Comprehensive Evaluation of Unsafe State of Arable Land Resources: A Case Study of Chengdu City

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Abstract We establish the unsafe state indicator system reflecting the unsafe state of arable land within the scope of the city. Using analytic hierarchy process and entropy method, we determine the weight of indicator; using linear weighted method, we conduct comprehensive evaluation of unsafe operation of arable land resource system in Chengdu City during the period 1999 -2010. Through the unsafe state analysis, we draw the following conclusion: the share of arable land area in total land area, effective irrigation area, the area of low-yielding field, application rate of chemical fertilizer per unit area of arable land, and application rate of pesticide per unit area of arable land, are the key factors for easing the unsafe state in the short term. Finally we put forth the following recommendations: strengthening profound understanding of the seriousness of unsafe state of arable land; strengthening the basic arable land protection; continuing to tap the quality enhancement potential of arable land; consistently implementing the guideline and policy of "Combination of Use and Maintenance".

Key words Arable land resources, Comprehensive evaluation of unsafe state, Chengdu City

Due to the area limitedness, location fixity, fertility difference and other properties of arable land, along with the social and economic development, arable land use has become an important factor influencing the evolution of geographical functions. With the entry of external embedded economic module, the area of arable land is dwindling; the quality of arable land is constantly declining; the ecological environment of arable land is deteriorated significantly; the arable land use form experiences dramatic changes. Unsafe state of arable land resources is the abnormal situation occurring in the process of arable land use. The decay of arable land system not only triggers disorder of geographical function, but also brings great pressure on the carrying capacity of arable land, thus leading to the safety problems of arable land resources[1-2]. Based on this, there is an urgent need to put unsafe state as the measure of resources safety, guide allocation of arable land factor and promote micro-scale rational utilization of arable land, based on unsafe state of arable land from macro scale.

Chengdu (102°54′ -104°53′E, 30°05′ -31°26′N), formerly transliterated Chengtu, is the capital of Sichuan province in Southwest China. It holds sub-provincial administrative status. The urban area houses 14 047 625 inhabitants: 7 123 697 within the municipality's nine districts and 6 730 749 in the surrounding region. Chengdu is one of the most important economic, transportation, and communication centers in Western China. Chengdu has a monsoon-influenced humid subtropical climate and is largely mild and humid. It has four distinct seasons, blessed with abundant rainfall, and relieved from both sweltering summers and freezing winters. Its favorable climate contributes to the development of agriculture and animal husbandry, making Chengdu a comfortable place for sustained human habitat. The excellent climate conditions have created a long history of farming, and low mountain areas have been developed into arable land. The area of arable land reaches 432 000 hm^2.

With the acceleration of regional urbanization and industrialization process, the arable land resources within Chengdu City are declining, the quality of arable land is reduced, but there is a shortage of reserve arable land resources, and the arable land security problem is very acute. Through the comprehensive evaluation of operating status of arable land in Chengdu City, we determine the use state of arable land, which can not only provide reference for formulating the farmland protection policy and land use planning revision in line with the actual situation of Chengdu, but also be of great significance to solving issues concerning regional food security and sustainable development of society, economy and environment, agriculture, countryside and farmers, protecting the interests of farmers and promoting harmonious development of man-land relationship.

1 Comprehensive evaluation method for unsafe state of arable land resources

1.1 Establishment of comprehensive evaluation indicator system The selection of unsafe state indicators should be adapted to the local natural environment and social development conditions. Based on the characteristics and problems of arable land resources and actual development of arable land security in Chengdu City, we follow the principles of scientificity, operability, dynamics, independence and domination, combined with the recommendations of the experts and scholars, to establish the three-layer unsafe state indicator system including objective layer, criteria layer

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and indicator layer (Table 1).

