Sustainable Use of Agricultural Land in Zhoukou City Based on Emergy Analysis

Qian WEN[1*], Shuijuan SUN[2], Qingsong LI[1], Huiping FAN[1]

1. College of Resources and Environment, Henan Agricultural University, Zhengzhou 450002, China; 2. College of Resources and Environment, Hunan Agricultural University, Changsha 410128, China

Abstract Taking Zhoukou City in Henan Province as an example, we select the statistics during the period 2000 – 2009, and use emergy analysis method to research the sustainable use of agricultural land in Zhoukou City. The study results show that: (i) The agricultural input is mainly based on resources purchase input, which accounts for more than 90% of total emergy input; the industrial energy input is to a large extent dependent on the input of chemical fertilizer and pesticide; precipitation significantly affects the input of renewable environmental resources. (ii) The agricultural output is mainly based on farming and animal husbandry, with the proportion reaching 99%; the proportion of fishery and forestry is too low; the agricultural output structure is relatively simple. (iii) The use of agricultural land has achieved initial success in terms of economic sustainability, but in terms of ecological sustainability and social sustainability, it is at a low level; the sustainable use index shows the great vitality and development potential of agricultural system; unsustainability is reflected in considerable input of chemical fertilizer and pesticide, and simple agricultural output structure.

Key words Emergy analysis, Agricultural land, Sustainable use, Zhoukou City

The land is an important carrier of all environmental factors and resources, which plays a pivotal role in the socio-economic development. With the acceleration of the process of industrialization and urbanization as well as the increase in population, the scarcity of land resources is increasingly prominent. Due to irrational use of land by mankind, the breadth and depth of the land use is undergoing profound changes, which will not only change the function and structure of terrestrial ecosystems, but also lead to land cover change. Especially for agricultural land, its intensive utilization has become the most significant form of land cover change[1]. Therefore, the research on the sustainable use of land resources has attracted scholars' great attention.

Currently, many scholars have conducted researches on the sustainable use of land resources from different angles, such as the angle of circular economy[2], the angle of farmers' diversified industry[3], and the angle of land property rights theory[4]. Some scholars use different methods to study this, such as entropy method[5], hierarchy analysis[6], as well as the ecological footprint method[7], but they are basically based on different levels of system and dimension.

Emergy theory can convert different levels of system and dimension into a unified standard for the study, but at resent, only a small number of scholars evaluate the sustainable use of land resources from the point of view of emergy, for example, Zhang Wen[8] and Liang Shanshan[9] use emergy analysis to evaluate the sustainable use of oasis system in Fukang City of Xinjiang and agricultural land in Xi'an, respectively.

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* Corresponding author. E-mail: wenqian23@163.com

1 Overview of the study area

Zhoukou is a prefecture-level city in eastern Henan province, People's Republic of China. It borders Zhumadian to the southeast, Xuchang and Luohe to the west, Kaifeng to the northwest, Shangqiu to the northeast, and the province of Anhui on all other sides. There are four fan-shaped river nets within the city: Shaying River, Guo River, Xifei River, and Ruhe River. The altitude is about 35.5 – 64.3 m, and the climate is warm temperate semi – humid monsoon climate, with the annual average temperature of 14.5 – 15.8 ℃, and annual precipitation of 689 – 816 mm. The average annual sunshine hours are 2 025 – 2 269 h, and the total amount of annual solar radiation is 5.11 × 105 J/cm^2.

In 2010, the total land area in the whole city was 1 195 944 hm^2, and the agricultural land area accounted for about 82.65% of the total land area. The permanent population was 8.94 million at the end of 2010, the urbanization rate was 29.7 %, and GNP was 122.83 billion yuan. It is an important commodity grain production base. The growing area of grain in the city was 1 132 600 hm^2 and total grain output was 7.237 1 million t in 2010.

2 Research methods

2.1 Emergy analysis theory Emergy is defined by H. T. Odum (1987) as follows: Emergy is the available energy (exergy) of one kind that is used up in transformations directly and indirectly to make a product or service. Emergy accounts for, and in effect, measures quality differences between forms of energy. Emergy is an expression of all the energy used in the work processes that generate a product or service in units of one type of energy. The unit of emergy is the emjoule, a unit referring to the available energy of one kind consumed in transformations[10]. Emergy accounts for different forms of energy and resources (*e. g.*

sunlight, water, fossil fuels, minerals, *etc.*).

