

Research Progress of Land Ecological Security Evaluation in China

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Abstract

Land ecological security evaluation is not only the core and foundation of land resources' sustainable utilization, but also the key reference of land planning, management and protection of decision-making. Research on land ecological security evaluation has become a hot field in the land ecological security problems since the late 1990s. Based on lots of references after comprehensive analysis, the study progress and achievement of land ecological security evaluation are discussed in 3 aspects which are evaluation scale, evaluation index and evaluation methods in domestic country, indicating the following main problems: a) The spatial scale evaluation is not deep and wide, and the time scale evaluation most for static evaluation. b) Construction of index system has strong subjectivity c) Innovation and the comparison is lacked between the evaluation methods. Finally, this paper put forward that dynamic evaluation, objective evaluation indexes, integrated evaluation methods will be the future trends in the field of land eco-security evaluation.

Keywords: Land ecological security, Evaluation index, Evaluation methods

Land ecosystem provide the necessary basic material resources for human development, the number and quality of land resources is an important factor that decides the level of national security. In recent years, China's land issues, particularly land ecological problems such as soil erosion, desertification and land pollution, are an increasingly grim. At the same time, ecological damage of non-agricultural land also becomes increasingly serious. Land use is not carried out according to ecological laws has triggered a number of serious ecological problems, which had made the land ecosystem services declined, directly affecting China's sustainable socio-economic development (Like Liang, 2006).

The study on land ecological security has increasingly become the frontal topics of land resources sustainable use but what is the land eco-security is still no uniform definition. Different scholars have had different formulations. Launching a comprehensive study of land ecological security, land ecological security implications can be summarized as follows. Within a certain time and space, land ecosystem service function that human survival and development requires are not subject to or less damage and threat status, maintaining the land ecological environment instinct not impaired, but also their economic and social sustainable development is in good condition. Land ecological security evaluation is the fundamental work in this area, also the core and foundation of building a security pattern of land use and land-use patterns optimized with a great significance of study on land ecological construction and eco-friendly land use (Pei-jun Shi *et al.* 2002; Shi-liang Liu, 2007; Xiang-hao Zhong *et al.*, 2008). Since 90's of 20(th) Century, numerous scholars of the land ecological security evaluation have done a large number of studies from the theory to methods, focusing on evaluation index system and methods of evaluation, and monographic empirical research at different spatial and temporal scales. However, the land ecological security assessment involves a number of factors, the domestic research is still in the stage of exploration and practice (Jie Tang *et al.*, 2006). Therefore, this paper summarize up and review the evaluation scale, evaluation index system and evaluation approach of land ecological security, forecasting its development trend, and thus it is of great methodological significance, which may be useful for subsequent follow-up studies.

1. Research status of land ecological security evaluation

1.1 Evaluation Scale

Land ecological security evaluation mainly includes two aspects. ① The status evaluation of land and development of ecological security, analyzing the current situation and existing problems through land ecological security evaluation, and providing a gist for land resource sustainable development. ② Evaluation of the key factors affecting land ecological security, time and scale. Based on types and characteristics of the framework of ecosystem within the evaluation scale, selecting the appropriate representation factors to evaluate in order to take protective or restoration measures. Currently, land ecological safety assessment of China have shown the mainstream of space scales and the time scale for the branch, regional land ecological security assessment research as the core of the pattern (Hongxia Li, 2006; Jie-sheng Yao and Jing-yi Tian, 2007).

