中

# 区域生态保护

## 生态系统结构、过程与功能

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中国环境科学出版社

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# 献　　给

## 中国环境科学研究院成立三十周年

# 《区域生态保护论文集》（2000—2008）
# 编委会

# 序　一

生态环境是人类生存与发展的基础。目前，陆地上80%的生态系统因人类干扰和自然变化而发生改变或退化。我国社会经济飞速发展，用短短几十年的时间走完了发达国家上百年的路程，大规模的资源开发和高强度的人类活动，使得生态环境遭到了严重的破坏。保护与修复各类生态系统已成为我国当前重大的环境科技需求。

中国环境科学研究院是国家级大型综合性环境科研机构。建院30年来，为适应国家环境管理需要，开展了大量环境管理和实用技术的研究与开发，为国家环境管理决策提供了雄厚的技术支持。随着环境问题的全球化、多样化和复杂化，中国环境科学研究院顺应时代要求，积极探索科研体制改革的新路子，以“自然和谐、厚积薄发”为理念，致力于全球性、区域性、综合性和战略性的环境科学问题研究，在生态环境、水环境、大气环境、固体废弃物等问题研究方面逐步形成了学科特色与优势。

生态所是中国环境科学研究院最早成立的二级科研单位之一，也是国家公益性科研事业单位科技改革首批试点单位之一。相继成立了“区域与城市生态保护”和“环境变化生态系统效应”二个创新基地，学科方向涉及生态监测与评估、生态格局与过程、生态系统服务功能、生态规划与修复、生态系统效应以及生态多样性与生物安全等领域。在开展区域生态保护与管理技术研究的同时，不断加强全球和流域尺度的生态保护与管理科学研究。承担了多个国家重大基础性研究项目、国际合作研究项目以及地方政府应用咨询项目，产出了丰硕的成果。生态所已经成为国内区域生态领域的知名研究队伍，有力地支撑了国家和地方的生态环境管理工作。

本论文集汇编了生态所科研工作者2000—2008年间正式发表的主要论文，论文聚焦生态学领域的热点、难点，展现创新思路和实用技术，对推动我国生态环境保护理论研究与实践应用具有重要的意义。

中国环境科学研究院　院长　  　研究员

2008年12月20日

# 序　二

2008年是值得成千上万科技工作者精神振奋的一年。在改革开放起步的30年前，我国科学史上的空前盛会——全国科学大会胜利召开。邓小平同志在大会开幕式上发表了重要讲话，向全党全国发出了“向科学技术现代化进军”的号召，明确提出了“现代化的关键是科学技术现代化”、“知识分子是工人阶级的一部分”的著名论断，重申了“科学技术是生产力”这一马克思主义的基本观点。这次大会彻底解放了中国的知识分子，解放了中国的科学，迎来了科学技术事业大发展的春天。

沐浴着改革开放的明媚春光，中国环境科学研究院也走过了30个不平凡的春秋。30年来，环科院几经改革，在开展基础研究的同时，逐步形成了学科优势与特色，为国家环境管理提供了重要技术支持。生态所是环科院最早成立的研究所之一，陆续在污染生态、区域生态、生物多样性保护以及气候变化的生态效应等领域开展了大量研究工作，取得了丰硕成果。

2002年，为响应国家公益性科研事业单位改革的需求，生态所成为环科院首批改革试点单位，相继成立了区域与城市生态保护创新基地和生态效应创新基地。经过短短几年的建设，科研实力不断提升，取得了令人瞩目的成就。这本论文集涉及生态监测与评价、生态系统结构、过程与功能、生态效应与生态规划等多个方面的内容，全面体现了生态所探索和发展区域生态学理论及其应用技术的翔实过程。

