Survey and Assessment of Land Ecological Quality in Cixi City

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Abstract Soil, atmosphere, water and quality of agricultural product constitute the content of land ecological quality. Cixi City, through survey pilot project of basic farmland quality, carried out high precision soil geochemical survey and survey of agricultural products, irrigation water and air quality, and established ecological quality evaluation model of land. Based on the evaluation of soil geochemical quality, we conducted comprehensive quality assessment of atmosphere, water, agricultural products, and assessed the ecological quality of agricultural land in Cixi City. The evaluation results show that the ecological quality of most agricultural land in Cixi City is excellent, and there is ecological risk only in some local areas such as urban periphery. The experimental results provide demonstration and basis for the fine management of basic farmland and ecological protection.
Key words Land ecological quality, Geochemical assessment, Atmosphere, Irrigation water, Agricultural product quality

1 Introduction

Land ecological quality refers to the ability to maintain the biological productivity, protect the quality of the environment, improve animal and human health, and address the environmental problems of atmosphere and water, within the range of ecosystem; it is an important component of land quality connotation. Land ecological quality, land natural quality and socio-economic attributes, together constitute the land value and quality. With the development of economy and civilization, there is growing emphasis on food safety and land ecological quality. At present, the Ministry of Land Resources has basically completed agricultural land grading nationwide; on the basis of land natural quality, it takes into account the conditions of production, land use and economic level for land quality classification and grading (Wu Kening, 2010), and makes an important step toward the management of land quality and quantity. In accordance with the requirements of "laying equal stress on the management of quantity and quality" proposed by the State Council and Premier Wen Jiabao on the future land resource management, the survey of land ecological quality has been elevated to the national level and height. Zhejiang Provincial Department of Land Resources carried out the survey of land ecological quality, and selected Cixi City one of the experimental areas to explore the fine management methods and techniques for the land quantity and quality, to provide technical support for the land quality survey and management in the new century.

2 Methods and materials

In Cixi City, the survey object of land ecological quality is soil, irrigation water, atmospheric fallout, and agricultural products. The survey was carried out during the period 2007 – 2009, and the content was mainly based on soil geochemical survey, supplemented by irrigation water, atmosphere, agricultural product quality, natural features of the land, and the production environment survey. The soil geochemical survey precision is 1∶50000, with sample of 4/km^2, 27 items of analytical testing amount, 15 effective states and 2 items of organic pollutants (Liu Junbao *et al*, 2010). We assess the soil nutrient, environmental quality, soil contamination, irrigation water quality, safety of agricultural products and selenium-rich land resources. According to the *Geochemical Assessment Technical Requirements of Land Quality* (DD2008 – 06) released by China Geological Survey Bureau, we carry out the geochemical assessment of land quality, combined with the survey of atmosphere, water and agricultural product quality, to complete the assessment of land ecological quality in Cixi City.

3 Geochemical assessment of land quality

The geochemical assessment of land quality is the land quality grading, based on land beneficial elements, toxic elements, content of organic pollutants, and the impact on the basic functions of land. Its content includes basic fertility of the land, environment and soil health quality assessment. The construction links of assessment model include indicator screening, weight assignment, establishment of membership function model, index calculation and so on.

3.1 Indicator screening Fertility factors: N, P, K, and organic matter are the dominant factors for soil fertility. They should be selected based on the principle of dominance.

However, N is well correlated with organic carbon, with correlation coefficient of 0. 92, having a good linear relation (Fig. 1). Based on the principles of independence and spatial variation, the two choose OrgC. P, K have a real impact on the effective state of land quality, and according to the evaluation of effective state of soil in Cixi City, available K and available P are both short, so we choose available K and available P as the indicators for evaluation.

The beneficial soil trace elements Fe, Mn, Cu, Zn, Mo, B are in abundant and relatively rich state, in the local classification

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evaluation of effective state, and available Mo is relatively short. According to the limiting law of soil nutrient, we select Mo as the indicator for evaluation.