1.1.1 Evaluation of spatial scales

Since 90's of 20(th) Century, land ecological safety evaluation of China was carry out empirical research and continue to analyze in-depth. The choice of the size of spatial scale, upward and downward transform is an essential part of the research process. According to the evaluation scales of land ecological security, macroscopic scale (global scale, national scale, provincial scale, and river basin scale), medium-scale (city field-scale, county scale), microcosmic scale (blocks' scale) and so on. Land ecological security assessment may include a macro on a global scale, the concept on a national scale and micro-regional scale. China has carried out the land ecological security evaluation mainly included township and county (city), province and other administrative units as the data carrier, and a large regional scale as the research object(Keming Tian and Guoqiang Wang,2005;Yan-bo Qu *et al.*2008), also includes a variety of land use types (agricultural land, cultivated land, etc.) scale assessment, large regional scale, as the research object(Keming Tian and Guoqiang Wang,2005;Yan-bo Qu *et al.*2008),also includes the evaluation of a variety of land use types (agricultural land, cultivated land, etc.).

The study on township scale is less, so far, only Yue-qing Xu (2007) *et al*, Hui-yong Wang (2007) *et al.* and Yan-bo Qu *et al.*(2006) have made the relevant studies. Most researchers study on the evaluation of the county (city) scale as a carrier and in this based on the analysis of spatial and temporal differences. With the constant deepening of its studies on land ecological security evaluation, provincial-scale studies are more concentrated in recent years, such as Yu-ping Li *et al*, Xiao-hu Zhang *et al.* have done the provincial-scale evaluations(Yuping Li, Yun-long Cai, 2007; Xiaohu Zhang *et al.*,2009; Bo Li *et al.*,2008).Large regional-scale study include along river region(Huayong Li *et al.*,2009), the farming-pastoral zone(Hua-lin Xie,2008; Zhangpin Lin and Xiang-nan Liu,2002; Ying Ma,2007), mountains(Yanbo Qu *et al.*,2008), hilly area(Hongbo Zhang *et al.*,2007), lake(Ai-zhen Deng,2006)and so on, which usually focused on the evaluation of ecologically fragile zone. Ke-ming Tian (2005; 2007) *et al*, Hong-bo Zhu (2007) *et al*, also carry out studies on agricultural land and farmland ecological safety evaluation. Shi-liang Liu (2007) and others also launch a multi-scale assessment attempt to the typical fragile areas in Loess Plateau. However, studies on the national level evaluation almost do not involve.

1.1.2 Evaluation of time scales

At present, most studies in China have focused on a particular point in time assessment of regional land ecological security status that is static evaluation. Static evaluation does not reveal, however, a few years or decades, changes in trends and causal relationship of these changes(Hong-bo Zhang, 2007). Therefore, it is more important to evaluate the dynamics than to evaluate the land ecological security situation each point in time. According to land sustainable use evaluation, time scale of land ecological security is divided into short-term for 3-5 years, mid-term for 7-10 years and long-term for more than 10 years. Hong-bo Zhang *et al.*(2007) presented that dynamic evaluate methods based on condition evaluate model and trend analysis model, reflecting land ecological security state and changing trend on the time scale. Hong-bo Zhu *et al.*(2007)select 6 typical periods(1981,1985,1990,2000,2004) after reform-opening up to analysis the dynamic changing discipline of farmland ecological security. On the basis of pressure, state and response model, Hui-fei Wang *et al.* (2008) dynamic early warning evaluated and forecasted land ecological security of Xi'an city in 10 years.

1.2 Evaluation Index System

1.2.1 Establishment of Evaluation Index System

Because of in different ecological system and scale we evaluate land ecological security in different index elements, the establishment of evaluation index system is very complex and there are no unified standards in China. But there are some results in land quality evaluation index system and land sustainable evaluation index system research, which could provide the base and reference to establish the land ecological evaluation index

system (Hua-lin Xie, 2008). Zhi-guo Li points out that the studies of land ecological security evaluation mainly adopt system decomposition methods, which divided the land ecological system into many sub-systems, then to select suitable index to evaluate. At present system decomposition methods is mainly about 'Ecology (nature)-Economy (humanity)-Society (environment)' sub-systems. Most scholars established land ecological security index referring to Pressure-State-Response Model identified by the World Bank, Food and Agriculture Organization, the United Nations Development Program and United Nations Environment Program in the late 1980s (Tong C, 2000; Allen H, 1995). But the boundary between Pressure-State-Response is unclear, so we should combine this three index when analyzing. Therefore, on the basis of this situation, the improvement is:

