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Impacts of economic development on ecosystem risk in the Yellow River Delta

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Abstract

With the economic development and population growth, humans have changed ecosystems more rapidly and extensively to meet the rapidly growing demand for food, fresh water, timber, fiber and fuel. This has led to a substantial and largely irreversible loss of the biodiversity on earth. The ecosystem risk is created as a new concept to understand the environmental problems. Therefore, it is important to develop quantitative methods for regional ecosystem risk analysis. Yellow River Delta is the widest, most intact and youngest delta both in China and in the world; its ecosystem environment is much more vulnerable due to its special location and industrial structure. Therefore, it is very important to manage them wisely and strategically. Therefore, Yellow River Delta is selected as the case area to reveal the impacts of economic development on ecosystem risk in this study. This study selected the ecological quality index to show the potential ecosystem risk and estimated the impacts of economic development on ecosystem risk using the panel data model on the pixel level based on the GIS, RS technique. It's found that the economic development will have impacts on the ecological environment to a certain degree, however, these impacts can exchange to a greater degree with the development. Then more funds and advanced technologies can be used to promote the intensive development of land use, which may decrease the impacts of economic development on the environment. Therefore, we need to ensure the coordinated development of the economy and ecological environment. The research results provide meaningful decision-making information for the urbanization process and environmental protection in the Yellow River Delta.

Key words: economic development; ecosystem risk; Yellow River Delta; panel data model; Monte Carlo model

1. Introduction

With the development of industry, the human activities have led to a series of ecological environmental problems such as species extinction, land degradation and global warming, which lead to the degradation of environmental

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quality, impact the quality of human life seriously and constrain the sustainable development of society and economy (Hunsaker et al., 1989; McDonald et al., 1997; Cook et al., 1999). There have been frequently ecological environmental problems which directly threat the human survival in recent years, e.g. Chernobyl accident, water pollution in Songhua River, pollution of oil exploitation in Arctic, water bloom pollution in Taihu Lake and arsenic pollution in Yangzonghai Lake in Yunnan Province, all of which raise more and more concern for how to avoid and alleviate the loss from ecological disasters (Burmaster and Anderson, 1994; Qin and Zhu, 2000; IAEA, 2006; World Wildlife Fund, 2007). There have been a lot of researches on the ecological environment in many countries all over the world in order to control the regional ecological environmental degradation and improve the living environment of human beings; researches on environmental assessment have also continually deepened (Gaudet, 1994; McDonald et al., 1997; Wallack and Hope, 2002; Moraes and Molander, 2004; Wang and Zhang, 2007).

China is at the economic transition stage, the economic growth mode has transited very slowly, the resource is excessively consumed and the economic growth is at the heavy price of resource and environment. It is the objective requirement of sustainable development of national economy to emphasize both the environmental protection and economic growth and promote the environmental protection and economic development synchronously (Michael et al., 1998). On one hand, the economic development influences the ecological environment; the environmental Kuznets Curve indicates that the relationship between economic growth and ecological environmental quality shows as the "U" curve, i.e. the ecological environment will degrade with the economic growth at the initial stage of economic development, while the economic development reaches a certain stage, the degradation of ecological environment will be constrained and the ecological environment will be even improved (Grossman and Krueger, 1992; Shafik and Bandyopadhyay, 1992). On the other hand, the quality of ecological environment also impacts the economic development. The most important value of the ecological environment lies in its heath, safety and integrity. When the ecological environment becomes abnormal, the regional economic can't develop sustainably. When the heath and safety of the ecological environment are shocked by the ecological risk, the healthy development of economy will surely be influenced, consequently it is difficult to realize the synchronous development of social benefit, economic benefit and environmental benefit, the sustainable development will be influenced at last (Che, 2004). So the relationship between the ecological risk and regional economic development is one of the key problems which should be studied in the developing countries.

The ecological risk assessment originally developed from the safety assessment and health risk assessment, it has been wildly used in the developed countries and regions such as America and EU; it has been seen as an important basis of environmental decision-making. The ecological risk assessments at large scales were mostly based on EPA in the late 1990s (EPA, 1992; EPA, 1998). For example, ORNL commission carried out ecological risk assessment on Clinch River watershed in Tennessee, the USA, in which the influence of chemical poisonous matter on special species in the watershed was assessed. Although the comprehensive ecological risk assessment was not implemented in this research, it indicated that it is possible to carry out risk research at the watershed and large scales (Adam et al., 1997; Baron et al., 1999; Jones et al., 1999; Sample et al., 1999; Cook et al., 1999). Valiela et al. (2000) carried out risk assessment of Nitrogen in Waquoit Bay Massachusetts, which indicated that the single factor can have impacts on the whole ecosystem. All these researches suggested there are some disadvantages of the existing assessment framework, for example, it doesn't integrate the spatial structure, scale, multi-factors and multiple risk receptors effectively. In addition, there is no clear understanding of the complex system.

