

Eco-compensation of Wetlands in Yellow River Delta of Shandong Province, China

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Abstract: Wetlands play an important ecological role and provide many functions for people, yet wetlands are currently decreasing and deteriorating. The ability to calculate an economic value for the loss of wetlands is becoming increasingly important for policy makers. In this study, remote sensing, field investigations, department visits, and other methods were used to survey wetland types, assess wetland area changes, and calculate wetland economic value. Market value loss and ecological function value loss, caused by reduction of wetland area and environmental pollution were calculated using commonly accepted methods of market valuation, ecological valuation, environmental protection investment cost analysis, and outcome parameters. According to market value loss and ecological function value loss, preliminarily fund allocation for wetland and ecological compensation was calculated. This will provide an important reference for future Yellow River Delta eco-compensation studies.

Keywords: Yellow River Delta; wetland; eco-compensation; compensation standard

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1 Introduction

In recent years, due to the deterioration of ecological environments, eco-compensation has increasingly become a concern among Chinese and international scholars. Over the past 20 years, many international scholars have investigated the concepts, mechanisms, models, and methods of eco-compensation (Lai *et al.*, 2008); however, eco-compensation issues have significant interdisciplinary and regional differences, causing discrepancy among results and conclusions.

Regarding the concept of eco-compensation, opinions differ among scholars (Allen and Feddema, 1996; Couperus *et al.*, 1996). For example, Ye *et al.* (1998) thought that natural eco-compensation was viewed as the buffer and compensation role of the natural ecosystem to the eco-environmental destruction originated from the social and economic actions. Xiong and Wang

(2010) thought eco-compensation was mainly considered as the fiscal transfer compensation mechanism to the eco-environmental protection and its operators. In fact, eco-compensation mechanisms and modes are the focus of many Chinese and international scholars (Canters *et al.*, 1999; Johst *et al.*, 2002; Kleijn *et al.*, 2004; Aschwanden *et al.*, 2005; Blaine *et al.*, 2005). Zhen *et al.* (2006) discussed the eco-compensation mechanism for the natural reserves in Hainan. Liu *et al.* (2006) researched the eco-compensation mechanisms for watersheds covering Beijing, Tianjin, and North Hebei. Scherr *et al.* (2004) analyzed American eco-compensation modes. Jenkins *et al.* (2004) researched the ecological compensation modes of Mexico, Brazil, Costa Rica, and other countries. These results show that although governments are the main ecological benefit buyers, market competition mechanisms play an increasingly important role in the implementation of eco-

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logical compensation policy.

Compensation standards, which relate to compensation effects and feasibility, are foundational to ecological compensation; however, experts have different views on how to establish compensation standards. For example, Zheng and Zhang (2006) thought that ecological compensation standards should be the comprehensively account for cost estimation, ecological service value increments, willingness to pay, and ability to pay. Jin *et al.* (2005) thought compensation standards depend on lost amount (benefit), compensation deadline, moral habits, and other factors. At present, most scholars determine eco-compensation standards according to the ecosystem services value. They employed opportunity cost approaches, market price approaches, and shadow value methods to evaluate the ecosystem services value, and then use the outcomes to establish economic values (Zhang *et al.*, 2005a; Wang *et al.*, 2007). For example, Xiong and Wang (2003) took the ecological service value increment as the upper limit of compensation standards and the loss of opportunity cost of farmers as the lower limit.

Eco-compensation benefit evaluation is an important way to verify the eco-compensation effect. International scholars, using 3S technology and ecology models have quantitatively analyzed resource and environment effects and social and economic benefits of eco-compensation. For example, Herzog *et al.* (2005) and Dietschi *et al.* (2007) analyzed the influence of eco-compensation of biological diversity. Morris *et al.* (2000) and Rodrigo and Eric (2006) analyzed the influence of eco-compensation on land utilization change, and Pagiola *et al.* (2005) analyzed the influence of eco-compensation on eliminating poverty. In China, the evaluation of ecological compensation benefits are moving from qualitative to quantitative studies (Hao *et al.*, 2010).

The research objects of ecological compensation mainly include forest, mining, water, and wetlands. Among these, forest ecological compensation is the most advanced, especially in respect to laws and regulations (Wu *et al.*, 2001a). Relative to the forest eco-compensation, wetland ecological compensation research started later. Now, wetland ecological compensation research mainly includes wetland eco-compensation mechanisms (Bao *et al.*, 2007), wetland eco-compensation benefit analysis (Rubec and Hanson, 2009), and the determinant factors of wetland eco-compensation (Bendor and Brozovic, 2007).