The objective layer reflects the overall state of arable land resources, which is the generalization of criteria layer and indicator layer; criteria layer divides the system into three sub-systems (quantity, quality, ecological environment), which is the refinement of objective layer system; indicator layer reflects the status of criteria layer, characterizing the role and influence of each criterion, and the indicators and indicator groups that can be measured, compared and obtained are adopted.

Table 1 Unsafe state indicator system of arable land resources in Chengdu City

Objective layer	Criteria layer	Criteria layer weight	Indicator layer	Indicator layer weight	Comprehensive weight
Arable land resources security(A)	Amount of arable land (B_1)	0.426 7	Per capita arable land area(C_1)	0.391 2	0.166 9
			The supplementary coefficient of arable land(C_2)	0.216 9	0.092 6
			Basic arable land protection rate (C_3)	0.223 9	0.095 5
			The share of arable land area in total land area(C_4)	0.168 0	0.071 7
	Quality of arable land (B_2)	0.305 7	The area of low-yielding field(C_5)	0.176 2	0.053 9
			The organic matter content in soil(C_6)	0.153 2	0.046 8
			The proportion of slope land with gradient more than 15°(C_7)	0.122 1	0.037 3
			Grain yield(C_8)	0.257 1	0.078 6
			Cropping index(C_9)	0.163 7	0.050 0
			Proportion of effective irrigation area(C_{10})	0.127 8	0.039 1
	Arable land ecological environment(B_3)	0.267 6	Application rate of pesticide per unit area of arable land(C_{11})	0.255 0	0.068 2
			Application rate of chemical fertilizer per unit area of arable land(C_{12})	0.227 9	0.061 0
			Application rate of plastic film per unit area of arable land(C_{13})	0.197 5	0.052 8
			Livestock manure pollution load(C_14)	0.115 9	0.031 0
			Industrial "three wastes" load (C_15)	0.203 8	0.054 5

1.2 Determining of the indicator weight Using the analytic hierarchy process and entropy method[3], we get a subjective and objective comprehensive weighting result, to improve the credibility and accuracy of comprehensive evaluation of unsafe state. The weight of each indicator is listed in Table 1.

As can be seen from Table 1, in the 15 comprehensive evaluation indicators of unsafe state of arable land resources in Chengdu City, the top 5 indicators with large weight are per capita arable land area, basic arable land protection rate, the supplementary coefficient of arable land, grain yield, the share of arable land area in total land area, accounting for one third of total number of indicators, with the weight of 0.166 9, 0.095 5, 0.092 6, 0.078 6, 0.071 7, occupying 50.53% of total weight.

1.3 Evaluation model of unsafe state The single indicator and its weight just reflect one aspect of comprehensive evaluation objective. For comprehensive analysis, the operation and development of comprehensive evaluation system must apply a mathematical model to synthesize an overall comprehensive evaluation value[4]. This research uses the linear weighted method for the synthesis of the comprehensive evaluation.

The so-called linear weighted synthesis refers to the comprehensive evaluation using the linear weighted sum model. The model is as follows:

$$x = \sum_{j=1}^{m} w_j p_j \quad (1)$$

where x is the comprehensive evaluation value of the criteria layer; W_j is the weight of each individual indicator; P_j is the quantified value of single indicator.

$$Y = \sum_{i=1}^{m} w_i p_i \quad (2)$$

where Y is the total comprehensive evaluation value of system (or evaluation object); W_i is the weight of various types of criteria layer; x_i is the comprehensive evaluation value of individual criteria layer.

1.4 Analysis model of unsafe state We use the concept of "sensitivity" to analyze the changes in the unsafe state indicators of arable land. Sensitivity is the size of the contribution of the indicator to the improvement of unsafe state[5].

The degree of change in sensitivity can be expressed by the following formula:

$$S = (A_j - A)/A/100\% \quad (3)$$

where S represents the degree of change in sensitivity; A represents the evaluation value of arable land resources security in the base period; A_j represents the evaluation value of arable land resources security in the expected period. 1999 is regarded as the base period and 2010 is regarded as the expected period.

