flowing into larger bodies of water, such as the Taihu Lake, the Yangtze River, the East China Sea, and the 'South-to-North Water Transfer Project'. Following these adjustments, the number of compensation sites reaches 72, including 27 new sites, four sites whose location was changed, and six check sites (Figure 1). These changes make the compensation scheme cover the whole province.

3.2. Eco-compensation payment estimation

According to the monitoring data of the 72 compensation sites in 2013, only 23 sites (about 32%) had all three water quality factors meeting the standards, indicating the poor situation of the water pollution in the province. As an economic means to promote local environmental protection, eco-compensation links environmental pollution with economic compensation. It thereby further incites the local government to take their responsibilities for promoting environmental protection and encourages the local initiatives to fight pollution in order to achieve the water quality targets. The annual positive and reverse compensation payments are calculated at each site based on the three aforementioned compensation standards. The social and economic development of each city in the Jiangsu Province and the economic suitability and operational feasibility of the proposed bidirectional compensation method have been considered to conduct this estimate. The net annual eco-compensation payment is then calculated for each city based on the compensation direction of each site under the city's responsibility.

Theoretically, the eco-compensation payment should be higher than the economic cost of pollution control, so as to encourage local governments' initiatives in pollution control and incite them to fulfill their responsibility for the improvement of environmental quality. As can be seen from Table 1, the financial expenditure of each city estimated according to Standard two is significantly higher than

Table 1. Estimation of the annual eco-compensation payment of each prefecture-level city in 2013 based on Standards two and three.

	Standard two			Standard three		
City	Net expenditure	Total expenditure	Total revenue	Net expenditure	Total expenditure	Total revenue
Nanjing	9,428.2	9,948.2	520	2,771	3,291	520
Wuxi	452.6	5,716.6	5,264	−117.3	2,229.4	2,346.7
Changzhou	−899.2	4,601	5,500.2	−633.8	1,602.6	2,236.4
Suzhou	−365	929.9	1,294.9	−285.7	497.1	782.8
Zhenjiang	1,821.9	2,301.9	480	241.2	721.2	480
Xuzhou	2,170.7	2,950.7	780	201	981	780
Nantong	1,111.2	1,391.2	280	440.4	720.4	280
Lianyungang	849.9	5,574.1	4,724.2	786.3	2,640.6	1,854.3
Huaian	231	931	700	−412.8	287.2	700
Yancheng	−612.7	1,016.5	1,629.2	−496.3	931.7	1,428
Yangzhou	105.9	585.9	480	−191.4	288.6	480
Taizhou	−698.3	241.7	940	−699.5	240.5	940
Suqian	3,380.7	3,860.7	480	954.6	1,434.6	480
Provincial Finance	−16,976.9	5,460	22,436.9	−2,557.7	5,460.0	8,017.7
Total	0	45,509.4	45,509.4	0	21,325.9	21,325.9

Unit: Ten thousand yuan.

the range its current development can bear. There is a clear imbalance in the payment used for eco-compensation in various cities, among which the net expenditure of four cities (Nanjing, Zhenjiang, Xuzhou, and Suqian) is too high. In particular, eco-compensation payments by Nanjing city reach nearly 100 million yuan. Under this standard, local financial pressure is often too high due to the high compensation cost, which will dampen the enthusiasm of local governments to participate in eco-compensation works. At worst, some local governments may default on compensation fees, thus evading their responsibilities on the management of the river basin. The local government's financial payments used for eco-compensation estimated by Standard three are significantly lower, being generally kept within 10 million yuan except for Nanjing. This low compensation standard, however, may not well promote the efforts of local governments to improve the water environment. The financial expenditure under Standard one (Table 2) is more reasonable, and the total investment of eco-compensation in the whole of Jiangsu Province is about 350 million yuan, which is more suitable for the current economic development of all cities in the province. Nanjing and Lianyungang have relatively higher compensation payments of 66 million yuan and 48 million yuan, respectively. Wuxi comes next with about 36 million yuan. Changzhou and Suqian follow by with 26–29 million yuan. Zhenjiang and Xuzhou are 14–20 million yuan, and the compensation payments of the remaining six cities are less than 10 million yuan. From the perspective of the regional fiscal input, 151 million yuan are invested by the southern Jiangsu Province cities, 122 million yuan by the Northern Jiangsu Province cities, and 55 million yuan by the Provincial Finance. Net revenues, including income, are approximately −60, −40, and 100 million yuan, respectively. Standard one is then conducive to the implementation of regional water environment eco-compensation. In addition, the net revenue of the provincial finance has been further increased, which will allow the government to invest more money in the provincial water environment treatment, water quality monitoring, and water source protection. Therefore, this study recommends the use of the compensation Standard one and a reverse monthly reward coefficient of 0.2 million yuan when the water quality meets the standard.