Yellow River Delta Wetland is one of the most typical river delta wetlands in warm temperate climates, leading to a plethora of studies in the region. Because of the rise of sea levels (Xiao *et al.*, 2003), the course changes of the Yellow River (Li *et al.*, 2006), changes in Yellow River runoff and sediment discharge (Wu *et al.*, 2001b; Yuan *et al.*, 2006; Zhang *et al.*, 2010) and human activities (Cui and Liu, 2001), the wetland area, type, biotope, and other aspects are constantly changing. The use of remote sensing (RS) and geographic information system (GIS) are effective methods to study dynamic wetland changes (Ye *et al.*, 2003). There have been many evaluations of the Yellow River Delta wetland ecology, including wetland ecological value evaluation (Han and Zhang, 2009; Liu *et al.*, 2010), the evaluation of wetland ecology water requirements (Cui *et al.*, 2005; Zhang *et al.*, 2005b; Liu *et al.*, 2009), wetland ecological risk assessment (Xu *et al.*, 2001), and potential wetland development evaluation (Lu and Liu, 2010; Yang *et al.*, 2010). These studies quantitatively evaluated wetland ecological value and ecological water requirements using the methods of ecological economics, mathematics, GIS, and RS, and lay a solid foundation for the theories and methods of wetland ecological research. Studies about wetland biodiversity of the Yellow River Delta (Jia *et al.*, 2002; Xia *et al.*, 2009) and ecological niche (He *et al.*, 2008; Hu *et al.*, 2009; Li *et al.*, 2009), adequately explain the formation mechanisms of wetland biological symbiosis and ecosystem stability. The research and practice of wetland ecological restoration techniques (Fang *et al.*, 2004; Xing *et al.*, 2005; Shan, 2007; He *et al.*, 2010) promote the environmental improvement of wetlands.

However, the construction and development of the Shengli Oilfield in Yellow River Delta has polluted the wetlands, but there has been no systematic study on wetland eco-compensation of this area. This study will establish a reasonable standard for eco-compensation and provide a framework for future local policy decisions.

2 Materials and Methods

2.1 Study area

The study area is Yellow River Delta, and its scope takes Ninghai as the apex, with the southeast to the Zhimai River estuary, the northwest to the Taoer River estuary (Fig. 1). The entire fan-shaped area comprises more than

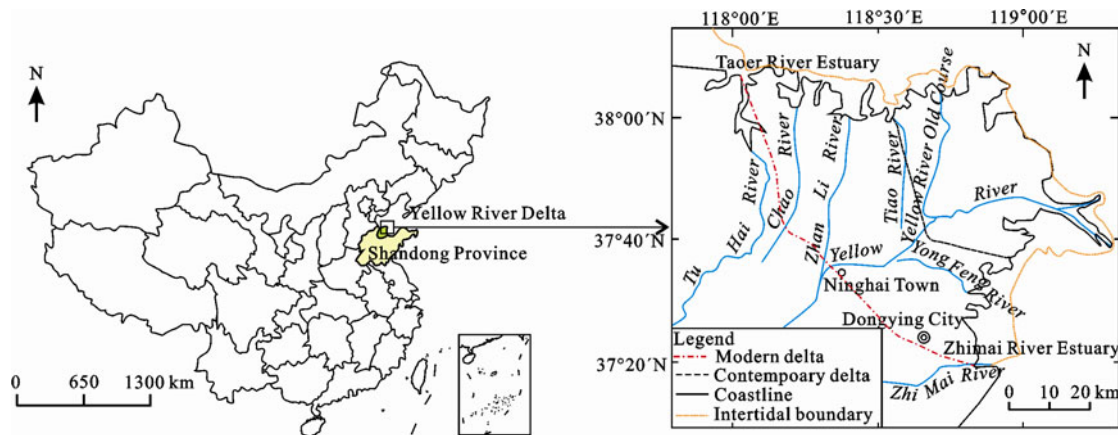


Fig. 1 Location of Yellow River Delta

5400 km². The administrative area includes Kenli County, Hekou District, Dongying District, Lijin County, and part of Guangrao, four townships of Zhanhua County and a small part of Wudi County.