- a) Driving-State-Response (DSR) Model
- b) Driving-Pressure-State-Expose-Effect-Response (DPSEER) Model (Ci-fang Wu, Haijun Bao, 2004; Xing Chen, *et al.*, 2005).
- c) Lei Zhu (2008) evaluates the land ecological security of Chun'an country in Zhejiang Province by Driving-Pressure-State-Influence-Response (DPSIR) Model.
- d) Xiao-yan Li *et al.* (2008) establish ecological security conceptual frameworks, that is Pressure (demand-driven)-Feedback (Ecosystem service)-Control (decompress) (PFC) conceptual model in the west of Jilin Province.
- e) Yan-bo Qu (2006) builds the small towns' land ecological security evaluation index system from economical security, towns' environmental safety, environmental safety of rural area under administration and the use of urban-rural resources.

1.2.2 Weight Determination of Indexes

According to the different data sources when calculating weight number, the method of weight determination of indexes is divided into two categories by scholars that are objective weighted model and subjective weighted model. Subjective weighted model is on the basis of expertise experiences such as Delphi method, AHP method and so on. Those methods are relatively mature but less objective. Weight number of subjective weighted model is formed by actual data of each index, which doesn't rely on objective judgment and more subjective such as principal component analysis, mean square methods, entropy method and so on (Jian-xin Zhang *et al.*, 2002). Lei Zhu *et al.* (2008) studies on determining the weight by variable weight theory, which could reflect the importance of indicator in complex situation than simply relying on AHP. The application of any mathematic methods has some requirements, limits, subjectivity and less flexibility, so we should choose the suitable methods to determine weight in accordance with actual situation (Shi-liang Liu *et al.*, 2007).

1.3 Evaluation Methodology

On the basis of absorbing the results of relative subjects and areas, there is a great progress in land ecological security evaluation, developing from qualitative description to quantitative study. Every evaluation methods start around evaluation steps, but determined by evaluation model. Different models evaluate differently.

1.3.1 Evaluation Methodology Based on Mathematical Model

Mathematical Model mainly contains synthetically index method, principal component analysis, analytic hierarchy process, fuzzy comprehensive evaluation, grey relation method, matter element analysis and so on. After summarizing relative research, mathematical models of land ecological security evaluation over these years are as follows (table 1).

Evaluation research initially mainly focus on single-index Model and synthetically index method. With the development of mathematic technology, evaluation methods were expanded in greater scope and depth. After 2006, the combination of mathematic methods, ecological methods and 3S technology is applied widely. Those two years, the integrative use of matter-element model and other models is the hot point of land ecological evaluation.

1.3.2 Evaluation Methodology Based on Ecology Model

Landscape ecology method and ecological model are the main methods in land ecological evaluation. With a view to relatively macroscopical requires, it is suitable to study land ecological security on space scale, and it could synthetically evaluates every potential ecological type on the viewpoint of ecological system structure. So landscape ecology methods become an important mean for land ecological evaluation (Hong Liu *et al.*, 2005). Hong-bo Zhang *et al.* (2006) deem that quantitative landscape ecological index is a worthy method to explore in the process of evaluate land ecological security. Bing Zhang *et al.* (2007) analysis the land ecological

security state in middle part of Gansu Province by landscape pattern change and landscape heterogeneous index, pointing out that it is possible to enhance the investigation of different level and scale relationships in order to understand inter mechanism of land ecological security.