区域生态学是近几十年应频发的大尺度生态问题而兴起的新的生态学分支，基础理论尚未建立，研究方法尚不成熟，许多难题尚待解决。此时此刻能够看到这本论文集，我感到非常欣慰并引以为豪。生态所的科研工作者们在局地野外监测和大尺度遥感监测技术上，在流域和区域等多尺度生态过程和结构研究上，在生态现状评估和规划方法以及生态修复技术上，都展现出了成熟的、与国际接轨的研究水平。

没有最好，只有更好。区域生态保护研究依旧任重而道远，希望中国环科院生态所能够把取得的研究成果作为新的起点，瞄准生态学发展前沿，秉承勇于探索、勤于实践的科学精神，发扬“两弹一星”和载人航天精神，凝聚各方面的智慧和力量，提高自主创新能力，为维护国家生态安全提供坚实的科技支撑；希望能够以生态文明建设为契机，以促进环境保护三个历史性转变为动力，戒骄戒躁，再接再厉，再创辉煌。

金鉴明

2008年12月于北京

# 目　录
# Contents

# 生态系统结构、过程与功能

# Key issues on watershed ecological security assessment*

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**Abstract**: Based on analyses of key issues concerning watershed ecological security assessment including the subject, content, and methodology of assessment, this paper points out that ecological security should be assessed dynamically at different levels (e. g. watershed and ecosystem levels) with human being as the main assessment subject. Both the functional security and the structural security must be considered in watershed ecological security assessment. In order to reflect the overall and timely security status of the watershed, the PSR (pressure – state – response) method should be employed. Longitudinal Range – Gorge Region (LRGR) was researched as an example. An index system of watershed ecological security assessment has been proposed, which includes structural index, functional index, pressure and response index, and the state of ecological security is analyzed for LRGR in Yunnan Province.

**Key Words**: ecological security; assessment; Longitudinal Range-Gorge Region

Ecological security is an important aspect of the national security, and more and more facts have shown that ecological security is one of the most important bases of national security[1-3]. As a result, countries all over the world, especially developing countries, have paid great attention to ecological security[4-6]. Since the 1990s, a great deal of research has been done in China to study ecological security assessment, and some important results have been obtained[7-13]. Nevertheless, research on ecological security is still at the level of constructing oconcept system and discussing assessment methods, and no good index system and assessment method have been established. The reason is that no consensus has been reached among different researchers regarding some basic questions such as the concept of ecological security, assessment scale, assessment subjects and assessment contents[13-15]. The underlying reason is that no profound anatomy on key issues of ecological security.

Thus, upon analysis at the scale of watershed, this paper raises a series of key issues concerning regional ecological security assessment, including scale, subject, method and index system of the assessment. This paper tries to propose a relatively comprehensive and consistent framework for watershed ecological security assessment, which hopefully may provide some basic theories and methods as guidance to full scale watershed ecological assessment in China. On top of the study on theories, this paper takes LRGR as a case study, where the theories are applied for a-

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nalysis.

## 1 Key points of watershed ecological security assessment

### 1.1 The main subjects of watershed ecological security assessment

Ecological security is proposed to address the insecurity of ecology when human survival is threatened and human development is restricted by resources and environment. The ecological security therefore implicates that human is its main subjects. Therefore, generally speaking ecological security is human-oriented, in other words, human is the main subject of ecological security assessment.

Treating human as the main subjects is more important for the security assessment of watershed because, although biodiversity conservation is probably very important for local regions, the core factor of the whole watershed must be the human society. The main subjects of the watershed ecological security assessment must be human.

However, it should be clear that biodiversity is essential to human survival and development and it is an important aspect of ecological security. Under the present situation when biodiversity cannot be well conserved and is threatening human survival and development, biodiversity security must be considered as an integral element of ecological security. At the scale of watershed particularly, two factors of biodiversity, namely species security and eco – system security, shall be first ensured.