The Yellow River Delta Wetland has various wetland types, abundant species varieties, and powerful ecological functions. It is an important transfer station, wintering habitat, and breeding grounds for migrating birds in Northeast Asia and the Western Pacific. In recent years, due to natural and anthropogenic factors, the wetland area extent has decreased dramatically, which has seriously deteriorated the ecosystem and caused a reduction in ecological function.

2.2 Data sources

The data of the wetland's area and type were derived from landsat 7 ETM remote sensing images and landsat 5 TM remote sensing images. The resolution is 30 m. Projector parameters and coordinate system transformation of the images were conducted using EDARS 8.5 software. A 1/100 000 topographic map of the study area was used to adjust the remote sensing images and field investigations were conducted for final verification.

Tidal flat wetlands are mainly used in the region for crude salt production and aquaculture. Due to significant fluctuations in market prices of crude salt and aquaculture, a survey was conducted at 20 aquaculture farms and 20 salt fields to obtain reliable data. The aquaculture survey included questions about culture period, annual culture area, culture type, unit price, and yield. The salt field survey included questions about the salt production period, annual salt field area, unit price, and yield. Sur-

vey results were combined with yield data from Shandong Statistical Yearbooks (Shandong Province Bureau, 2002–2009). Total area data of salt fields and aquaculture products were derived from survey and Shandong Statistical Yearbooks (Shandong Province Bureau, 2002–2009). Costs of man-made ditches were collected at first-hand from employees of Dongying City Water Department. Costs of environmental engineering were collected at first-hand from employees of Oilfield Environmental Protection Agency.

2.3 Eco-compensation calculation

Current methods of determining the eco-compensation should consider the condition of the local wetland's damage and restoration due to the construction of the Shengli Oilfield, which has significantly affected the ecology of the Yellow River Delta Wetland. The losses of market value and ecological functions value are primarily due to the area of land occupied by the Shengli Oilfield and the pollution of land in close proximity to the oilfield. This is the basis for recalculating an eco-compensation standard for Yellow River Delta.

The market value loss includes two aspects of wetland ecological damage and wetland environmental pollution, and the equation is as follows:

$$EC = EC_1 + EC_2 \quad (1)$$

where EC is the eco-compensation of wetland, EC_1 is the loss due to wetland ecological damage and EC_2 is the loss due to wetland environmental pollution.

The market value loss caused by wetland ecological damage includes direct and indirect loss. Direct loss was calculated with the method of market value which is a method to measure economic profit and loss caused by

changes in wetland area. Indirect loss was calculated with the recovery cost method. This method measures the cost of protection and restoration of the ecological system.

$$EC_1 = \sum_{i=1}^n E_i L_i + EC_r = E_1 L_1 + E_2 L_2 + E_3 L_3 + E_4 L_4 + EC_r \quad (2)$$

where $\sum E_i L_i$ is the direct loss of wetland area of type i , EC_r is the indirect loss of wetland area, $E_1 L_1$ is the loss of ditch wetland, $E_2 L_2$ is the loss of tidal flat wetland, $E_3 L_3$ is the loss of rice paddy wetland, and $E_4 L_4$ is the loss of pit pond wetland.

The market value loss is caused by oilfield environmental pollution. It is difficult to accurately measure this loss because of the restriction of data and methodology. However, these effects could be mitigated and restored through environmental engineering. Therefore, the calculation of environmental pollution loss used the method which takes the cost of environmental protection engineering as equivalent to loss caused by environment pollution, and the equation is as follows:

$$EC_2 = L_A + L_W + L_{SW} + L_N \quad (3)$$

where EC_2 is the loss from oilfield pollution; L_A is the loss from air pollution; L_W is the loss from water pollution; L_{SW} is the loss from solid waste pollution; and L_N is the loss from noise pollution. Because the service span of environmental equipment averages ten years, the annual costs of air, water, and noise pollution are calculated at 10% of the total environmental protection investment. Oil sludge, a hazardous solid waste according to the Management Regulations of Sewage Charge (State Council No. 369), has a solid waste treatment fee of 1000 yuan (RMB)/ton plus additional costs for oil silt and drilling mud disposal.

3 Results

3.1 Loss of wetland ecological damage

Because the ditch, tidal flat, rice paddy, and pit pond wetland areas decreased the most from 2001 to 2008 (Table 1), these four wetland types were selected to calculate the loss from ecological deterioration (Equation 2).