At present, land resources carrying capacity method and ecological footprint method are the main method of ecological model. Yue-ping Zhang *et al.* (2004), Chao Liu(2008)study on land ecological security in provincial scale and city-field scale by land resources carrying capacity method. Xiu-jie Yang *et al.* (2005) study on the ecological security carrying capacity of Yunyang country in the Three Changjiang River Gorges. Rong-bao Zheng (2006) indicate that evaluating and anticipating ecological security in different scale by ecological model and artificial neural network method is the leading developed area in the future. This is the summarization of the characteristics of ecological methods. (Table 2)

1.3.3 Application of 3S Technology

There is a hot point in the combination of 3S Technology and mathematical model. Dynamic information extraction and monitoring by remote sensing were used as early as three decades ago. After 20 centuries 90's, there is a great progress in evaluate and monitor land degradation by remote sensing technology(Some book W. g. & Sims D,1995; Valle H. F. De. *et al.*,1998; Seixas J.,2002; Tripathy G. K, *et al.*,1996; David Mount, *et al.*,1997; Lambin E. F. & Strahler A. H.,1994; William G. Kepner, *et al.*,2000). Land ecological security valuating in China with 3S Technologies though starts late, but develops very quickly. Zhang-ping Lin *et al.* (2002) study on land ecological security mode in Farming-Pasture Zone of Northeastern China with GIS in 2002. With the development of 3S Technology, Hua-lin Xie (2008) evaluates land ecological security of typical farming-pastoral acetone, pointing that land ecological security is a syntheses of every element and every element can not stand for the whole result is safety. The combined action of every element leads to the final result. On the basis of spatial analysis the evaluation factor by GIS, Yan-bo Qu *et al.* (2008) establish the land ecological security evaluation mode with terrain as the leading factor. With RS and GIS, Xiao-yan Li *et al.* (2008) analyze different land use mode and ecological security zoning through interactive and visual interpretation. Lei Zhu *et al.* (2008) solve the problem that GIS software can't complete complex model on desktop module directly, providing a new approach for complicated operation in GIS.

2. Problems in land ecological security evaluation research

Base on the previous comprehensive analysis, though there are a large number of results in land ecological security evaluation by Chinese scholars, some problems still remain, too.

(1) It is difficult to operate for scale evaluation

In the course of spatial scale evaluation, as an evaluation of overall status, macroscopical evaluation taking administrative unit as the basic research unit could cover the underlying problems of land ecological security. The study on Vulnerable Ecotone is not deep enough. The study on Loess Plateau, Arid and Semi-arid Areas of Northwest China and Desert Area is more, thus the study on Red Earth Hilly Area of South China, Karst Area and other types of Vulnerable Ecotone is less. Lack of adherence to other land types evaluation besides arable and farm land, there are such different evaluation results in different scale that is lack of transform and comparison of different evaluation results.

Existing land ecological security assessment studies have mostly focused on the current development state assessment, while ignoring the evaluation of land ecological potential and co-ordinate degree. The research on time scale evaluation usually neglect there are different time scale in different spatial unit, different decision maker and content, different land ecological security problems and different impact factor. Different social-economic development phases values the state and measurement criteria of land ecological security differently, which leads the results can not objectively and comprehensively reflect fact of evaluation system.

(2) Indicators Selection is somewhat arbitrary

The problem in evaluation index system is: ①Level Division of evaluation index system is indistinct, Its Own Characteristics is not clear, the relation among index is crossing and overlapping.. ② Different understanding of land ecological security are explained by different index and methods, leading to diversity of index system, less comparable and limit to reference. ③ At present, most studies concentrate on researchers' point of view. Because different interests subject such as government, enterprise, mass, farmers and researchers focus on different problems, how to establish index system based on every interests subject is worth to think deeply. ④The problem of consistency in assessment indicators and scales is existing, too. The sensitivity of indicators would be decreased with scaling up, further research is needed for the sensitivity of single indicator with scale changed. ⑤

Different land use pattern has different land ecological problems, how to establish comprehensive index system with clear target is worth considering. ⑥ It is one of the difficulties to build objective evaluation criterion, determine the safety threshold especially the indicators safety threshold to reduce human factors in the progress of evaluate.