The environmental risk research has developed relatively late in China, which mainly concentrated on the emergency of dangerous chemicals, heavy mental pollution and refractory organic toxicants, there have been no specific frameworks on the ecological risk assessment. Therefore, the hazard analysis and comprehensive assessment in the regional ecological risk assessment are both based on the ecological fragility and ecological loss, and there have been very few researches on the ecological risk assessment in the oil exploitation regions (Hong et al., 1995; Jia et al., 1997; He et al., 2002; Peng et al., 2009). The "blowouts" and leakage in the oil exploitation process always pollute the water and soil of the regions, for these pollutants are difficult to vanish or degrade, which get into the environment in many ways and lead to the hazards for the ecosystem. Therefore, it is necessary to focus on the oil exploitation regions.

Ecological risk assessment is carried out in one of the major oil exploitation bases, Yellow River Delta in Shandong Province, which is a coastal area that has developed relatively fast in China. On the basis of ecological risk assessment, the influence of ecological risk on the economic development was analyzed with panel data model. The results of this research can provide some scientific reference for formulating ecological protection measures and promoting the sustainable economic development.

2. Study area

Yellow River Delta is located between 36°55′N -38°10′N, 118°07′E -119°10′E, lying in the northern part of Shandong Province, and it is confronted with Bohai Sea in the east and north and adjoins Zibo and Weifang in the south and Bingzhou in the west. It has a maximum distance of 74 km from east to west and 123 km from north to south, covering a total area of 7923 km^2 (CIWRHR, 1997). In this research Yellow River Delta is defined as including Dongying District, Hekou District, Lijin County, Kenli County and Guangrao County (Fig 1).

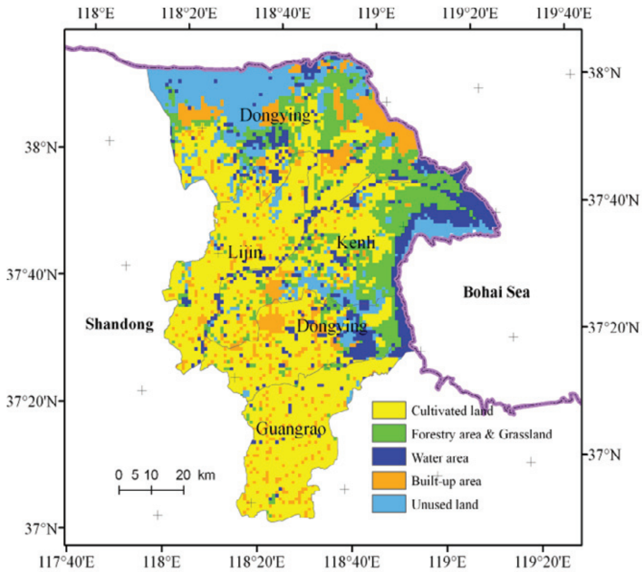


Fig.1. The location of Yellow River Delta

The climate of Yellow River Delta is the sub-humid continental monsoon climate in the warm temperate zone. There are rich natural resources such as oil, natural gas, geothermal resource, mine and salt mine, and it is major compound accumulation area of oil and natural gas (Xu, 1998). The biodiversity is rich in this region. There are 270 kinds of birds which including seven kinds of class I nationally protected birds and 33 kinds of class II nationally protected birds. There are more than 40 kinds of livestock and poultry and more than 600 kinds of aquatic animals; there are almost 180 kinds of woody plants (varieties included), about 120 kinds of phytoplankton and four kinds of ferns. The sea-land change in Yellow River Delta is the most active in China and Yellow River brings a lot of sediment to the estuarine and makes land continually. However, with the deterioration of draught-up of Yellow River in the drought period in recent years, the epeirogenesis rate has slowed down and the coastal erosion has been intensified. Yellow River Delta is also an important production base of oil and commodity grain in China. Shengli Oilfield in Yellow River Delta is the second largest oilfield in China, only secondary to Daqing Oilfield. The oil exploitation, petrochemical industry and other related industries play the role of pillar industries in Yellow River Delta. Therefore, there is much potential ecosystem risk in Yellow River Delta (Xu et al., 2004).