The area of ditch wetland decreased 16 919 ha from 2001 to 2008. The lost value of the ditch wetlands, half of which were natural and half of which were artificial,

was primarily based on the investment of the construction project. The average cost of ditch wetland construction is about 75 000 yuan/ha; therefore, the direct loss is 6.34×10^8 yuan ($E_1 L_1$) due to the reduction of ditch wetland.

The direct market value of tidal flat wetlands was primarily based on the output of crude salt production and aquaculture. From 2001 to 2008, the average annual area of salt pan was 4930 ha, the average annual yield of salt pan was 1.25×10^6 t, the total annual sales value was 3.2×10^8 yuan, and the annual output was 63 900 yuan/ha. Due to the wide variety of product types, fluctuating production, and market prices, it was difficult to determine the unit price of aquaculture. The average unit price of aquaculture products of tidal wetlands from 2001 to 2008 was 15 yuan/kg. The average aquaculture area of tidal wetland was 60 090 ha/yr, the average yield was 162 737 t/yr (Table 2), and the average value was 2.44×10^9 yuan/yr.

Table 1 Wetland area sizes of Yellow River Delta in 2001 and 2008

Wetland type		Area (ha)		Difference
		2001	2008	
Natural	River	15912	15901	-11
	Tidal flat	106579	90880	-15699
	Reed	34483	41590	7107
	Woodland shrub	9952	9082	-870
Artificial	Reservoir	22326	22527	201
	Pit pond	24105	21826	-2279
	Ditch	52069	35150	-16919
	Rice paddy	20998	17284	-3714
Total		286424	254240	-32184

Table 2 Aquaculture production of tidal flat wetlands in Yellow River Delta from 2001 to 2008

Year	Total area (ha)	Aquaculture area (ha)	Yield (t)
2001	106579	51059	11244
2002	100287	53259	128406
2003	93552	55525	139368
2004	92593	58636	159475
2005	90581	61003	191058
2006	92448	63473	212836
2007	91776	66083	222198
2008	90880	71685	237312
Mean	94837	60090	162737

The gross output value of tidal flat wetlands (2.76×10^9 yuan) was composed of the output value of salt pans and aquaculture. The average area of tidal wetland was 94 837 ha/yr; and the output per unit area of tidal flat wetland was 29 000 yuan/yr, which was divided between the two industries. The decrease in area of tidal flat wetland was 15 699 ha and the lost market value was 4.6×10^8 yuan.

The average price of rice in China from 2001 to 2008 was 2.12 yuan/kg. The average yield of rice was 5976 kg/ha. The value of rice from 2001 to 2008 in the study area was 12 826 yuan/ha and the area decrease in rice paddy wetlands was 3714 ha, causing a direct economic loss of rice paddy wetland of 4.67×10^7 yuan.

The decreased area of pit pond wetlands was 2279 ha from 2001 to 2008. Pit pond wetlands are mainly used for fresh water aquaculture, and the price of freshwater aquaculture products was lower than that of marine aquaculture products. Annual output value per unit area

of pit pond wetland was about 45 000 yuan/ha, therefore, the lost economic value of pit pond wetland was 1.03×10^8 yuan.

EC_r as the indirect economic loss of wetlands is determined by multiplying total compensation costs of the Shengli Oilfield (Table 3) as well as the proportion of oilfield area on wetlands (Table 4).

The total of direct ecological lost value of wetlands was 1.24×10^9 yuan, and the total indirect economic loss of wetlands during the study period was 7.67×10^7 yuan, resulting in a total ecological economic loss of 1.3167×10^9 yuan.

3.2 Loss of wetland environmental pollution

Environmental pollution in this study included air, water, noise, and solid waste. Their losses were measured by calculating the cost of environmental engineering (Table 5 and Table 6).

Total economic loss caused by oilfields was $3.64 \times$

Table 3 Tax payments of Shengli Oilfield from 2001 to 2008 ($\times 10^6$ yuan)

Tax type	2001	2002	2003	2004	2005	2006	2007	2008	Total
Soil and water conservation compensation	0.79	0.97	1.21	1.47	0.60	0.97	1.11	1.17	8.29
Pollution incidents compensation	48.3	55.3	61.2	65.4	75.4	80.4	85.8	86.1	557.9
Young crop compensation	200.3	210.4	221.6	230.3	267.1	272.0	277.3	277.9	1956.8
Land acquisition costs	138.1	153.3	168.8	190.0	206.4	223.3	240.6	241.1	1561.4
Total	387.5	419.9	452.8	487.1	549.4	576.6	604.8	606.3	4084.3