Environmental factors: Soil environmental quality evaluation shows that the toxic heavy metals Cd, Hg are prominent, and DDT residues has exceeded the standard in the some places, so according to the principle of the dominance, we select Cd, Hg, DDT as the harmful element indicators for the evaluation.

In addition, Cixi City is coastal plain area, pH and salinity are important physical and chemical indicators for environmental quality, so according to the principle of systematicity, we select pH and salinity as the indicators for evaluation.

Health factors: In the environmental health indicators (I, F, Se), I and F are high, but we do not find threat to the local ecology. Se is regarded as an important indicator for soil health, and the survey shows that Cixi City abounds in selenium-rich soil and many selenium-rich agricultural products, such as bayberry and rice, so Se is selected as the evaluation indicator.

In summary, we establish the indicator system for geochemical assessment of land quality in Cixi City (Table 1).

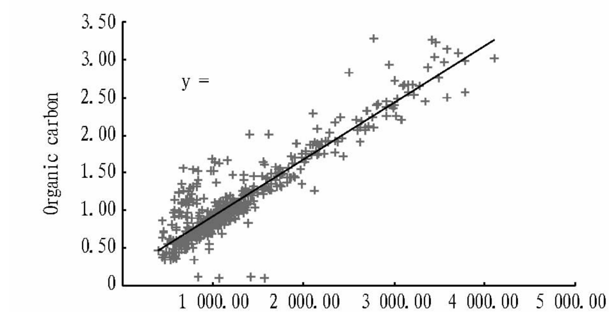

Fig. 1 Soil N and OrgC scatter plot in Cixi City

Table 1 The evaluation indicator system for geochemical assessment of land quality in Cixi City

Target layer	Geochemical assessment of land quality		
Decision layer	Fertility factors	Environmental factors	Health factors
Indicator layer	OrgC, available K, available P, available Mo	Cd, Hg, DDT, salinity, pH	Se

3.2 Weight assignment The size of weight of evaluation indicator is, in essence, the indicator's measuring of the degree of influence on the quality of the land. The influence on the quality of land is mainly determined by the contribution of elements to crop growth and quality safety, the abundance of the study area and spatial variation.

The weight assignment of evaluation indicator for geochemical assessment of land quality in Cixi City is carried out using Analytic Hierarchy Process (AHP).

(1) Building layers. The indicator system for geochemical assessment of land quality can be divided into three layers: the first layer is the target layer, namely geochemical assessment of land quality; the second layer is decision layer, including soil nutrients, soil environment and other factors; the third layer is indicator layer, containing pH, org C, available P, available K, Cd, Hg, Se, available Mo, salinity and other evaluation indicators.

(2) Judgment matrix. AHP is to establish judgment matrix through pairwise comparison, for example, in fertility indicator layer, the organic carbon is the main factor determining the essential quality of land, which is absolutely essential; in the harmful elements, the contamination proportion of Cd is larger than that of Hg, DDT, so Cd is more important. pH is relatively important.

(3) Weight analysis. Through building layers and judgment matrix, the weight of indicators is calculated (see Table 2).

Table 2 AHP indicator weight

Indicator layer		Indicator weight				
Fertility indicators	Essential main elements	orgC	Available P	Available K	0.8320	0.7311
		0.6320	0.2486	0.1194		
	Essential trace elements	Available Mo			0.1680	
Environmental health indicators	Physical and chemical factors	PH		Salinity	0.1185	0.2689
		0.69		0.31		
	Harmful elements	Cd	Hg	DDT	0.5503	
		0.5991	0.2877	0.1132		
	Health elements	Se	0.3228			

3.3 Membership function model Membership function model includes three types: Z-type, S-type and Peak-type (Yang Zhongfang et al, 2008), (see Fig. 2).

OrgC, available K, available P, available Mo and other fertility indicators use Z-type. The soil selenium content in the study area is 0.01 – 2.9 mg/kg, and the majority of content is 0.05 – 0.2 mg/kg (relative lack), so Z-type model is used.