2 Evaluation results and analysis

2.1 Calculation of comprehensive value of arable land security Taking the districts under the jurisdiction of Chengdu City during the period 1999 – 2010 as the survey object, according to Census Report of Quality of Arable Land in Chengdu City, Sichuan Agricultural Statistics Yearbook, Statistical Yearbook of Chengdu, Chengdu Statistical Manual, Sichuan Statistical Year-

book and some data provided by Agricultural Commission of Chengdu and Chengdu Land and Resources Bureau.

Through collection, the data are substituted into equation (1), and the comprehensive evaluation value of unsafe state of arable land resources is calculated (Table 2).

Table 2 shows that during the period 1999 – 2010, the integrated value of arable land security in the study area presents an overall declining trend. The rate of decline of B_1 (amount of arable land) is the most evident, B_2 (quality of arable land) and B_3 (arable land ecological environment) show a volatile downward trend.

Table 2 The calculation results of integrated value of arable land resources security in Chengdu City during the period 1999 – 2010

Year	B_1	B_2	B_3	Integrated value	Year	B_1	B_2	B_3	Integrated value
1999	0.266 0	0.198 5	0.231 4	0.695 9	2005	0.074 2	0.138 4	0.111 5	0.324 1
2000	0.426 7	0.141 4	0.240 6	0.808 7	2006	0.045 9	0.173 9	0.061 8	0.281 6
2001	0.299 9	0.156 4	0.144 4	0.600 7	2007	0.052 6	0.143 3	0.059 2	0.255 1
2002	0.252 1	0.165 6	0.105 8	0.523 5	2008	0.034 0	0.160 4	0.042 7	0.237 1
2003	0.212 4	0.127 6	0.110 1	0.450 1	2009	0.028 7	0.164 7	0.063 9	0.257 3
2004	0.181 2	0.079 9	0.117 6	0.378 7	2010	0.012 8	0.171 8	0.080 2	0.264 8

2.2 Classification standard of unsafe state Currently, there is still no scientific and unified classification of unsafe state of arable land resources, so on the basis of the research results of Liu Youzhao[6], Lu Wenbin[7] and Wu Cifang[8], we refer to the similar domestic research methods, and use systematic method[9], to divide the unsafe state. Then appropriate adjustments are conducted through expert advice, to get the final comprehensive degree of unsafe state.

In accordance with the specific circumstances of Chengdu City, the standard of unsafe state degree of arable land resources is as follows: $x > 0.352$, safe state; $0.352 \geqslant x > 0.314$, slightly unsafe state; $0.314 \geqslant x > 0.275$, mildly unsafe state; $0.275 \geqslant x > 0.237$, severely unsafe state; $0.237 \geqslant x$, extremely unsafe state.

2.3 Evaluation results of unsafe state Based on the classification standard of unsafe state degree, we conduct comprehensive evaluation of unsafe state of arable land resources in Chengdu City during the period 1999 – 2010, and the results are shown in Table 3.

As can be seen from Table 3, the arable land resources system in Chengdu City showed unsafe state from 2005, reaching mildly unsafe state in 2006; it showed severely unsafe state for three consecutive years from 2007 to 2010, and the arable land resources situation is very grim.

Table 3 Evaluation results of unsafe state of arable land resources in Chengdu City

Year	Value of unsafe state	Degree of unsafe state	Year	Value of unsafe state	Degree of unsafe state
1999	0.695 9	Safe state	2005	0.3241	Slightly unsafe state
2000	0.808 7	Safe state	2006	0.2816	Mildly unsafe state
2001	0.600 7	Safe state	2007	0.2551	Severely unsafe state
2002	0.523 5	Safe state	2008	0.2371	Severely unsafe state
2003	0.450 1	Safe state	2009	0.2573	Severely unsafe state
2004	0.3787	Safe state	2010	0.2648	Severely unsafe state

2.4 Unsafe state analysis From Table 2 – 3, we see that the trend of integrated security value of arable land resources in Chengdu City is very similar to the trend of change in the security value of amount of arable land; the pressure of security of amount of arable land on total system of arable land resources in the whole city is obvious.