Table 4 Wetland ratio in Shengli oil field area (ha)

Year	2001	2002	2003	2004	2005	2006	2007	2008
Total oilfield area	174	264	88	270	308	303	331	334
Wetland area occupied by oilfield (%)	2.88	6.29	1.94	5.40	4.94	5.26	5.58	6.34
Total proportion (%)	1.66	2.38	2.20	2.00	1.60	1.74	1.69	1.90

Table 5 Environmental protection investment of Shengli Oilfield in Yellow River Delta from 2001 to 2008 ($\times 10^6$ yuan)

Environmental protection investment	2001	2002	2003	2004	2005	2006	2007	2008
Waste water treatment	222.6	88.9	114.0	176.0	380.8	306.8	188.5	211.1
Waste gas treatment	7.37	6.65	39.16	68.02	28.97	176.59	406.34	104.73
Solid waste treatment	1.99	2.00	8.17	2.74	1.81	42.41	5.00	9.16
Noise control	0.21	1.70	1.62	1.05	1.72	2.86	4.08	1.89

Table 6 Economic loss from oilfields pollution from 2001 to 2008 ($\times 10^6$ yuan)

Year	2001	2002	2003	2004	2005	2006	2007	2008
L_W	22.26	8.89	11.40	17.60	38.08	20.68	18.85	21.11
L_A	0.74	0.67	3.92	6.80	2.90	17.66	40.63	10.47
L_{SW}	170.0	159.9	166.4	245.9	258.0	249.2	253.2	214.7
L_N	0.02	0.17	0.16	0.11	0.17	0.29	0.41	0.19
EC_2	193	170	182	270	299	288	313	246

Notes: L_A is the loss from air pollution, L_W is the loss from water pollution, L_{SW} is the loss from solid waste pollution, L_N is the loss from noise pollution, and EC_2 is the loss from oilfield pollution.

10^6 yuan. When this is added to the total ecological economic loss, the total loss of market value is 1.3531×10^9 yuan.

3.3 Compensation standard

Allocation data for compensation of rice paddy, tidal flat, ditch, and pit pond wetlands were calculated according

to the market value loss and the percentage of reduced wetland area (Table 7). The annual compensation standard was 4381 yuan/ha.

The allocation of compensation fund for each wetland type according to the loss of ecosystem services value and the percentage of decreased wetland area was calculated at 6599 yuan/ha (Han and Zhang, 2009) (Table 8).

Table 7 Allocation of ecological compensation fund for Yellow River Delta wetlands based on market value

Wetland type	Area decrease (ha)	Percent reduction (%)	Fund allocation ($\times 10^6$ yuan)	Annual compensation fund ($\times 10^6$ yuan)
Rice paddy	3714	9.6	130.2	16.3
Tidal flat	15699	40.7	550.2	68.8
Ditch	16919	43.8	592.9	74.1
Pit pond	2279	5.9	79.8	9.9
Total	38611	100.0	1353.1	169.1

Table 8 Allocation of ecological compensation for Yellow River Delta wetlands based on ecosystem service value

Wetland type	Annual area (ha)		Difference (ha)	Reduction (%)	Fund allocation ($\times 10^6$ yuan)	Annual compensation ($\times 10^6$ yuan)
	2001	2008				
River	15912	15901	11	0.03	1	0.2
Tidal flat	106579	90880	15699	39.8	829	103.6
Woodland shrub	9952	9082	870	2.2	46	5.8
Pit pond	24105	21826	2279	5.8	120	15.1
Ditch	52069	35150	16919	42.8	893	111.6
Rice paddy	20998	17284	3714	9.4	196	24.5
Total	286424	254240	39492	100.0	2085	260.6

Source: Han and Zhang, 2009

4 Conclusions

In this paper, the market valuation method, the method of environmental protection investment, and the method of ecological valuation were all used to calculate eco-compensation. This enriches and improves the quantification method of wetland eco-compensation and provides an important reference for future eco-compensation studies.

(1) The eco-compensation of wetlands includes the loss due to ecological destruction and environmental pollution. From 2001 to 2008, the direct market value losses of ecological destruction and environmental pollution are 1.3167×10^9 yuan and 3.64×10^6 yuan, respectively, and the total lost value is 1.3531×10^9 yuan. The lost ecosystem services value is 2.09×10^9 yuan and the lost value of ecosystem services is far greater than the lost market value.