### 1.2 The spatial scale of watershed ecological security assessment

The ecological security assessment can be done at different scales. In the sense of spatial scales, ecological units can have several levels including biosphere, region, landscape, ecosystem, community and species. The study on ecological security whereas is meant for slightly different aim, therefore is usually carried out at global, national, watershed, ecosystem and species levels[16-18].

Since ecological security at a lower-level is the precondition and basis for that at a higher-level, the assessment of higher-level ecological security should take into account the assessment of lower-level ecological security. As a result, in addition to consideration at the whole watershed level, watershed ecological security assessment cannot do without consideration of ecosystem heath and species security.

Another important factor of watershed ecological security assessment at the space scale is the regional spatial characteristics of the watershed. The ecological security of the upper reaches of a river does not equal that of the lower reaches, and vice *versa*. The spatial harmonization and common ecological security between the upper, middle and lower reaches of a river are extremely important, and the ecological security at the upper reach is particularly important to that at the lower reaches of the river. It is therefore worth noticing that watershed ecological security assessment shall not only be carried out at various ecological unit levels, but also at least be done at three spatial levels of upper, middle and lower reaches of the riven[19-21].

### 1.3 Relativity and dynamics of watershed ecological security assessment

Ecological security is a relative concept. There is no absolute security, but only relative security in the world. The differences in environmental condition, custom and social development level result in differences in livelihood and degree of satisfaction of different communities, which in turn determine the differences in understanding and significance of ecological security[22,23]. So, different benchmarks and standards should be employed in watershed ecological security assessment for different regions and human groups.

Ecological security is a dynamic concept too. No ecological security, either at the watershed level or at the national level, can be ensured once and for all. It can be changed either from safety to unsafety or from unsafety to safety. The human survival and development have been threatened with deterioration of global environment, which results in continuous change in security degree. Moreover, human life quality and demands are changing with the development of human society, and the degree of ecological security is changing correspondingly. Therefore, watershed ecological security assessment should be analyzed dynamically and historcally.

### 1.4 Adjustability of watershed ecological security assessment

Ecological security is adjustable. Unsafe situation and region can be changed to safe ones through human's measures and self-adjustments, which can reduce unsafe factors and change unsafe situation to safe[24~26]. Therefore, the adjustability must be considered in watershed ecological security assessment.

## 2 Key points on the content of watershed ecological security assessment

As is talked above, the concept of ecological security has been raised as the resources and environment are not able to secure human survival and development. Therefore, previous studies on ecological security have focused on the aspects of the security of ecological functions. However, since structural security is the basis of ecological function security and suitable structure is the premise of sound ecological functions, it is not sufficient to study only function security without considering structural security. In fact, to a certain extent, structural security is more important than function security for an ecosystem or a watershed because normal functions can only be achieved and sustained with appropriate structures. Thus, structural security and function security must be considered in the study of watershed ecological security assessment[27~28].

### 2.1 Structural security

Structural security means sound ecosystem structure and sound relationship between ecological elements and components. For watershed ecosystem, structure security should be considered from three aspects: human-land structure, land-land structure and biology-land structure. The human-land structure means the relationship between human and land use, and the ways and degree in which human uses land in a watershed scope. The land-land structure means the relationship among different parts of a watershed, especially between the upper and middle reaches, the middle and lower reaches of the river. The biology-land structure means the relationship between biodiversity conservation and land in the watershed. Only when the relationships between

different reaches of a river, between human and land and between biodiversity conservation and land are harmonious and sound, can the overall, integral and harmonious development as well as the ecological security be safeguarded in the watershed[29~31] (Figure 1).