Cd, Hg and DDT use S-type. Given that this area is close to the sea, the salt content is relatively high and has become an important factor influencing the quality of land in Cixi City, so salinity uses S-type model. pH uses Peak-type model.

3.4 Calculation of membership function Using the background value method, the threshold value of L, U, O_1, O_2 in the study area is determined. The membership function of indicators

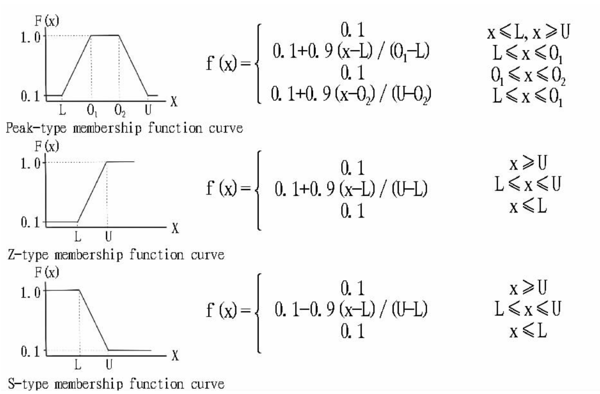

Fig. 2 Membership function model

uses the soil background 20% , 40% , 60% , 80% cumulative frequency classification in Cixi City (Wang Qinghua et al, 2005).

But the fertility indicators are based on the fertility grading standards of the second general soil survey; harmful elements are based on GB15618 – 95 standard; pH, O_1, O_2 take the value 6.0 to 8.0 according to actual agricultural production pattern and crop tolerance and adaptation in Cixi City (Table 3).

3.5 Evaluation index model In accordance with the selected indicators, calculation model of membership function value and weight results, we use the additive model to calculate the weight and degree of membership of actual measured values of each participating indicator, to obtain the soil fertility and soil environmental geochemical composite index P.

$$P = \Sigma f_i \times C_i (i = 1,2,3,4\cdots\cdots n)$$

where P is the composite index; f_i is the membership function value of evaluation indicator i; C_i is the weight of evaluation indicator i.

The evaluation indicators are various indicators for soil fertility and land environmental health.

3.6 Evaluation grading Based on soil fertility composite parameter ($P_{fertility}$) and land environment composite parameter ($P_{environment}$), we carry out grading on soil fertility and land environment (divided into three levels). The composite parameter value at the corresponding level can be seen in Table 4.

Table 3 Membership function model value of land quality evaluation indicators

Indicators	OrgC	Available K	Available P	Available Mo	Cd	Hg	pH	Salinity	Se	DDT
L	0.29	40	5.0	0.1	0.2	0.15	5.5	1.63	0.167	0
U	3.49	200	20	0.3	1.0	1.5	8.5	1.85	0.221	0.5
O_1							6.0			
O_2							8.0			

Unit: OrgC, CaO//%; salinity//g/kg; Others//mg/kg.

Table 4 Grading of soil fertility and land environment and corresponding composite parameter

Composite parameter ($P_{fertility}$ or $P_{environment}$)	1 – 0.7	0.7 – 0.3	<0.3
Soil fertility classification	Rich (Class I)	Moderate (Class II)	Lack (Class III)
Land environment classification	Clean (Class I)	Normal (Class II)	Polluted (Class III)

Based on the assessment results of soil fertility quality level and land environment quality level, the classification scheme in Table 5 is used, to carry out geochemical classification of land quality for the evaluation map spot.

Table 5 Comprehensive geochemical classification of land quality

Comprehensive quality	Rich	Moderate	Lack
Clean	High quality	Excellent	Good
Normal	Excellent	Excellent	Good
Polluted	Medium	Medium	Poor

3.7 Assessment results The comprehensive assessment results of land quality in Cixi City are as follows:

(1) The area of high quality first-class land is 22.7 km^2, accounting for 3.4% of the farmland area in the assessment area, distributed in the river net and plain areas in yitang, such as Heng River, Kuangyan;

(2) The area of excellent second-class land is 537.9 km^2, accounting for 80.65% of the farmland area in the assessment area;

(3) The area of good third -class land is 105.9km^2, accounting for 15.87% of the farmland area in the assessment area, mainly scattered in Yitang to Qitang;

(4) The area of medium fourth -class land is 0.5km^2, accounting for 0.08% of the farmland area in the assessment area.