According to the amplitude, it can be further divided into three stages:

(1) The stage of steep rise in security value of arable land (1999 – 2000). From the composition of security value, the rise in the security value at this stage was mainly caused by rise in the comprehensive evaluation value of security of amount of arable land, and at this time, the state of arable land resources was the best in Chengdu City.

(2) The stage of continuing fall in security value of arable land (2000 – 2008). At this stage, the security value of arable land resources in Chengdu City declined incessantly, the security situation turned from favorable level to inferior level, and the level of unsafe state also turned from safe state to severely unsafe state.

(3) The stage of slight increase in security value of arable land (2008 – 2010). After reaching the level of severely unsafe state in 2008, the security value of arable land resources in 2009 and 2010 increased slightly, and the unsafe state of arable land resources in Chengdu City showed the possible trend of slowing. Through further investigation, we can find that the security value of quality of arable land and arable land ecological environment at this stage increased slightly; in other words, the weakening of unsafe state of arable land is based on the enhancement of quality of arable land and improvement of arable land ecological environment.

For the unsafe state of arable land resources in Chengdu City, we simulate the change in the unsafe state indicators of arable land and conduct comparative analysis of changes in value of the total system and subsystem of arable land resources, to find out the key factors influencing unsafe state, which can help to effectively eliminate the hidden trouble in the security state of arable land, and lay solid foundation for the rational decision-making and planning. Calculation results of sensitivity of unsafe state indicators of arable land in Chengdu City are shown in Table 4.

Table 4 shows that the sensitivity of 4 unsafe state indicators of amount of arable land is sequenced in descending order as follows: basic arable land protection rate, per capita arable land area, the share of arable land area in total land area, the area of low-yielding field. The sensitivity of 6 unsafe state indicators of quality

of arable land is sequenced in descending order as follows: effective irrigation area, the area of low-yielding field, the organic matter content in soil, the proportion of slope land with gradient more than 15 °, grain yield, cropping index. The sensitivity of 5 unsafe state indicators of arable land ecological environment is sequenced in descending order as follows: application rate of chemical fertilizer per unit area of arable land, application rate of pesticide per unit area of arable land, application rate of plastic film per unit area of arable land, industrial "three wastes" load, livestock manure pollution load.

Table 4 Calculation results of sensitivity of unsafe state indicators of arable land in Chengdu City

Item	Indicator	Sensitivity//%
Sensitivity of unsafe state of amount of arable land	Per capita arable land area(C_1)	10.39
	The supplementary coefficient of arable land(C_2)	0.19
	Basic arable land protection rate (C_3)	13.37
	The share of arable land area in total land area(C_4)	8.65
	Total	32.6
Sensitivity of unsafe state of quality of arable land	The area of low-yielding field(C_5)	6.53
	The organic matter content in soil(C_6)	4.65
	The proportion of slope land with gradient more than 15 °(C_7)	4.49
	Grain yield(C_8)	3.93
	Cropping index(C_9)	2.42
	Proportion of effective irrigation area(C_{10})	8.57
	Total	30.59
Sensitivity of unsafe state of arable land ecological environment	Application rate of pesticide per unit area of arable land(C_{11})	6.38
	Application rate of chemical fertilizer per unit area of arable land(C_{12})	8.23
	Application rate of plastic film per unit area of arable land(C_{13})	1.77
	Livestock manure pollution load(C_{14})	1.59
	Industrial "three wastes" load (C_{15})	1.66
	Total	19.63

Based on the size of unsafe state indicators, we exclude the indicators that can not be changed due to the objective factors, and seek experts' opinion. We believe that Chengdu has the ability in the short term to control the following key indicators: the share of arable land area in total land area, effective irrigation area, the area of low-yielding field, application rate of chemical fertilizer per unit area of arable land, application rate of pesticide per unit area of arable land.