(2) The ecological compensation standards are formulated based on the loss of the ecosystem services value and market value. Market value compensation standard is 4381 yuan/ha. Ecosystem services value compensation standard is 6599 yuan/ha. The compensation standard of ecosystem services is far greater than the standard of market value. It is evident that the wetland ecological functions are crucial.

(3) The main causes of Yellow River Delta wetland damage are due to the area occupied by the Shengli Oil-field and pollution of land in close proximity to the oil-field. This research provides a quantitative standard for the implementation of ecological compensation.

References

- Allen A O, Feddema J J, 1996. Wetland loss and substitution by the section 404 permit program in southern California, USA. *Environmental Management*, 20(2): 263–274.

- Aschwanden J, Birrer S, Jenni L, 2005. Are ecological compensation areas attractive hunting sites for common kestrels (*Falco tinnunculus*) and long-eared owls (*Asio otus*)? *Journal of Ornithology*, 146(3): 279–286. doi: 10.1007/s10336-005-0090-9
- Bao Daming, Xie Qi, Wen Yali, 2007. Consideration on the establishment of the compensation institution on wetland ecological benefit in China. *Wetland Science*, 5(2): 128–132. (in Chinese)
- Bendor T, Brozovic N, 2007. Determinants of spatial and temporal patterns in compensatory wetland mitigation. *Environmental Management*, 40(3): 349–364. doi: 10.1007/s00267-006-0310-y
- Blaine T W, Lichtkoppler F R, Jones K R et al., 2005. An assessment of household willingness to pay for curbside recycling: A comparison of payment card and referendum approaches. *Journal of Environmental Management*, 76(1): 15–22. doi: 10.1016/j.jenvman.2005.01.004
- Canter K J, Udo de Haes H A, Cuperus R et al., 1999. Guidelines for ecological compensation associated with highways. *Biological Conservation*, 90(1): 41–51. doi: 10.1016/S0006-3207(99)00007-5
- Couperus R, Caters K J, Piepersb A A G, 1996. Ecological compensation of the impacts of a road. Preliminary method of A50 road link. *Ecological Engineering*, 7(4): 327–349. doi: 10.1016/S0925-8574(96)00024-9
- Cui Baoshan, Liu Xingtu, 2001. Ecological character changes and sustainability management of wetlands in the Yellow River Delta. *Scientia Geographica Sinica*, 21(3): 251–255. (in Chinese)
- Cui Baoshan, Li Yinghua, Yang Zhifeng, 2005. Management-oriented ecological water requirement for wetlands in the Yellow River Delta. *Acta Ecologica Sinica*, 25(3): 606–614. (in Chinese)
- Dietschi S, Holderegger R, Sckmidt S G et al., 2007. Agri-environment incentive payments and plant species richness under different management intensities in mountain meadows of Switzerland. *Acta Oecologica*, 31(2): 216–222. doi: 10.1016/j.actao.2006.10.006
- Fang Yong, Mu Zongzhao, Meng Zhenhong et al., 2004. Ecosystem conservation of wetland of the Yellow River Delta and recovery technique research. *Research of Soil and Water Conservation*, 11(2): 183–185. (in Chinese)
- Han Mei, Zhang Xiaohui, 2009. The value estimates of the dominant ecosystem services in Yellow River Delta wetland. *China Population Resources and Environment*, 19(6): 37–43. (in Chinese)
- Hao Chunxu, Yang Lifei, Wen Yali, 2010. The research of chinese wetland eco-compensation model based on the typical cases. *Issues of Forestry Economics*, 20(3): 189–198. (in Chinese)