(3) Lack of innovation and comparison in methodologies

The comparison in methodologies and the integration of comprehensive analysis are lacked. At the same time, a horizontal comparison analysis of different effectiveness of methods is lacked, too. Using a variety of methods on the same objective and the overall evaluation results, sorting the results make a difference. It is more difficult for land carrying capacity method and ecological footprint analysis method at the provincial level or large-scale and other macro-level ecological security assessment research applications. Lack of a combination of research methods on sociology or economics, making the results of the land ecological security evaluation is difficult to serve the land ecological security patterns and policies.

3. Prospects for the Study of Land Ecological Security Evaluation in China

Land ecological security evaluation is a way to improve the status quo of land ecosystem and establish a long-term ecological security of land protection, maintenance and management mechanism. At present overseas research focuses on microeconomic point of view such as soil quality evaluation in natural science point of view, and ultimately serves the optimization of land use patterns. Of course, the evaluation itself does not determine the manner of land use, land ecological security evaluation should be a key influence for this choice of implementation (Vondi Nkana J C. & Tonye J., 2003; Jonathan B & Butcher., 1999; Johnes P. J. *et al.*, 2007; Siim Veski *et al.*, 2005; Jesse Bellemare *et al.*, 2002; Bai-ming Chen, 1996). China should make its own characteristics and contributions in the field of land ecological security evaluation based on making use of macro-evaluation advantages and combining features of China's land resources.

The development of land ecological security assessment research should be based on the development of the theory of land ecological security as a foundation. Only the theoretical is developing and continuously improving and mature, it will provide a solid theoretical support for the empirical evaluation studies. Therefore, strengthening the theoretical basis of land ecological security is the cornerstone of research and long-term guarantee of the development.

About evaluation of spatial scales, we should strengthen the evaluation of multi-level, sub-regional, various types of land and Ecotone. Fully operational on the evaluation studies on agricultural land, construction land, small towns, urban fringe, particularly in less developed regions in the western urban fringe. In addition, in the context of urban and rural co-ordinate, it is a future development direction to strengthen the coordinate regulation of different spatial scales. On evaluation of time scales, the transform from static evaluation of the status quo to evaluation of dynamic early warning is the trend for future research.

To establish a unified, mature, scientific land ecological security assessment index system, evaluation index should be divided into levels and types, distinguishing evaluation index system between different land use types, explicating the contents of evaluation index system on the various scales, the guidelines depending on the specific issues, to carry out the evaluation index system based on 3S technology. Giving full consideration to the vast differences in various regions of China's natural, social and economic situation, we constitute scientific and rational assessment criteria according to local conditions. For the regions where conditions permit, we could establish a sound expert decision-making system, combining with mathematical models to determine the index weight and safety threshold.

Integration of evaluation method is the trend in future. An evaluation for the same object, we could try to use various methods and comparing mutual authentication, which will help to comprehensively grasp spatial variability of the characteristics and rules of the scale effect of the study object. Using a mathematical model evaluation, improvement and innovation of the model methods, such as improved comprehensive evaluation method, improved AHP (Analytic Hierarchy Process) and so on, will be more objectively reflected the land ecological security and increased the accuracy of evaluation studies. In addition, the combination of modern science technology, supported by 3S technology, the use of satellite spectral data and information and digital environmental information to the study on identification and evaluation the natural and social - economic factors of land ecological security and the dynamic monitoring of long-term future is also direction of development. At the same time, we must conscious, targeted use of sociology or economic research methods, exchanging and combining on the method between natural sciences and social sciences to form a methodology to solve practical problems

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Table 1. The main mathematical model that scholars have recently evaluated land ecological security in China