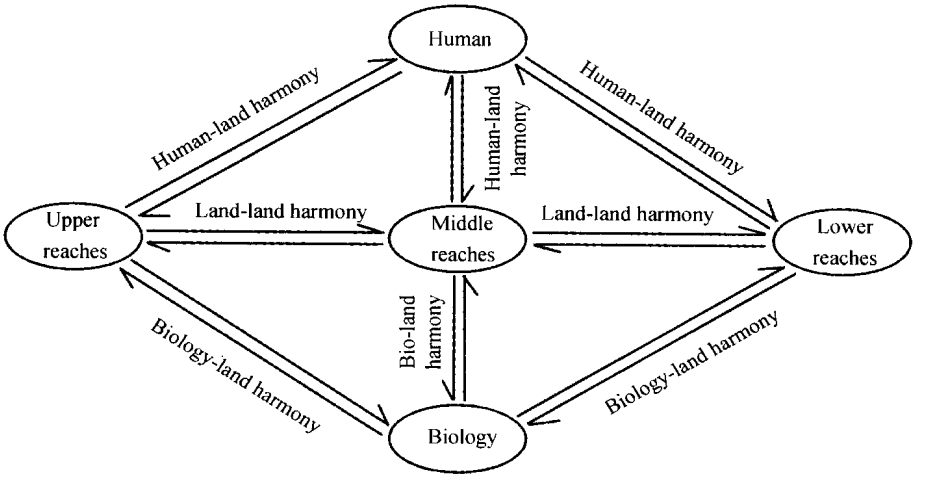


**Fig. 1 Framework of ecological security in a watershed**

## 2.2 Function security

The basic condition of watershed ecological function security is that, through material and energy exchanges inside and outside the whole watershed and every ecosystem or ecological units, all kinds of resources needed for human survival and development can be provided, all kinds of waste discharged in human life and production can be absorbed, sustainable development of human society can be sustained, and biodiversity conservation demands can also be met[32~35]. Harmonizing regional ecological functions is another key issue of watershed ecological security. For example, if the upper reach of rivers only takes its own development into account, but ignores the security and development of middle and lower reaches of the river, this watershed ecology will not be safe[36,37], and *vice versa*. So, the key to the watershed ecological security is to set up appropriate functions for different reaches of the river according to the overall resource and environment conditions in the whole watershed in order to maximize the ecological function of the whole watershed.

As a result, watershed ecological function security is achieved if the following aspects are true. Vertically speaking, the ecological functions of upper, middle and lower reaches of a river match each other. In the sense of service objects, the watershed shall be able to not only maintain human survival and development, but also satisfy biodiversity conservation. In the sense of service type the watershed provides, it shall have the functions of land production, water supply, environmental carrying capacity, environmental adjustability and biodiversity conservation (Figure 2).