Each form is generated by transformation processes in nature and each has different ability to support work in natural and human dominated systems. The recognition of these differences in quality is a key concept of the emergy methodology. The unit of emergy is the emjoule or emergy joule. Using emergy, sunlight, fuel, electricity, and human service can be put on a common basis by expressing each of them in the emjoules of solar energy that is required to produce them. If solar emergy is the baseline, then the results are solar emjoules (abbreviated sej). Although other baselines have been used, such as coal emjoules or electrical emjoules, in most cases emergy data are given in solar emjoules[10].

2.2 Data source and calculation method The data for the emergy analysis of agricultural system in *Zhoukou City are mainly from Zhoukou Historical Statistics Yearbook*, *Henan Statistical Yearbook*. Based on agricultural land use data in Zhoukou City during the period 2000 – 2009, we first refer to *Agroecology*[11] to translate some data into unit of energy, then refer to the emergy conversion rate provided by *Emergy Analysis of Ecological* and *Economic System*[10] to convert energy into emergy, ultimately forming the emergy input-output table of agricultural system in Zhoukou City during the period 2000 – 2009.

Finally, based on the emergy input and output data of agricultural land in Zhoukou City, from economic sustainability, ecological sustainability and social sustainability, we select land emergy net income, emergy investment ratio, net emergy yield ratio (EYR), environmental loading ratio (ELR), emergy use intensity, emergy self-sufficiency ratio, and sustainable use index based on emergy as the emergy evaluation index of sustainable use of agricultural land in Zhoukou City (Table 1).

Table 1 Sustainable use indicators of agricultural land in Zhoukou City

Item	Expression	Remark
Net gains of land emergy	$(U_{out} - U_{in}) // \text{area}$	Economic sustainability
Emergy investment ratio	$F // (R + N)$	Economic and ecological sustainability
Net emergy yield ratio (EYR)	$U_{out} // (F + R_1)$	Economic sustainability
Environmental loading ratio(ELR)	$(N + F) // (R + R_1)$	Ecological sustainability
Emergy use intensity	Uin // area	Social sustainability
Emergy self-sufficiency raio	$(R + N) // U_{in}$	Social sustainability
Sustainable use index based on emergy	EYR // ELR	Economic, social, ecological sustainability

Note: The area is the area of agricultural land in Zhoukou City.

3 Results and analysis

3.1 Emergy input analysis of agricultural land in Zhoukou City During the period 2000 – 2009, the emergy input in Zhoukou City showed an overall downward trend (Table 2), decreasing by 14.3%, from 1.43×10^{22} sej in 2000 to 1.23×10^{22} sej in 2009. The emergy input is mainly focused on the input of unrenewable industrial auxiliary energy and renewable organic energy, namely the resources purchase input, accounting for more than 90% of emergy input of the entire agricultural system, and the proportion of input increases in recent years, indicating that the agricultural intensification in Zhoukou City is increased gradually, which has played an important role in promoting agricultural production in Zhoukou City.

In various types of emergy input, the share of renewable resources input in total emergy input shows an overall downward trend, generally declining by 0.67%, from 9.11% in 2000 to 8.44% in 2009. And the input of chemical potential of rainwater and cycle energy of earth is the most principal emergy input, but the cycle energy of earth remains unchanged over 10 years, having little effect on the emergy input of renewable resources, so changes in rainfall in Zhoukou City cause changes in the emergy input of renewable resources of agricultural land in Zhoukou City.

The input of renewable organic energy shows a declining trend, and the change amplitude is very prominent, decreasing by 62.53% during a decade. The share of organic fertilizer in total emergy input decreased from 37.14% in 2000 to 13.71% in 2009, a decrease of 23.42% during a decade; manpower also occupies a large share in organic emergy input, and the input proportion rises year by year, but the proportion of it to total emergy input is basically stable at around 6%, which shows that the modernization level of agriculture is not very high, and agricultural production activities still occupy more labor forces, hampering farmers' income increase and improvement of living conditions in rural areas.