3. Methodology

3.1. Ecological risk assessment model

The ecological risk was assessed with Monte Carlo analysis method. The basic principle of this method is to assess the maximum potential loss of the ecological indicators or their integration during a certain period under premise of the given confidence level, integrate the different ecological factors and ecological risks into a simple numerical value so as to briefly and precisely obtain the threshold value of the ecosystem risk. Therefore, it is the basis of ecological assessment to recognize the ecological risk. The author first set a series of functions of typical ecological risk factors and then summarized them (Landis and Wiegers, 1997; Landis and Kelly, 2005). At last, the author assessed the maximum future loss of the given ecological indicator under the certain confidence level according to the historical data of each ecological factor.

Suppose P_{i0} is the original value of the given ecological indicator i of the studied ecosystem, R_i is the increasing rate (or changing rate) of this ecological indicator during the study period. Suppose the average and standard variance of R_i are u_i and α_i, respectively. Set P_i to be the possible value of the given ecological indicator under a certain confidence level. Then

$$Prob\ (\Delta P_i - ER_i) = 1 - \alpha \quad (1)$$

where $\Delta P_i = P_i - P_{i0}$ means the possible loss of the ecological indicator during the study period, $1 - \alpha$ is the given co nfidence level.

Generally, $E(P_i)$ is supposed to be the average of the ecological indicator during the study period, P_i^* is set to be the minimum ecological indicator value, then we get ER_i :

$$ER_i = E(P_i) - P_i^* = P_{i0}(1 + u_i) - P_{i0}(1 + R_i^*) = -P_{i0}(R_i^* - u_i) \quad (2)$$

where R_i^* is the minimum increasing rate of the ecological indicator under the given confidence level.

Then ER_i defined in equilibrium (2) is the maximum loss that the ecological indictor may suffer under the given confidence level when compared with the predicted value (average) of the ecological indicator.

The ecosystem risk can be got by the sum of each indictor's ecosystem risk as follows:

$$ER = \sum_{i=1}^{n} (\omega_i ER_i) \quad (3)$$

where ω_i is the weight of each ecological indicator, and it is got from the judgment matrix which based on the relative significance.

3.2. Panel data model

Panel data model includes two kinds of information in cross-sectional time-series data, i.e. the cross-sectional information reflected in the differences between subjects and the time-series or within-subject information reflected in the changes within subjects over time. A panel dataset should have data on n cases, over t time periods, for a total of $n \times t$ observations (Baltagi, 2005; Hausman and Jerry, 1978). It can describe not only the laws of sample data from various regions in some time, but also the changing rules with the time going. Compared to the cross sectional data model and time series model, panel data model increases the sample space, promotes the degree of freedom of sample and reduces the impacts of multi-collinearity among the explanatory variables on the estimation results (Hausman et al., 1984). Ecosystem risk involves a lot of influencing factors such as natural environmental conditions, economic development, population, transportation, these factors have the spatial and temporal variability, so they are suit to construct the panel data model to explore the impacts of various factors on the ecosystem risk.

The panel data model was used to explore the key driving factors for the ecosystem risk in Yellow River Delta. The model parameters were made linear with the logarithm transformation of the original data value of all variables, the panel data model is as follows:

$$Y_{it} = \beta_1 + \sum_{j=2}^{k} \beta_j X_{jit} + \sum_{p=1}^{s} \gamma_p Z_{pi} + \delta t + \xi_{it} \quad (4)$$

where Y is the dependent variable, X_j are observed explanatory variables and the Z_P are unobserved explanatory variables. The index i refers to the unit of observation, t refers to the time period and j and p are used to differentiate between different observed and unobserved explanatory variables. ε_{it} is a disturbance term assumed to satisfy the usual regression model conditions. A trend term t has been introduced to allow for a shift of the intercept over time. The X_j variables are usually the variables of interest, while the Z_p variables are responsible for unobserved heterogeneity and as such constitute a nuisance component of the model.

3.3. Model selection

Panel data may have the group effect, time effect or both. These effects are either fixed effect or random effect. A fixed effect model assumes differences in intercepts across groups or time periods, whereas a random effect model explores differences in error variances. The Hausman test is used to test whether a fixed or random effects model is appropriate. The Hausman test tests the null hypothesis that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator. If they are (insignificant P-value, Prob>chi2= -37724.01, much smaller than 0.05) then it is safe to use fixed effects. If you get a significant P-value, however, you should use fixed effects. Judging from the test results, this paper should choose fixed effect model to estimate the effect of factors on ecosystem risk (Table 1).