The fifth-class land never appears (Fig. 3). The overall geochemical assessment result of land quality is good.

4 Land ecological quality assessment

On the basis of geochemical assessment of land quality, we comprehensively take into account atmosphere, water, and agricultural products, to assess the land ecological quality. The assessment of atmosphere, water, and agricultural products is the grading assessment based on special ecological evaluation, and the scheme in Table 6 is used.

Superposition method is used to comprehensively assess the land ecological quality, and the superposition is conducted without having an impact on the geochemical assessment of land quality. In the geochemical assessment of land quality, we superimpose different signs to signify different levels and ecological assessment indicator types. The numbers are used to express the evaluation results. The first number consists of 1 to 5, denoting 5 levels of geochemical assessment of land quality, respectively; the second number signifies atmosphere; the third number signifies irrigation water; the fourth number signifies crop safety. The illustration and description can be shown in Table 7. The statistics on assessment results of land ecological quality in Cixi City are shown in Table 8.

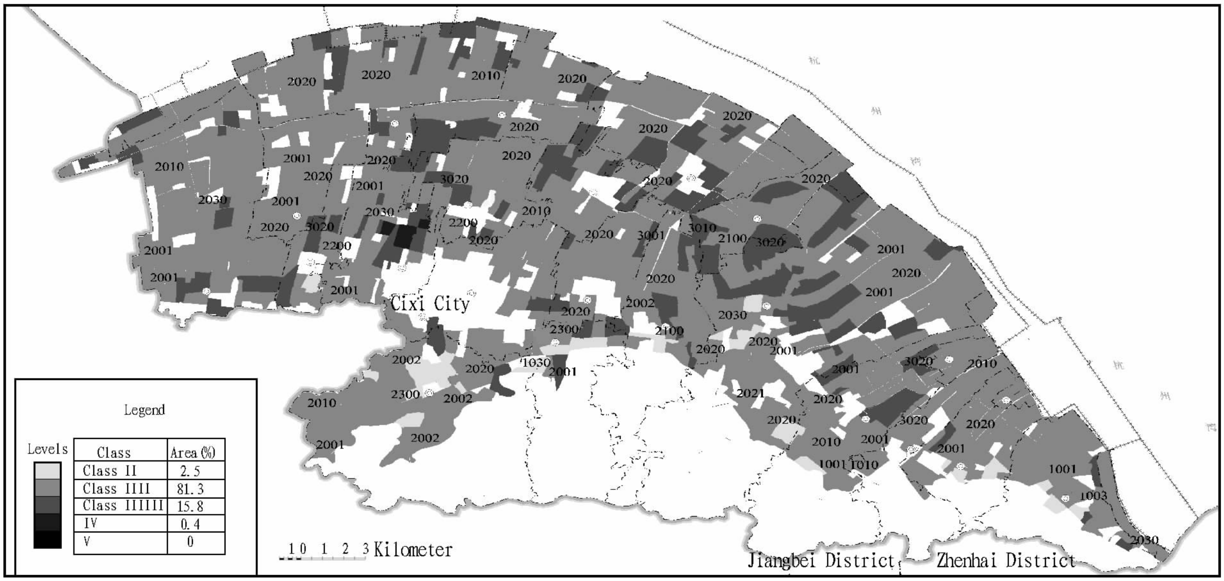

Fig. 3 Comprehensive geochemical assessment of land ecological quality in Cixi City

Table 6 Quality grading of land ecological quality factors and corresponding composite parameters