3.3. Analysis of the eco-compensation sites pollutant flux

3.3.1. Southern Jiangsu Province. The Taihu Lake Basin is the main area assessed in the southern Jiangsu Province, including water bodies along the Wangyu River, Beijing-Hangzhou Canal, and the rivers entering into the Taihu Lake. The locations mainly include four cities: Zhenjiang, Changzhou, Wuxi, and Suzhou. Based on the concentration of the water quality indicators and the river discharge, the contribution – in percentage – to the flux of pollutant flowing to the surrounding rivers at each compensation site can be estimated (Table 3). A high percentage indicates that the compensation sites enable the pollutant flux to be estimated and controlled appropriately.

The results listed in Table 3 show that the flux control rate of each city is about 70%, i.e., the pollutant flux of the eco-compensation sites in the Taihu Lake Basin can cover all the major rivers and the water quality of the main rivers in the Taihu Lake Basin is appropriately reflected by the compensation sites.

3.3.2. Northern Jiangsu Province. In the northern Jiangsu Province, the main assessed area is the Huaihe River Basin, which includes water bodies such as the 'South-to-North Water Transfer Project', the main stream of Tongyu River, and its tributaries, as well as other rivers flowing into the East China Sea. The pollutant flux percentage in the Huaihe River Basin is shown in Table 4, expressed in the same way as in Table 3.

Table 2. Estimation of the annual eco-compensation payment of each prefecture-level city in 2013 based on Standard one.

City	Positive compensation payment	Positive accepted compensation payment	Reverse compensation payment	Reverse accepted compensation payment	Net expenditure	Total expenditure	Total revenue
Nanjing	6,573.8	0	0	520	6,053.8	6,573.8	520
Wuxi	2,993.9	2,459.3	640	1,140	34.6	3,633.9	3,599.3
Changzhou	2,506.7	2,913.1	360	760	−806.4	2,866.7	3,673.1
Suzhou	295.3	423.9	340	560	−348.6	635.3	983.9
Zhenjiang	1,412.2	0	0	480	932.2	1,412.2	480
Xuzhou	1,955.3	0	0	780	1,175.3	1,955.3	780
Nantong	576.8	0	240	280	536.8	816.8	280
Lianyungang	4,274.1	2,753.5	500	460	1,560.6	4,774.1	3,213.5
Huaian	550.6	0	0	700	−149.4	550.6	700
Yancheng	58.4	175.8	900	1,340	−557.4	958.4	1,515.8
Yangzhou	355.4	0	0	480	−124.6	355.4	480
Taizhou	0.8	0	240	940	−699.2	240.8	940
Suqian	2,377.9	0	240	480	2,137.9	2,617.9	480
Provincial Finance	0	15,205.6	5,460	0	−9,745.6	5,460	15,205.6
Total	23,931.2	23,931.2	8,920	8,920	0	32,851.2	32,851.2

Unit: Ten thousand yuan.

Table 3. Water discharge and flux of pollutants in the rivers surrounding each compensation site, expressed as absolute values and as contributions, in percentage, of each compensation site to the total discharge and pollutant flux in the Taihu Lake Basin.