Table 1. HAUSMAN test of parametric estimation models

	(b)	(B)	(b-B)	sqrt(diag(V_b-V_B))
	Fixed effect model	Random effect model	Difference	S.E.
lnland_5	.0060824	.0077081	-.0016257	.0004458
lnpergdp	-.0009892	-.0063193	.0053301	.0001026
lngdp1_2	.0024966	-.0015851	.0040816	.0006555
lngdp2	-.0318483	-.0851904	.0533421	.0047456
lngdp2_2	.0034825	.0074808	-.0039983	.0003696
lngdp3	.0457162	.047866	-.0021498	.0009022
lngdp3_2	-.0026085	-.0044312	.0018228	.0000806
lnfmincome	-.0184493	.0189059	-.0373552	.0035769
lnconsu	.0266426	.0202886	.0063541	.0015602
lnurban	.0220977	-.014995	.0370927	.0055152
		Chi2=(b-B)'[(V_b-V_B)^(-1)](b-B)		
		Prob>chi2= -37724.01		

4. Results of ecosystem risk assessment

4.1. Indicators

The sources of regional ecological risk can be categorized into the natural source and human source in general. The natural ecological risk source generally refers to the natural disaster. The natural disaster in Yellow River Delta mainly includes the flood, drought, hail, storm, tsunamis, etc. The human ecological risk mainly refers to the human activities that harm or seriously disturb the ecosystem. The human ecological risk mainly includes the oil exploitation that generates waste gas, waste water and sludge generated, the direct discharge of domestic sewage and industrial waste water and the exploitation and construction that lead to soil erosion and salinization.

There is frequently tsunami in the northern part of Yellow River Delta, which causes serious loss. There have been more than 60 big tsunamis since 1976 according to the statistical data, which lead to shoreline erosion, threaten the exploitation and development of Shengli oilfield and cause loss of national territory. The ground water is highly mineralized and difficult to use in Yellow River Delta which heavily depends on the fresh water resource of Yellow River, the draught-up of Yellow River is surely a new risk to the industrial production and residents' daily life. The harm of draught-up of Yellow River shows as the following aspects: it leads to the shortage of fresh water resource for both human and species and constrains production of the oilfield; the crop yield will reduce for shortage of irrigation and the rice can no longer be grown; the river channel of Yellow River will shrink, lead to the big alluvial flat and cause great disaster even when there is a little water; the shoreline will change from expansion to erosion, the land area will decrease and the tsunami will influence the inner land; the wetland will degrade, the ecosystem changes, the rare species will be disturbed and forced to emigrate and even die out.

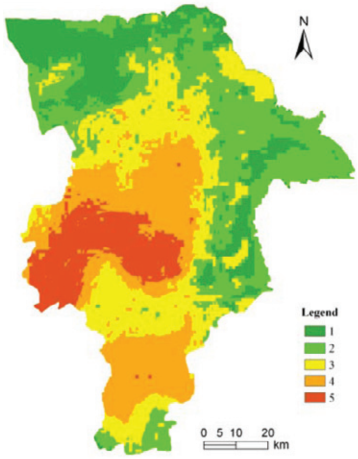
Twelve ecological indicators in the land use, supply of fresh water, wetland, oil exploitation and condition of the disaster were selected on the basis of the analysis above (Table 2). These data of ecological indicators which are from 1985 to 2005 are from the survey and statistical department.

Table 2. Indicator system of ecological risk assessment

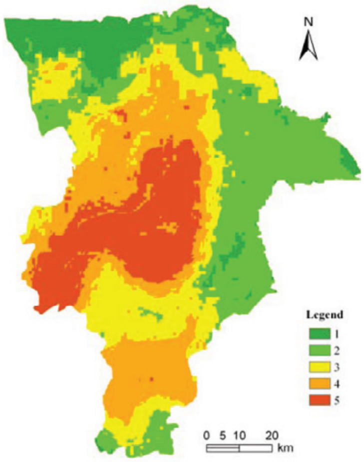
Land use	Supply of fresh water	Wetland	Oil exploitation	Condition of the disaster
Land use intensity; Soil Erosion Intensity;	Fresh water resource per capita; Irrigation rate	Landscape diversity index; Fragmentation index; Biomas	Waste water treatment rate (Oil exploitation); Density of oil well; NDVI	Percentage of disaster area; Percentage of damage area