The emergy input of nonrenewable energy in Zhoukou City is divided into two parts. One is the emergy input of nonrenewable resources, mainly the loss energy of topsoil, in a rising trend on the whole over 10 years, indicating that the soil erosion in Zhoukou City is gradually deteriorated. The other part is nonrenewable industrial auxiliary energy, the share of which in total emergy input increased from 45.76% in 2000 to 71.63% in 2009. This indicates that the agricultural production in Zhoukou City is largely dependent on nonrenewable industrial energy input, especially the input of chemical fertilizer and pesticide, accounting for about 59% of industrial energy. Considerable application of chemical fertilizer and pesticide will increase the cost of agricultural production and cause decline in the quality of agricultural products, ultimately not conducive to the sustainable use of agricultural land in Zhoukou City.

In addition, the emergy input of total power of agricultural machinery in Zhoukou City also shows a rising trend year by year, basically accounting for one third of the entire industrial energy input in 2009, indicating that the mechanization level of agriculture in Zhoukou City develops rapidly, which has played a significant role in promoting farmers' income.

3.2 The emergy output analysis of agricultural land in Zhoukou City The emergy output of agricultural land use system in Zhoukou City is mainly the farming output and livestock output (Table 3), and the proportion of the two reach 99%; during the period 2000 – 2009, the emergy output of agricultural land in

Zhoukou City showed an overall upward trend, but it declined two times in the period, namely in 2003, the emergy output of agricultural land reached the lowest point in nearly a decade, which might be related to the rare autumn flood disaster in Zhoukou City in 2003, resulting in significant decline in crop production; but the emergy output of agricultural land rebounded quickly in 2004, an increase of 16.75% compared with 2003.

During the period 2004 – 2007, the emergy output of agricultural land in Zhoukou City increased year by year, but in 2008, the emergy output of agricultural land experienced significant reduction, decreasing by 20.33% compared to 2007, which might be related to the snow and ice storms nationwide in 2008. In 2009, the emergy output of agricultural land in Zhoukou City showed a rebound trend, an increase of 4.2% compared with 2008.

Table 2 The agricultural system emergy input in Zhoukou City during the period 2000 – 2009

Emergy input types	Emergy conversion rate	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Solar energy // 10^{18} sej	1.00E+00	8.84	9.86	9.42	6.47	9.21	8.94	9.03	8.25	9.07	9.27
Wind energy // 10^{19} sej	6.63E+02	5.35	5.34	5.34	5.34	5.34	5.33	5.33	5.33	5.33	5.33
Rainwater chemical potential // 10^{20} sej	1.54E+04	7.81	4.14	4.99	9.20	7.30	6.51	5.76	6.46	5.75	5.28
Rain geological potential // 10^{19} sej	8.89E+03	4.47	2.37	2.85	5.26	4.17	3.72	3.29	3.69	3.29	3.02
Earth cycle energy // 10^{20} sej	2.90E+04	4.17	4.17	4.16	4.16	4.16	4.16	4.16	4.16	4.16	4.16
Total renewable environmental resources (R) // 10^{21} sej		1.31	0.92	1.01	1.45	1.25	1.17	1.09	1.16	1.09	1.04
Topsoil net loss // 10^{19} sej	6.25E+04	3.88	3.88	3.88	3.88	3.88	3.87	3.87	3.87	3.87	3.87
Total nonrenewable environmental resources (N) // 10^{19} sej		3.88	3.88	3.88	3.88	3.88	3.87	3.87	3.87	3.87	3.87
Nitrogen // 10^{21} sej	4.62E+09	1.25	1.32	1.36	1.30	1.50	1.53	1.52	1.48	1.56	1.34
Phosphorus // 10^{21} sej	1.78E+10	2.51	2.72	2.77	2.91	2.33	2.32	2.34	2.49	2.32	2.46
Potassium // 10^{20} sej	2.96E+09	1.19	1.24	1.28	1.33	1.60	1.70	1.73	1.75	1.77	2.28
Compound fertilizer // 10^{20} sej	2.80E+09	1.98	2.48	2.92	2.46	2.58	4.70	7.53	7.90	8.30	8.71
Pesticides // 10^{19} sej	1.62E+09	3.27	3.49	3.59	3.19	2.87	2.96	3.04	3.14	3.20	3.02
Plastic sheeting // 10^{18} sej	3.80E+08	3.16	3.35	4.08	3.79	3.99	3.80	3.80	3.63	3.33	3.59
Diesel fuel // 10^{20} sej	6.60E+04	2.90	3.43	3.42	3.05	3.39	3.52	3.54	3.55	3.61	3.92
Total power of agricultural machinery // 10^{21} sej	7.50E+07	1.78	1.91	2.06	2.14	2.26	2.36	2.45	2.52	2.64	2.77
Power // 10^{20} sej	1.59E+05	3.75	4.25	4.48	4.52	4.85	4.88	5.59	6.23	6.62	6.97
Total nonrenewable industrial auxiliary energy (F) // 10^{21} sej		6.56	7.13	7.44	7.52	7.36	7.71	8.18	8.47	8.59	8.79
Manpower // 10^{20} sej	3.80E+05	8.34	8.34	11.05	8.02	7.80	7.68	7.17	7.22	7.14	7.22
Animal power // 10^{20} sej	1.46E+05	2.72	2.52	2.77	2.14	1.73	1.51	1.19	0.90	0.04	0.02
Organic manure // 10^{21} sej	2.70E+04	5.32	4.68	4.12	3.63	3.19	2.81	2.47	2.17	1.91	1.68
Total renewable organic energy (R1) // 10^{21} sej		6.43	5.77	5.50	4.64	4.14	3.73	3.31	2.99	2.63	2.41
Total emergy input (U_{in}) // 10^{22} sej		1.43	1.39	1.40	1.36	1.28	1.26	1.26	1.27	1.23	1.23