Indicator		Zhenjiang	Changzhou	Wuxi	Suzhou
Total flux of major outgoing river	Water discharge (10^8·m^3/a)	18.7	41.1	71.7	37.5
	COD (t/a)	30,981	90,792	146,824	82,179
	NH_4^+-N (t/a)	1,939	12,642	21,312	13,090
	TP (t/a)	425	1,390	1,464	986
Flux of compensation sites	Water discharge (10^8·m^3/a)	15.3	29.4	60.7	23.2
	COD (t/a)	23,815	62,073	123,958	53,696
	NH_4^+-N (t/a)	1,741	10,122	19,954	11,547
	TP (t/a)	381	1,006	1,233	672
Control rate	Water discharge (%)	81.8	71.5	84.7	61.9
	COD (%)	76.9	68.4	84.4	65.3
	NH_4^+-N (%)	89.8	80.1	93.6	88.2
	TP (%)	89.7	72.4	84.2	68.2

The complexity of the river network system in the northern Jiangsu Province, as well as the existing monitoring capability and regional development level, is likely to affect the control that each city has over the outflowing amount of pollutant. Although the compensation sites cover most of the major water bodies, five of the eight prefecture-level cities have a low control rate of pollutant flux, with values less than 30%. With the gradual improvement of eco-compensation efforts, the capabilities of the compensation sites should be expanded step by step according to the enforcement status and the local development level.

3.3.3. Public waters. Eleven compensation sites have been added along the Yangtze River, and each city's pollutant flux percentage to major rivers flowing into the Yangtze River is shown in Table 5.

The pollutant flux control rates of the compensation sites into the Yangtze River are generally lower than 30%, except for Nanjing, Changzhou, and Wuxi. In particular, the control rates in Zhenjiang, Taizhou, and Nantong are even lower than 10%. As the largest river in China, the Yangtze River is an important lifeline for the sustainable development of China's economy and society. Such low flux control rate does not enable the impact of this development on the pollutant flux to be evaluated.

In Nantong, Lianyungang, and Yancheng, which are three coastal cities of Jiangsu Province, the control rates are shown to be relatively low. As there are relatively few rivers joining the sea in Nantong city, the control rate of about 53% is slightly higher than that of the other two cities (about 20%). Therefore, a follow-up study could aim at studying the effect of increasing the number of the coastal compensation sites of Lianyungang and Yancheng, as well as the compensation sites in the Yangtze River to improve the control rate of pollutant flux in the whole province.

4. Conclusions

The regional eco-compensation scheme in the Jiangsu Province is still in its experimental stage and should be further improved following the principle that the occurrence of poor water quality should be

Table 4. Same as Table 3 for the Huaihe River Basin.

Indicator		Lianyungang	Xuzhou	Suqian	Huaian	Yancheng	Taizhou	Nantong	Yangzhou
Total flux of major outgoing river	Water discharge ($10^8 \cdot m^3/a$)	94.9	124	221.4	254.7	208.6	90	52.6	201.1
	COD (t/a)	189,729	247,802	442,930	509,722	417,681	180,163	105,393	402,125
	NH_4^+-N (t/a)	9,487	12,389	22,146	25,487	20,883	9,009	5,270	20,107
	TP (t/a)	1,898	2,479	4,431	5,098	4,178	1,802	1,054	4,022
Flux of compensation sites	Water discharge ($10^8 \cdot m^3/a$)	25.1	101.3	15.5	78	44.3	65	32	50.9
	COD (t/a)	50,351	202,629	31,062	156,155	88,811	130,030	64,043	101,807
	NH_4^+-N (t/a)	2,518	10,131	1,553	7,808	4,440	6,502	3,202	5,090
	TP (t/a)	504	2,027	311	1,562	889	1,300	641	1,018
Control rate	Water discharge (%)	26.5	81.7	7	30.6	21.2	72.2	60.8	25.3
	COD (%)	26.5	81.8	7	30.6	21.3	72.2	60.8	25.3
	NH_4^+-N (%)	26.5	81.8	7	30.6	21.3	72.2	60.8	25.3
	TP (%)	26.6	81.8	7	30.6	21.3	72.1	60.8	25.3

Table 5. Same as Table 3 for the Yangtze River.