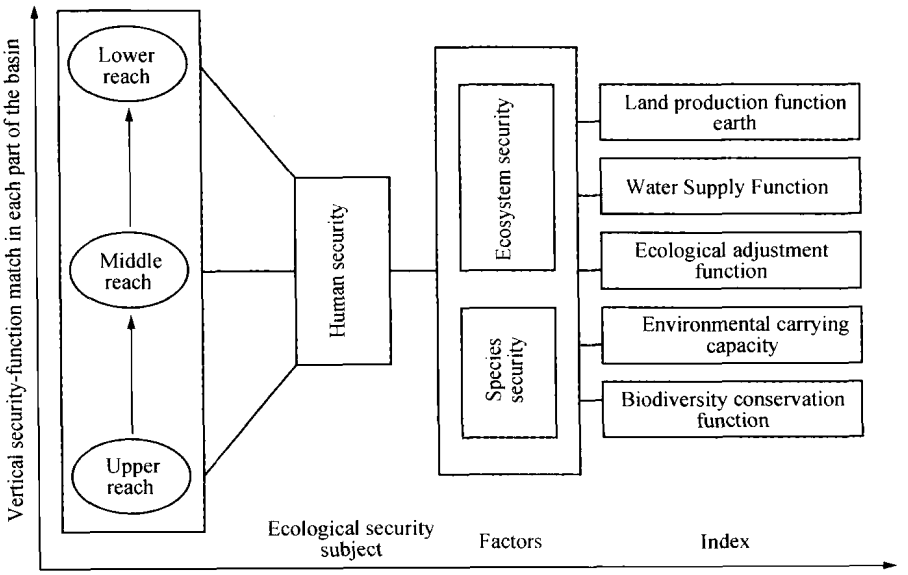


**Fig. 2 Horizontal security to satisfy human demands and biodiversity conservation need**

## 3 Key points on technics of watershed ecological security assessment

In the system of pressure-state-response (PSR), pressure is the prime driver for ecosystem changes, while response is the measures adopted to adapt to the ecosystem changes[38—45]. So, watershed ecological security should accord with two conditions. Firstly, pressure must be within threshold. Secondly, systems can response in time when inside and outside conditions of the system change. Therefore, pressure in the endurable range is a precondition for ecological security. Then under the pressure, security condition is decided by the timely response measure. Watershed ecological security assessment should be studied within the system of pressure security, state security, and response security.

However, the system of PRS cannot reflect a watershed ecological security state completely. PRS aims at an ecological unit or an ecosystem. The watershed ecological security can be evaluated from the harmonization between upper, middle, and lower reaches of a river. Thereby, watershed ecological security should be evaluated both vertically and horizontally (Figures 1 and 3).

### 3.1 Pressure assessment

Pressure is the power for social development. However, it is just pressure that changes a safe region into unsafe, and *vice verse*[46]. So if pressure is beyond the critical point of a system, the system would break down. The driving force which has affected the whole process of human society in the history can be divided into human factors and natural factors. Therefore, ecological security pressure can also be assessed from these two as pects.

3.1.1 Human factors

Human factors include the variation in population size, continuous development of economy and

progress of the society. Watershed ecological security can therefore be studied from the three aspects.

3.1.2 Natural factors

Natural factors which affect ecological security are different in different historical periods. In the human history, several great environmental evolvements have been caused by natural changes. At present, global climate change, including changes in temperature and precipitation, is the main pressure for human ecological security. So temperature and precipitation are the main natural factors affecting watershed ecological security.

### 3.2 State assessment

State security which includes structural security and functional security is the basis and core of ecological security[47,48]. Therefore, assessment of state security should be done from these two sides as discussed before.

### 3.3 Response assessment

Response is the ability of a system to respond to changes both inside and outside the system, and is the hinge of ecological security.

Whether change is caused by human activities or natural pressures, as long as human beings can take appropriate and effective measures to address the changes, the ecological security can be maintained. Otherwise, ecological security may change into ecological insecurity[47,48], and the ecological security would be in danger. Response can reflect directly or response to the pressure directly, so the response assessment can be done on both the pressure response side and the state response side.

3.3.1 State response

State response means inner adjustment or some measures taken to adapt to the changes when the state of the ecosystem changes. Human being can adapt to the change by adjusting its state once the inner conditions of the system have changed, and can therefore maintain themselves at the safe state. So, the state adjustment is one of the important measures to ensure the ecological security.

3.3.2 Pressure response

Pressure response means the reaction of the system to the changes when in pressure. Pressure is the basic factor which changed watershed ecosystem from unsafe state to safe state. Timely response to pressures and effective measures therefore are fundamental to adjust sustainable development in the whole watershed.

## 4 The outline of establishing index for watershed ecological security assessment

Assessment index system is the basis of ecological security assessment and the selection of index has direct impact on the assessment results. Following the principle of integration, pertinency, science, expressive and measurable features and maneuverability, the system of watershed ecological security assessment index is established, which consists of structure security, function