Table 3 The emergy output of agricultural system in Zhoukou City during the period 2000 – 2009

Emergy input types	Emergy conversion rate	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Rice // 10^{18} sej	3.59E+04	2.28	2.22	2.06	0.65	1.95	2.17	2.87	2.44	2.82	3.31
Wheat // 10^{21} sej	6.80E+04	4.05	4.20	3.84	3.85	4.21	4.26	4.56	5.01	5.16	5.25
Corn // 10^{21} sej	5.81E+04	0.96	1.17	1.27	0.30	1.04	1.04	1.60	1.80	1.74	1.68
Beans // 10^{21} sej	6.90E+05	3.46	3.83	3.92	1.33	3.63	4.12	4.56	3.66	4.71	5.34
Potato // 10^{18} sej	2.70E+03	3.76	3.57	3.63	0.74	2.56	2.87	3.21	1.69	2.45	2.89
Oil crop // 10^{21} sej	6.90E+05	6.13	6.33	6.74	1.89	4.75	5.09	5.13	4.98	5.24	5.51
Cotton // 10^{21} sej	1.90E+06	7.01	9.02	9.29	2.68	5.58	7.27	8.20	7.06	5.94	4.76
Vegetables // 10^{20} sej	2.70E+04	3.21	3.77	3.96	2.95	4.10	4.34	4.85	4.97	5.09	5.34
Fruits // 10^{20} sej	5.30E+05	4.09	4.03	4.28	4.02	4.51	3.41	5.12	6.11	6.23	6.85
Total input of farming // 10^{22} sej		2.23	2.53	2.59	1.07	2.01	2.26	2.51	2.36	2.39	2.38
Meat // 10^{22} sej	3.17E+06	4.73	5.02	5.56	5.80	6.01	6.09	6.53	7.11	4.99	5.31
Dairy // 10^{19} sej	1.70E+06	1.92	1.39	3.69	6.33	8.74	17.56	27.67	42.17	44.98	49.55
Honey // 10^{17} sej	1.71E+06	0.99	21.08	16.12	20.53	25.84	10.86	29.36	33.87	28.71	33.77
Eggs // 10^{21} sej	2.00E+06	2.62	2.78	2.92	3.16	3.46	3.71	3.91	3.50	3.78	4.00
Hairs // 10^{17} sej	4.40E+06	3.37	2.62	2.24	2.24	18.33	19.07	14.96	4.49	4.49	4.86
Total input of animal husbandry // 10^{22} sej		5.00	5.30	5.85	6.12	6.37	6.48	6.95	7.50	5.42	5.76
Aquatic products // 10^{14} sej	3.49E+04	7.66	8.03	8.38	7.39	7.92	8.74	12.86	17.05	18.83	19.85
Total input of fishery // 10^{14} sej		7.66	8.03	8.38	7.39	7.92	8.74	12.86	17.05	18.83	19.85
The output value of forestry // 10^{20} sej	1.20E+12	5.89	6.41	6.44	5.15	8.38	9.26	9.83	10.81	13.34	14.30
Total input of forestry // 10^{20} sej		5.89	6.41	6.44	5.15	8.38	9.26	9.83	10.81	13.34	14.30
The total emergy output (Uout) // 10^{22} sej		7.29	7.90	8.51	7.25	8.46	8.83	9.55	9.97	7.94	8.27

Note: The conversion rate unit of emergy of output value of forestry is "sej//yuan".