Indicator		Nanjing	Zhenjiang	Changzhou	Wuxi	Suzhou	Yangzhou	Taizhou	Nantong
Total flux of major outgoing river	Water discharge (10^8·m^3/a)	12,091.4	29,426.3	7,835.6	3,846.4	8,944.2	8,412.8	15,477	21,126.6
	COD (t/a)	50,789	64,672.7	25,023	15,517	36,960	30,519	46,458	72,433
	NH_4^+-N (t/a)	11,354.6	19,005.3	3,787.1	3,093.5	3,693.4	2,510.6	4,869.9	12,296.5
	TP (t/a)	2,221.2	2,612.7	932.3	716.4	680.7	783.2	1,881.8	2,854.8
Flux of compensation sites	Water discharge (10^8·m^3/a)	8,594.9	741.9	2,474.8	3,846.4	2,427.8	889.2	1,160	118.6
	COD (t/a)	38,985.4	2,908.5	10,414.8	15,517	7,485.7	4,431.3	2,822.6	753.8
	NH_4^+-N (t/a)	8,182	410.5	1,926.4	3,093.5	1,529.5	1,566.7	429.2	153.8
	TP (t/a)	1,533.2	76.6	451.7	716.4	317.6	336.4	118.5	26.8
Control rate	Water discharge (%)	71.1	2.5	31.6	100	27.1	10.6	7.5	0.6
	COD (%)	76.8	4.5	41.6	100	20.3	14.5	6.1	1
	NH_4^+-N (%)	72.1	2.2	50.9	100	41.4	62.4	8.8	1.3
	TP (%)	69	2.9	48.4	100	46.7	43	6.3	0.9

penalized and that meeting the water quality standard should be rewarded. In particular, upstream areas would then be encouraged to provide adequate water treatment and pollution management. In this paper, the number and location of the original compensation sites were adjusted based on the characteristics of the river network system and the water pollution situation in the Jiangsu Province, following which a scheme for the calculation of a bidirectional eco-compensation payment is devised based on the excess multiple of the water quality standard. The following conclusions are obtained:

1. The method of bidirectional compensation allows the reciprocating flow and stagnant flow of rivers in Jiangsu Province to be accounted for. The calculated amount of fiscal expenditures by each city to pay for the eco-compensation is reasonable and appears to be suitable for the current economic development of all cities in the province. Such amounts are conducive to carrying out regional water environment eco-compensation, and the income generated to the provincial government is beneficial for furthering the investments in provincial water treatment and protection, as well as water quality monitoring.
2. Although the number of compensation sites has been increased by 60% for this study, the pollutant flux control rates for the Huaihe River Basin, the Yangtze River and the East China Sea are still low. We suggest that an intensification of the efforts in the construction and improvement of the automatic water quality and water quantity monitoring system in the whole province (especially in northern Jiangsu Province) would enable the number of compensation sites in the Huaihe River Basin and public water bodies to be increased, and the pollutant flux control rate to be improved.
3. The water quality standard multiple excess method is suitable for an operational application by the provincial government. Some deficiencies still exist during the implementation process, such as compensation standard being possibly too low in some cases, or the imbalance between the economic development level and compensation payment in some cities, or the fact that the difference in compensation payments caused by the pollutant flux cannot be reflected. Various other eco-compensation methods, for example, based on the excessive flux of pollutant or the loss of water resources can be explored from a technical point of view. In this way, more pilot projects could be carried out in various river basins to gradually refine the eco-compensation system and improve the quality of the water environment.

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