- He Qiang, Cui Baoshan, Zhao Xinsheng et al., 2008. Niches of plant species in wetlands of the Yellow River Delta under gradients of water table depth and soil salinity. *Chinese Journal of Applied Ecology*, 19(5): 969–975. (in Chinese)
- He Zhijuan, Huang Jinhui, Pan Yimin et al., 2010. The ecosystem characteristics and downstream ecological restoration practice in Yellow River. *Environment and Sustainable Development*, 35(4): 9–13. (in Chinese)
- Herzog F, Dreier S, Hofer G et al., 2005. Effect of ecological compensation on floristic and breeding bird diversity in Swiss agricultural landscapes. *Agriculture, Ecosystems and Environment*, 108(3): 189–204. doi: 10.1016/j.agee.2005.02.003
- Hu Qiaomu, Yang Shuqian, Li Wei et al., 2009. Niches of wetland plant species in the Yellow River Delta under soil nutrient gradients. *Journal of Beijing Normal University (Natural Science)*, 45(1): 75–79. (in Chinese)
- Jenkins M, Scherr S, Inbar M, 2004. Markets for biodiversity services: potential roles and challenges. *Environment*, 46(6): 32–42.
- Jia Wenze, Tian Jiayi, Pang Huaijian, 2002. Protection and sustainable utilization analysis of biology diversity in the Yellow River Delta. *Research of Environmental Sciences*, 15(4): 35–39. (in Chinese)
- Jin Rong, Shi Peiji, Wang Xueping, 2005. Ecological compensation mechanism and its benefit assessment in Heihe River Basin. *Yellow River*, 27(7): 4–7. (in Chinese)
- Johnst K, Drechsler M, Watzold F, 2002. An ecological economic modeling procedure to design compensation payments for the efficient spatiotemporal allocation of species protection measures. *Ecological Economics*, 41(2002): 37–49.
- Kleijn D, Berendse F, Smit R et al., 2004. Ecological effectiveness of agri-environment schemes in different agricultural landscapes in the Netherlands. *Biological Conservation*, 18(3): 775–786. doi: 10.1111/j.1523-1739.2004.00550.x
- Lai Li, Huang Xianjin, Liu Weiliang, 2008. Advances in theory and methodology of ecological compensation. *Acta Ecologica Sinica*, 28(6): 2870–2876. (in Chinese)
- Li Xiujian, Zhao Gengxing, Liu Hong et al., 2006. Dynamic monitoring of newborn estuary wetland since channel diversion of the Yellow River to Qingshuigou. *Journal of Natural Resources*, 21(2): 328–332. (in Chinese)
- Li Feng, Xie Yonghong, Chen Xinsheng et al., 2009. Composition of aquatic plants and their niche characteristics in wetlands of the Yellow River Delta. *Acta Ecologica Sinica*, 29(11): 6257–6265. (in Chinese)
- Liu Guihuan, Zhang Huiyuan, Wan Jun et al., 2006. Drainage area's ecological compensation mechanism discussion on in the north of Beijing-Tianjin-Hebei province. *China Population, Resources and Environment*, 16(4): 120–124. (in Chinese)
- Liu Xiaoyan, Lian Yi, Ke Sojuan, 2009. Analysis on water demand for ecosystem protection in Yellow River Delta. *Journal of Hydraulic Engineering*, 40(8): 956–968. (in Chinese)
- Liu Qing, Li Wei, Lu Zhaohua, 2010. Ecosystem services value assessment of green space in the Yellow River Delta based on RS and GIS. *Ecology and Environmental Sciences*, 19(8): 1838–1843. (in Chinese)
- Lu Jianshu, Liu Yang, 2010. Evaluation on exploitation potential of ecotourism resources of wetlands in Yellow River Delta.