In various types of emergy output, food (rice, wheat, corn, beans and potatoes) accounts for 11.38% of the total output; fruits and vegetables account for about 0.5%; meat accounts for about 68%; forestry accounts for about 1%, nearly 0. It indicates that the agricultural output in Zhoukou City is simple, most of which comes from the output of farming and animal husbandry, so it is necessary to increase input to vegetables, fishery and forestry, and optimize the structure of output of agricultural products in the future.

In addition, the sudden reduction of total emergy output in 2003 and 2008 was caused by sudden natural disasters, and there was a very significant impact on farming. The emergy output of farming decreased by 58.48% in 2003, indicating that farming is an important pillar of the emergy output of agricultural land use system in Zhoukou City, which plays a prominent role in promoting the economic benefits brought about by unit input of agricultural land.

The level of socio-economic development of Zhoukou City relies heavily on agricultural products, so in order to speed up Zhoukou City's economic development, we must carry out deep processing of agricultural products, and give full play to the great resource advantages of agricultural products.

3.3 The evaluation index analysis of agricultural land emergy in Zhoukou City

3.3.1 Net gains of land emergy. Net gains of land emergy is to evaluate the use of agricultural land from the perspective of economic sustainability, which can reveal the economic driving mechanism of land use type conversion, laying the foundation for the analysis of land use supply and spatial configuration[9].

During the period 2000 – 2009, net gains of land emergy showed an overall upward trend, rising from 5.908×10^{18} sej/km^2 in 2000 to 7.129×10^{18} sej/km^2 in 2009, an increase of 20.67%, indicating that the economic benefits produced by agricultural land in Zhoukou City increase ceaselessly, with huge development potential, but it declined in 2003 and 2008, due to decline in the emergy output of farming caused by natural disasters. Thus farming plays a vital role in agricultural development in Zhoukou City.

3.3.2 Emergy investment ratio. Emergy investment ratio, also known as the ratio between economic emergy and environmental emergy, is an indicator for measuring the degree of economic development and environmental load. It can be used to determine the benefit of economic activity under certain conditions, and measure the load rate of environmental resource conditions on economic activity. The greater the value of it, the higher the degree of economic development for the system; the smaller the value of it, the lower the level of development, the greater the dependence on the environment[10].

During the period 2000 – 2009, the emergy investment ratio showed an upward trend in Zhoukou City, rising from 4.877 in 2000 to 8.18 in 2009, an increase of 67.71%, indicating that the agricultural production conditions in Zhoukou City was gradually improved, the dependence on natural resources was gradually reduced, and the ability to resist natural disasters was gradually increased. However, due to the backward management level and means of agricultural production in Zhoukou City, the proportion of the input of chemical fertilizers and pesticides is high, which will affect the sustainable development of the agricultural use system in in Zhoukou City. Gradually increasing input to agriculture will lead to increase in the cost of production, and play a role in restricting farmers' income.

3.3.3 Net emergy yield ratio. Net emergy yield ratio is an indicator for measuring the contribution of system output to economy, and evaluating the efficiency of the output of the agricultural land from the economic sustainability of land. The greater the value of it, the higher the production efficiency of the system.

During the period 2000 – 2009, except the decline in value in 2003 and 2009, it showed an overall upward trend in other years, rising from 5.615 in 2000 to 7.386 in 2009, an increase of 31.55%. The decline in value in 2003 and 2009 was caused by the decrease in the emergy output of farming and animal husbandry in the year, respectively. The net emergy yield ratio in Zhoukou City is far greater than the national agricultural average net emergy yield ratio[12], indicating that the overall function of the agricultural use system in Zhoukou City is good, with high rate of return, which may be related to the fact that in recent years, Zhoukou City has increased agricultural scientific and technological input, minimized the application amount of chemical fertilizer and pesticide, and promoted the degree of mechanization of agriculture. These measures will improve the overall emergy output of the entire system, thereby improving the market competitiveness of agricultural products in Zhoukou City.