4.2. Ecological risk assessment in Yellow River Delta

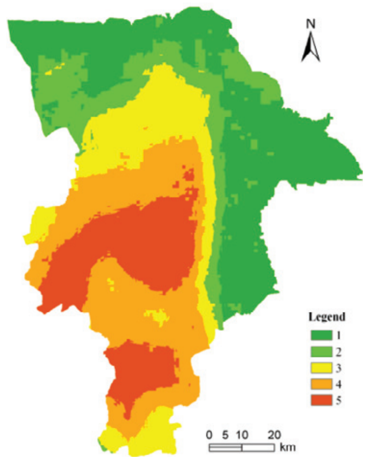
The ecological risk in Yellow River Delta in 1985, 1996 and 2005 was assessed with the Monte Carlo model and the indicator system above in this research. The assessment result indicated that the ecological risk was high in the northern and eastern parts of Yellow River Delta, the reasons for which are the increasing oil exploitation in recent years and the extreme weather events such as storm and tsunami that have continually hit China (Fig. 2). The ecological risk is relatively low in the middle and southern parts of Yellow River Delta, where it is the main agricultural zone and economic development zone of Yellow River Delta, the influence of oil exploitation and natural disaster on these regions is relatively slight. The ecological risk in Yellow River Delta continually changes with time. We can get that the region around these regions with relatively high ecological risk will evolve into regions with high ecological risk according to the distribution of ecosystem risk distribution. However, the ecological risk will decline in the middle and southern parts, in parts of which the ecological risk class changes from level two in 1985 to level three or level four in 2005.



(a) 1985



(b) 1996



(c) 2005

Fig.2. Map of ecological risk level in Yellow River Delta

5. Analysis for the relationship of ecosystem risk and economy

The panel data model was used to assess the coupling relationship between the ecological risk of Yellow River Delta and the economic development as the time goes on the basis of the results above. The research result indicated that the regional economic development and the urbanization level are the key factors influencing the ecological risk of Yellow River Delta. Especially at the initial stage of economic development, both of them have significant negative impacts on the ecological risk in this region, but there are obvious differences among the impacts of different economic factors on the ecological risk with the economic development. Among them, the expansion of urban land increases the ecological risk to a certain degree, but with more driving factors added into the function, the coefficient of urban land decreases from 0.115 to 0.006, which declines and finally tends to be stabilized (0.006) (Table 3). Therefore, the impacts of other factors on the ecological risk was attributed to urban land; with more driving factors added, the impact of urban land was gradually recognized and estimated properly at last.

The per capita GDP and GDP of the first, second and third industry were used to describe the regional economy and the influence of different economic structure on the ecological risk was analyzed from the perspective of the region and industrial structure. The influence of per capita GDP on the ecological risk is not negligible. Without the consumption quantity and urbanization level added, per capita GDP has a negative impact on the ecological risk, however, with the consumption quantity and urbanization level added, per capita GDP restrains the ecological risk to some degree. On one hand, this is because the increase of per capita GDP can make the local government invest more money to protect the environment, control environmental pollution and promote the economic development mode friend to the environment so as to reduce the ecological risk; on the other hand, it indicates that it is necessary to promote the economic development and environmental protection simultaneously. The first industry mainly makes use of the nature, which can be put into use without deep processing. Therefore, its influence on the ecological risk is not significant, and it can be neglected when all of the variables are added in the function. The secondary industry is the main cause of ecological degradation and the key factor of ecological risk, the coefficient of which is 0.032 (significant at 5% level). However, it will restrain the ecological risk when it develops to a certain level. The tertiary industry constrains the ecological risk to a certain degree, its linear coefficient to the ecological risk is -0.046, its nonlinear coefficient to the ecological risk is -0.003 (Table 3).

There is important influence of income of agricultural people on the ecological risk. The probability of ecological risk decrease when income of agricultural people increases. This is because the income of agricultural people influences the transfer of agricultural people to the cities and restrains the urbanization and consequently reduces the probability of ecological risk. The influence of per capita consumption and urbanization level is not negligible. When all the variables are added, the coefficient of per capita consumption is 0.027. The coefficient of urbanization level is 0.022, indicating that the ecological risk will increase with the urbanization level increasing (Table 3). In summary, both per capita consumption and urbanization level promote the ecological risk to a certain degree.