- Wetland Science*, 8(4): 339–346. (in Chinese)
- Morris J, Cowing D J G, Mills J *et al.*, 2000. Reconciling agricultural economic and environmental objectives: the case of recreating wetlands in the Fenland area of eastern England. *Agriculture, Ecosystems and Environment*, 79(2–3): 245–257. doi: 10.1016/S0167-8809(00)00128-6
- Pagiola S, Arcenas A, Platais G, 2005. Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America. *World Development*, 33(2): 237–253. doi: 10.1016/j.worlddev.2004.07.011
- Rodrigo S, Eric R, 2006. On the efficiency of environmental service payments: A forest conservation assessment in the Osa Peninsula, Costa Rica. *Ecological Economics*, 59(1): 131–141. doi: 10.1016/j.ecolecon.2005.10.010
- Rubec C, Hanson A, 2009. Wetland mitigation and compensation: Canadian experience. *Wetlands Ecology & Management*, 17(1): 3–14. doi: 10.1007/s11273-008-9078-6
- Scherr S J, White A, Kaimowitz D, 2004. A new agenda for forest conservation and poverty reduction: Making markets work for low income producers [EB/OL]. Available at: <http://www.forest.trends.org>, Washington, D.C.
- Shandong Province Bureau, 2002–2009. *Shandong Statistical Yearbook*. Beijing: China Statistics Press. (in Chinese)
- Shan Kai, 2007. Theory, Methodology and practices of wetland ecological restoration in Yellow River Delta Nature Reserve. *Wetland Science and Management*, 3(4): 16–20. (in Chinese)
- Wang X H, Bennett J, Xie C *et al.*, 2007. Estimating non-market environmental benefits of the conversion of cropland to forest and grassland program: A choice modeling approach. *Ecological Economics*, 63(1): 114–125. doi: 10.1016/j.ecolecon.2006.10.001
- Wu Shuirong, Ma Tianle, Zhao Wei, 2001a. The development of forest eco-benefit compensation policy and economic analysis. *Forest Economics*, (4): 20–23. (in Chinese)
- Wu Hongtao, Zhang Zhenyu, Chang Zongguang, 2001b. The prediction of Xiaolangdi projects effecting on the wetlands in the lower reaches of Yellow River. *Territory & Natural Resources Study*, (3): 53–55. (in Chinese)
- Xia Jiangbao, Li Chuanrong, Xu Jingwei *et al.*, 2009. Biodiversity of macrobenthos of estuary beach wetland in Yellow River Delta in summer. *Wetland Science*, 7(4): 299–305. (in Chinese)
- Xiao Duning, Han Mukang, Li Xiaowen *et al.*, 2003. Sea level rising around Bohai Sea and deltaic wetlands protection. *Quaternary Sciences*, 23(3): 237–246. (in Chinese)
- Xiong Ying, Wang Kelin, 2003. Study on eco-compensation of returning land to lake: A case of Dongting Lake areas. *Wetland Science*, 1(2): 86–91. (in Chinese)
- Xiong Y, Wang K L, 2010. Eco-compensation effects of the wetland recovery in Dongting Lake area. *Journal of Geography Science*, 20(3): 389–405. doi: 10.1007/s11442-010-0389-1
- Xing Shangjun, Zhang Jianfeng, Song Yumin *et al.*, 2005. The ecological function and ecological rehabilitation of wetland in the Yellow River Delta. *Journal of Shandong Forestry Science and Technology*, (2): 69–71. (in Chinese)
- Xu Xuegong, Lin Huiping, Fu Zaiyi, 2001. Regional ecological risk assessment of wetland in the Yellow River Delta. *Universitatis Pekinensis (Acta Scientiarum Naturalium)*, 37(1): 111–120. (in Chinese)
- Yang Haibo, He Tian, Li Jianfeng, 2010. Analysis based on fuzzy set for landscape evaluation of the Yellow River Delta. *Yellow River*, 32(5): 1–7. (in Chinese)
- Ye Wenhua, Wei Bin, Tong Chuan, 1998. Measurement and application of urban ecological compensation. *China Environmental Science*, 18(4): 298–301. (in Chinese)
- Ye Qinghua, Liu Gaohuan, Yao Yiming *et al.*, 2003. Tupu analysis of land use changes in the new born wetland of the Yellow River Delta. *Progress in Geography*, 22(2): 142–147. (in Chinese)
- Yuan Zugui, Chu Zehan, Yang Yuzhen, 2006. Estuary runoff and amount of transported sediments of Yellow River and ecological environments of Yellow River Delta. *Journal of Palaeogeography*, 8(1): 126–130. (in Chinese)
- Zhang Jinhe, Zhang Jie, Liang Yuelin *et al.*, 2005a. An analysis of touristic ecological footprint and eco-compensation of Jiuzhaigou in 2002. *Journal of Natural Resources*, 20(5): 735–744. (in Chinese)
- Zhang Changchun, Wang Guangqian, Wei Jiahua, 2005b. Study on water requirements in Yellow River Delta based on remote sensing. *Bulletin of Soil and Water Conservation*, 19(1): 150–152. (in Chinese)
- Zhang Changying, Zhang Zhihao, Liu Baoyu *et al.*, 2010. The impact analysis of variation of water and sediment to the Yellow River wetland environment. *Water Conservancy Science and Technology and Economy*, 16(1): 58–59. (in Chinese)
- Zhen Lin, Min Qingwen, Li Wenhua *et al.*, 2006. Socio-economic impact and eco-compensation mechanism in natural reserves of Hainan Province. *Resources Science*, 28(6): 10–19. (in Chinese)
- Zheng Haixia, Zhang Lubiao, 2006. Research on the standardization of compensation for the service of ecosystem in river valley. *Environmental Protection*, (1): 42–46. (in Chinese)