3.3.4 Environmental loading ratio. Environmental loading ratio is used to measure the pressure on the regional environmental system under certain economic conditions, and play a role of environmental early warning, which can explore the degree of sustainable use of agricultural land use system from ecological sustainability of land.

During the period 2000 – 2009, environmental loading ratio in Zhoukou City was in 0.853 – 2.565, lower than the national average of 5.89[12], indicating that the environmental resources of Zhoukou City has not yet been used efficiently, and agricultural development also has large potential. However, despite the environmental loading ratio far below the national average, it was in an upward trend over a decade, an increase of 200.67%. Zhoukou City is facing increasingly serious environmental problems. So in the future agricultural land use, we must vigorously strengthen the management of agricultural production, minimize input of chemical fertilizers, pesticides, plastic sheeting and other agricultural means of production, thereby reducing the issues of product quality and environmental pollution problems caused by these means of production.

3.3.5 Emergy use intensity. Emergy use intensity is an indicator for evaluating the level and degree of economic development of system, and evaluating the degree of sustainable use of agricultural land from the social sustainability of land. The greater the value of it, the higher the degree of economic development of the land, the greater the pressure on the environment.

Emergy use intensity of agricultural land in Zhoukou City showed an overall trend of decline, a decrease of 14.05%, from 1.445×10^{18} sej/km^2 in 2000 to 1.242×10^{18} sej/km^2 in 2009. It rebounded slightly in 2002 and 2007. Decline in emergy use intensity is mainly caused by the declining trend of total emergy input of agricultural land, indicating that the degree of economic development of the agricultural land in Zhoukou City still has large development space, and the pressure of agricultural land use on the environment is gradually eased.

3.3.6 Emergy self-sufficiency ratio. Emergy self-sufficiency ratio is an indicator for evaluating the sustainable utilization of agricultural land from social sustainability of land. The larger the value of it, the greater the self-sufficiency capacity of the system, the higher the degree of development of internal resources. But excessive development of local non-renewable resources and insufficient purchase emergy input, the regional resources may not be used well, resulting in low level of economic development.

The emergy self-sufficiency ratio in Zhoukou City basically fluctuates around 9.0%, far lower than the national average of agriculture of 16.8%[9], reflecting that the development of the agricultural economy is poor; the self-sufficiency capacity of agricultural land use system is weak; the level of development of internal resources is low; the degree of closure of use of agricultural land resources.

3.3.7 Sustainable use index based on emergy. Sustainable index is used to measure the sustainability and coordination of a regional ecological economic system, which can evaluate the degree of sustainable development of agricultural system from the economic, ecological and social sustainability. Studies have shown that if sustainable index < 1, it is consumer-based economic system, and the degree of utilization of nonrenewable resources in this region is high; if sustainable index is between 1 to 10, the system is full of vitality and development potential; if sustainable index > 10, the regional economy is underdeveloped[12].

During the period 2000 – 2009, the sustainable index of agricultural land use system in Zhoukou City experienced great changes and decline in fluctuation, and the fluctuation range was between 2.880 to 6.853, indicating that the agricultural land use system in Zhoukou City was full of vitality and development potential, and the degree of development and utilization of nonrenewable resources is moderate. Zhoukou City must strengthen scientific regulation and guidance on agricultural production, in order to ensure the sustainable development of the agricultural use system.