3 Recommendations

3.1 Strengthening profound understanding of the seriousness of unsafe state of arable land In view of the grim situation of tense man – land relationship in Chengdu City, the imperative task is to raise awareness, change concepts, and be clearly aware of the seriousness of unsafe state of arable land. The arable land security is a social problem, and it must rely on the joint participation of the whole society. Such participation is built on the basis of general improvement in thinking and understanding.

Therefore, it is necessary to conduct positive publicity and education, to make the arable land protection awareness sink deep into the hearts of the people, have the sense of crisis of unsafe state of arable land, and make the whole society realize that the unsafe state of arable land resources has come to a very serious degree.

At the same time, we should strengthen the publicity of some laws and regulations such as Agricultural Law, Land Management Law and Basic Farmland Protection Ordinance, to enhance the legal concept of society as a whole; make people discard the old concept and erect the awareness of unexpected development, spurn the thinking of local interests; make people cherish and rationally use every inch of land, and effectively protect arable land. The concept of support is the premise of effectively taking other measures[10].

3.2 Strengthening the basic arable land protection Basic arable land is a part of farmland, and the arable land that can not be occupied for a long time according to the demand of national economy for agricultural products and construction land occupancy in a certain period of time[11]. Basic arable land protection area refers to the area delimited by the law for special protection of basic arable land, which is the basis of the arable land resources security. Due to good conditions of irrigation of arable land in Chengdu City, the arable land can maintain high yield in most of the years, but in recent years, due to economic development, agricultural restructuring, coupled with the occurrence of natural disasters and some other objective and subjective factors, some basic arable land is arbitrarily changed into other land use types, resulting in decrease in amount of basic arable land, and the quality of basic arable land whose function has been changed is reduced. Therefore, we must pay attention to the protection of basic arable land protection areas; establish sound and complete archives of basic arable land protection, put in place the responsibility of protection of basic arable land; strictly implement the Basic Farmland Protection Ordinance, implement arable land conservation and environmental protection system, and especially implement permanent protection of arable land with good conditions of production and high yield potential.

3.3 Continuing to tap the quality enhancement potential of arable land The good quality of arable land is the basis of improvement in the level of food production. The arable land output in Chengdu City still has potential for considerable mining space, and the substance of improving effective irrigation area and the area of low-yielding field is to improve the quality of arable land. So, we need to rely on scientific and technological means to increase agricultural inputs and continue to improve the quality of arable land and arable land output in Chengdu City.

Firstly, we should increase input into breeding, cultivation, soil improvement, biological control of pests and diseases; abandon the old way of relying on chemical fertilizer to increase yield; secondly, we should strengthen the comprehensive land management, renovate the irrigation and drainage system, build the farm track, strengthen water conservancy construction, develop efficient facility agriculture, to do a good job in rural infrastructure building; for the low-yielding fields, it is necessary to improve the soil, increase soil fertility, fully use the rich organic matter resources in the Chengdu Plain, and guide farmers to reasonably use organic fertilizers[12].

3.4 Consistently implementing the guideline and policy of "Combination of Use and Maintenance" Chengdu City should implement the guideline and policy of "Combination of Use and Maintenance", focus on the point of view of building large-scale farming, and improve the development of ecological agriculture[13-14], in order to eliminate the hazards of unsafe state from the source.

The focus is to promote the application of organic fertilizer, reduce the application of pesticides and chemical fertilizer, use scientific means to choose the best fertilizing and spraying time, improve the efficiency in the use of chemical fertilizers, and pesticides, reduce drug residues; establish clear system of agricultural environmental protection, comprehensively control the pollution problems in arable land, improve, repair and purify the soil with poor conditions.

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