Year	Method	Character	Context	Researcher
2002	Synthetical index method; GIS	It cannot distinguish differentiation of single-index, but simple, objective.	A Case Study on Land Use Pattern under Ecological Security in Ecotone between Agriculture and Animal Husbandry in Northeastern China	Zhan-ping Lin <i>et al.</i> (2002)
2003	Main-element projection	Eliminate information overlapping of the sample. Reflect a full and correct degree of closeness between testing sample and ideal sample(Zhang-pin Lin & Xiang-nan Liu,2002)	Principal Component Project Applied to Evaluation of Regional Ecologic Security	Kai-ya Wu <i>et al.</i> (2003)
2004	Fuzzy related model; Fuzzy clustering methods; GIS	Solving the problem of fuzzy and uncertainty, but it cannot solve information overlapping among index. It is verbose to definite membership by multi-objective model(Run-qiu Li, Shi-liang Shi & Xin Peng,2008)	Assessment of Ecological Security and Adjustment of Land Use in Xilinhaote City of Inner Mongolia	Jin-fa Lu <i>et al.</i> (2004)
2005	Single-index Model Synthetical index method	Obtain the security level of each index and the totality simultaneously. Fully reflect ecological security level.	Evaluation on Ecological Security of Regional Land Resource—A Case Study of Center District of Zaozhuang, Shandong Province	Gui-qin Gao <i>et al.</i> (2005)
2006	Q-type Cluster Analysis, Principal component analysis	Solve the multilevel and multi-factor problem. Combination of qualitative and quantitative and location. Combination of language, graphic and mathematical models. (Yong-sheng Yang <i>et al.</i> ,2006) Fully consider the influence of multi-factor. Deal with the information that is part of the clear, some are not clear and the relevance of large systems. Be able to give an objective rating of system grade (Run-qiu Li, Shi-liang Shi & Xin Peng,2008)	Study on Quantitative Model of Land Ecological Evaluation System in Bashan Reservoir Area	Yong-sheng Yang <i>et al.</i> (2006)
2007	Grey relation method	To overcome the multi-angle, multi-factor identification of subjective one-sidedness, but the choice of correlation function is less, value range is defined difficultly(Hong-bo Zhang, Li-ming Liu, Jun-lian Zhang, <i>et al.</i> ,2007).	The Assessment on the Ecological Security of Land Use in the Farming-Pastoral Zone of Northern China	Ying Ma(2007)
2008	Fuzzy matter-element model		Assessment on Ecological Security of Regional Land Resources based on Multidimensional Data	Lei Zhu <i>et al.</i> (2008)
2009	Attribute recognition model	Classification and ordination of researching objects, it could make a correct classification even subordinate degrees of evaluation criteria at the same level is similar(Wen-hui Luo, Qing Zhao, Qian-kun Wang, <i>et al.</i> ,2009)	Regional Land Ecological Security Evaluation Based on Attribute Recognition Model—Case Study Xuzhou City	Wen-hui Luo <i>et al.</i> (2009)

Table 2. Characteristics of ecological methods

Name	Strong point	Weak point
Landscape ecology method	To reveal the stability of land ecological space by LUCC. To connect the change of special structure and globe, to combine the process and state, to integrate special structure, function, ecological fluidity, to analysis land ecological function, biodiversity and so on(Rong-bao Zheng.2006).	Limit by technology and method, the judgment of landscape element is immature now.(Rong-bao Zheng.2006)
Land resources carrying capacity method	Explain the essence of land ecological security to a certain degree (Xiao-yan Li, Lin-fu Xue & Xi-kui Wang, 2008).	The requirement of parameter is more, and the calculation is complex, and it is too difficult to obtain (Xiao-yan Li, Lin-fu Xue & Xi-kui Wang, 2008).
Ecological model	The concept is clear, the train of thought is new, calculation is simple, information content is big, and it is easy to obtain the data (Zhi-hua Chang, <i>et al.</i> ,2006).	It can not reflect every aspect of sustainable development. It is a static analytic method, the result is conservative and it is slow to change insensitively. (Zhi-hua Chang, <i>et al.</i> , 2006).
Ecological footprint method		