External factors	Assessment scheme	Grading	Grading significance	Assignment
Atmosphere quality	Indicator content value/ regional average <1	Class I	Good	1
	Content value/average 1 – 2.0	Class II	Average	2
	Content value/average >2.0	Class III	Poor	3
Irrigation water quality	Irrigation water quality (integrated) lower than standard V of GB3838 – 2002	Class I	Good	1
	Irrigation water quality (integrated) lower than standard III ofGB5084 – 92, higher than standard V of BG3838 – 2002	Class II	Average	2
	Irrigation water quality (integrated) higher thanGB5084 – 92 standards	Class III	Poor	3
Crop safety	The evaluation indicator content in the agricultural products below the safety standard limit of 1/2 of agricultural products	Class I	Safe	1
	The evaluation indicator content in the agricultural products below the safety standard limit of agricultural products, but above 1/2	Class II	Relatively safe	2
	The evaluation indicator content in the agricultural products above the safety standard limit of agricultural products	Class III	Unsafe	3

Table 7 The illustration of land ecological quality class and class significance

Illustration	Class significance
1120	Land quality geochemical level is Class I; atmosphere quality level is Class I; irrigation water quality level is Class II; crops are not be assessed.
2001	Land quality geochemical level is Class II; atmosphere and irrigation water are not assessed; crop quality level is Class I.
3132	Land quality geochemical level is Class III; atmosphere quality level is Class I; irrigation water quality level is Class III; crop quality level is Class II.
4213	Land quality geochemical level is Class IV; atmosphere quality level is Class II; irrigation water quality level is Class I; crop quality level is Class III.
5321	Land quality geochemical level is Class V; atmosphere quality level is Class III; irrigation water quality level is Class II; crop quality level is Class I.

From Fig. 3 and Table 8, we see that the overall land ecological quality in Cixi City is good. From the geochemical assessment of land quality, the land is mainly the Class I, II, III excellent and good land; the atmosphere quality is generally good, only Class III around the downtown of Cixi City; irrigation water quality generally declines, Class III appearing in Zhouxiang, and An-dong, and the river pollution is serious; the quality of the majority of agricultural products is in line with food hygiene and safety requirements, and excessive rice cadmium only happens in Long Mountain and other local places.

Therefore, there is ecological threat to local soil, air, water and agricultural products, affecting the ecological quality of land. We must pay close attention to it. On the one hand, it is necessary to strengthen the monitoring; on the other hand, there is a need to strengthen the pollution control and soil remediation in the local zones with ecological quality problems.

Table 8 The assessment rating of land ecological quality in Cixi City

Rating code	The number of assessment units	Rating code	The number of assessment units
1000	87	2021	1
1001	2	2030	5
1003	1	2100	2
1020	1	2200	3
1030	1	2300	2
2000	2039	3000	308
2001	21	3001	1
2002	5	3010	1
2010	8	3020	4
2020	33	4000	2

5 Conclusions

(1) Cixi City is the largest in the 5 pilot areas of land quality survey carried out in Zhejiang Province. On the basis of land quality geochemical survey, combined with the concept of the ecological quality of land, we carry out the integrated survey of atmosphere, irrigation water, agricultural product quality, using today's advanced techniques in China. The land ecological quality assessment carried out, is the relative grading of ecological quality, on the basis of geochemical assessment of land quality, superimposing atmosphere, water, agricultural product quality assessment, which enriches the connotation of ecological quality of the land. The geochemical assessment of land quality and grading of agricultural land is of important significance.

(2) The ecological quality of the land is an important component of land quality, an indispensable part of management of land resources quantity and quality. The ecological quality of the land and the natural, social and economic attributes of the land constitute the connotation of concept and value of the land. It is an integral part of land grading and evaluation, and can provide the basis and data for improving valuation of agricultural land.

(3) The survey and assessment of ecological quality of the land is the successful experience of basic farmland quality survey pilot area in Cixi City, which provides a basis for promoting the province's land survey and lays a foundation for realizing delicacy management of land.

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