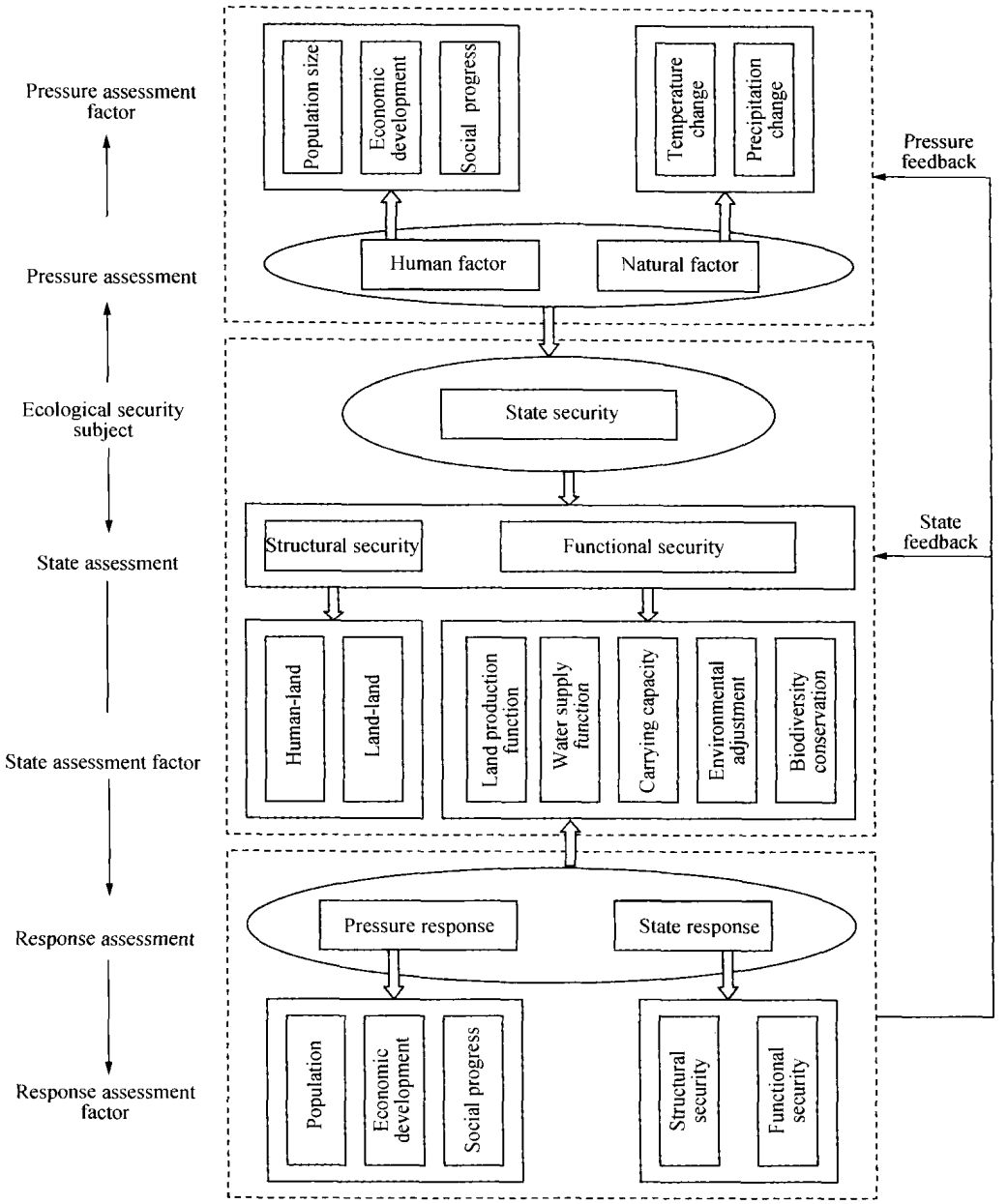


**Fig. 3 Framework plot to show watershed ecological security assessment**

security, human pressure, natural pressure, state response and pressure response. The indexes and principle of selection are as follows.

### 4.1 State index

The system of state assessment index is established from ecosystem structure and function, which is shown in Figure 4.

4.1.1 Structure index

(1) Human-land structure index: Comprehensive studies have demonstrated that human-land