Table 4 Emergy evaluation index of the sustainable use of agricultural land in Zhoukou City during the period 2000 – 2009

Year	Net gains of land emergy 10^{18} sej/km^2	Emergy investment ratio	Net emergy yield ratio (EYR)	Environmental loading ratio (ELR)	Emergy use intensity 10^{18} sej/km^2	Emergy self-sufficiency ratio	Sustainable use index based on emergy
2000	5.908	4.877	5.615	0.853	1.445	0.094	6.583
2001	6.575	7.449	6.126	1.072	1.398	0.069	5.716
2002	7.179	7.116	6.574	1.149	1.413	0.075	5.721
2003	5.944	5.055	5.960	1.241	1.379	0.109	4.802
2004	7.261	5.713	7.353	1.372	1.294	0.101	5.359
2005	7.656	6.401	7.720	1.584	1.279	0.095	4.874
2006	8.387	7.267	8.314	1.871	1.276	0.089	4.445
2007	8.805	7.066	8.702	2.052	1.280	0.095	4.242
2008	6.786	7.634	7.080	2.320	1.249	0.091	3.051
2009	7.129	8.180	7.386	2.565	1.242	0.088	2.880

3.4 Analysis of sustainable use of agricultural land in Zhoukou City In terms of economic sustainability, the economic benefits produced by agricultural land in Zhoukou City are increasing, with great potential for development; farming plays a crucial role in agricultural development in Zhoukou City; the agricultural production conditions are gradually improved, and the agricultural use system's overall function is good, with high rate of return.

In terms of ecological sustainability, the environmental resources in Zhoukou City have not yet achieved efficient use; the dependence of agricultural land use system on the natural resources is gradually reduced; the ability to resist natural disasters is gradually increased; agricultural development has large potential, with large room for growth. However, the continued rise of the environmental loading ratio indicates that Zhoukou City will face increasingly serious environmental problems.

In terms of social sustainability, the agricultural economic development level in Zhoukou City is not high; the self-sufficiency capacity of agricultural land use system is weak; the degree of development of internal resources is not high; the degree of closure of agricultural land resources use is high, and the degree of economic development of the agricultural land has a large space for development.

4 Conclusions

(1) The emergy input in Zhoukou City shows an overall downward trend. Changes in precipitation significantly affects the input of renewable environmental resources; the agricultural input is mainly the input of nonrenewable industrial auxiliary energy and renewable organic energy, which accounts for more than 90% of total emergy input; industrial energy input is heavily dependent on the input of chemical fertilizer and pesticide; the input of total power of agricultural machinery accounts for about 60% of total emergy input, while human input only accounts for about 6%, indicating that agricultural production in Zhoukou City has gradually gotten rid of the shackles of traditional agriculture.

(2) The agricultural output is mainly the output of farming and animal husbandry, which accounts for about 99%, particularly the food crops and meat; the output of agricultural products in Zhoukou City is single. In the future, it should increase input to vegetables, fisheries and forestry, and optimize the structure of agricultural output. And changes in farming output can cause changes

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Table 4 Evaluation result of water quality extension pre-warning grade

Season	Correlation					j^*	*Evaluation result*
	Safety	Quite safe	Pre-warning	Moderate warning	Heavy warning		
Spring	−0.412 70 39	−0.268	0.073 95	−0.197 41	−0.239 43	3.40955	*Pre-warning*
Summer	−0.328 55	0.145 40	−0.076 44	−0.441 80	−0.612 41	2.339 32	*Quite safe*
Autumn	−0.366 63	−0.09409	0.23016	−0.30302	−0.51307	2.66959	*Pre-warning*
Winter	−0.405 77	−0.252 82	0.000 55	−0.160 35	−0.24645	3.24646	*Pre-warning*

Compared with traditional single factor evaluation method, the extension pre-warning evaluation can effectively reflect different preference of same pre-warning system. Results displayed that the water quality in Yincungang in spring, summer, autumn and winter were in pre-warning, safe, pre-warning and pre-warning state, and the pre-warning in winter was much worse than that in autumn.

The water quality extension pre-warning system can effectively reflect the potential threat of matter-element and can avoid the influence of extreme factors. The single factor evaluation result suggested that each evaluation factor in autumn belonged to III level, but they were not any potential threats. The water quality extension pre-warning system being in pre-warning state showed potential threat in autumn. The water quality in winter was in pre-warning state, which avoid from getting worse under the influence of ammonia nitrogen.

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in the overall agricultural output.

(3) This paper evaluates the sustainable use of agricultural land in Zhoukou City from economy, society and ecology. The results show that the use of agricultural land has achieved initial success in terms of economic sustainability, but in terms of ecological sustainability and social sustainability, it is at a low level; the sustainable use index shows the great vitality and development potential of agricultural system; unsustainability is reflected in considerable input of chemical fertilizer and pesticide, and simple agricultural output structure.

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