Table 3. Regression results of fixed effects model based on panel data

	Dependent variable: ecosystem risk						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Lnland_5	0.115	0.016	0.015	0.010	0.008	0.006	0.006
	(33.80)**	(22.12)**	(21.81)**	(15.44)**	(13.90)**	(10.43)**	(10.43)**

lnpergdp		0.004	0.003	0.002	0.000	-0.001	-0.001
		(13.89)**	(13.01)**	(6.75)**	(2.11)*	(4.34)**	(4.34)**
Lngdp1		0.029	0.009	0.204	0.080	0.002	0.000
		(47.62)**	(6.06)**	(25.76)**	(8.58)**	(5.24)**	(.)
Lngdp1_2			0.002	0.012	0.003	0.002	0.000
			(13.63)**	(18.98)**	(3.61)**	(3.43)**	(.)
Lngdp2				0.108	0.050	0.469	0.032
				(30.17)**	(9.44)**	(34.24)**	(5.61)**
Lngdp2_2				-0.005	-0.004	-0.003	-0.003
				(17.48)**	(7.13)**	(6.74)**	(6.74)**
Lngdp3					0.003	-0.258	-0.046
					(1.48)	(31.44)**	(18.50)**
Lngdp3_2					0.003	-0.003	-0.003
					(8.84)**	(7.24)**	(7.24)**
Lnfmincome						1.058	-0.018
						(32.65)**	(4.66)**
lnconsu							0.027
							(15.98)**
lnurban							0.022
							(3.96)**
Constant	7.154	7.234	7.267	7.681	7.485	16.693	7.038
	(7.35)**	(22.98)**	(17.87)**	(6.37)**	(4.50)**	(5.00)**	(1.61)**
Observations	27845	27845	27845	27845	27845	27845	27845
R-squared	0.03	0.33	0.34	0.51	0.54	0.58	0.58

6. Conclusion

It is of great practical significance to the protection of wetland to carry out ecological risk assessment of Yellow River Delta and analyze the coupling relationship between ecological risk and economic development. Based on the regional ecological environmental characteristics of Yellow River Delta, the author selected the assessment indicators in 1985, 1996 and 2005 and assessed the ecological risk of Yellow River Delta with the panel data model. Taking the ecological risk as the dependent variable and driving factors as the explanatory variables, the author quantitatively analyzed the influence of socioeconomic driving factors on the regional ecological risk with the panel data model. The influencing mechanism of economic development on regional ecological risk during 1985-2005 was analyzed; the extent and direction of influence of driving factors on the regional risk were explored by introducing controlling variables step by step; the approaches and methods to coordinate the economic development and ecological environmental protection were explored, which can serve sustainable development of the ecosystem.

The results of ecological risk assessment of Yellow River Delta indicated that the ecological risk of Yellow River Delta showed an increasing trend on the whole as the time goes, but the regional discrepancy was very significant. The ecological risk was high in the northern oil exploitation regions and eastern coastal regions and low in the middle and southern parts. The changing trends of ecological risk are different among different regions of Yellow River Delta as time goes. The middle part with high ecological risk will gradually change into the region with low ecological risk, while ecological risk will intensify further in the northern and eastern regions with high ecological risk.

The author selected the ecological quality index to show the potential ecosystem risk and estimated the impacts of economic development on ecosystem risk using the panel data model on the pixel level based on the GIS, RS technique. The research on the coupling relationship between the ecological risk and economic development of Yellow River Delta indicated that the economic development will have impacts on the ecological environment to a certain degree. However, these impacts can change to a greater degree in different industries. Then more funds and advanced technologies can be used to promote the intensive development of land use, which may decrease the impacts of economic development on the environment. Therefore, it is necessary to ensure the coordinated development of the economy and ecological environment. The research results provide meaningful decision-making information for the urbanization process and environmental protection in the Yellow River Delta.

The ecological risk is still severe in Yellow River Delta, where the ecological risk management should pay attention to the following aspects.

1) Coordination of "drawing, transferring, storing, draining, irrigation and prevention" projects in the water conservancy project.

2) Ecological engineering construction

3) Pollution control of oilfield and other industries, promote the cleaner production

4) Construction and management of estuarine and coastal wetland nature reserves.

5) Construction of ecological risk monitoring and management system. Different risk management measures should be taken in regions with different ecological risk so as to coordinate the regional ecological environment; the biodiversity and stabilization of the ecosystem structure and functions should be effectively protected.

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