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Foundation of regional ecology and its methodologies

Ye Changming

Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Abstract— In this paper, the conceptions, basic contents, foundations and methodologies of regional ecology were discussed. The study mainly includes the structure, function, quality monitoring, assessment, simulation, prediction, management and protection of regional ecosystem. The theoretical foundations of regional ecology are mainly theories of general ecology, normal site, dissipative structure and integrated macro-chemistry, and the methodology of regional ecology has regional, comprehensive, systematic, optimal, quantitative and practical characteristics. The situation of regional ecology research in China is also introduced here.

Keywords: regional ecology; fundamentals; methodology; China.

1 Introduction

The word region in this paper means a natural geographic entity of different scale or a social economic district with human activity, such as a forest, a piece of grassland, a river catchment, a lake, an industrial or mineral area, an agricultural or pastoral area or an economic technological development district. The specification of a region is mainly based on characteristics of natural and social ecologies of the region, rather than administrative division. On the basis of structure, function and distribution feature of regional constituent elements, every region can be partitioned as felder, corridor and matrix. Among these components, felder is the basic one.

When a region composing of felder, corridor and matrix is studied from the view point of ecology, the impact of human exploitation and development activities on structure, function, shape and distribution of region space unit must be taken into account. In a region system, human being is usually considered as a main block for exploiting and protecting resources and maintaining and regulating ecology, the object acted up on by human activity is treated as carrier. To coordinate relationship between the main block and the carrier of a region, that is to control the interaction of humanity, resources and environment and ecological effects caused by the reaction is the major problems solved by regional ecology.

Experiences in the advancement of ecology studies indicate that only by considering comprehensively place of every part in the whole from the view point of the overall region, can mutual relation among parts be seized correctly, and the eco-environmental construction planning and engineering measures be given play to their most integrated benefit. At the beginning of 1980s, Professor Ma Shijun, a famous ecologist of China, founded the natural-social-economic compound ecological theory, to play a theoretical foundation for regional ecology.

In the present paper, we do not intend to concentrate our effort on terms, terminologies, conceptions and definitions, but have a preference for discussing basic theories of regional ecology and its methodology characteristics from practical requirements.

2 Basic contents of regional ecology research

Regional ecology aims at conducting multi - disciplinary studies on the correlation among physical, chemical, biological and socio - economic factors in regional ecosystems and advanced studies in theory and methods of recovering and rebuilding of regional eco - environment, focusing on ecological and environmental problems in regional development, impacts of global change on regional eco - environment and response strategies for the prevention and control of environmental pollution.

2.1 Structure and function of regional ecosystem

Different region has different ecological and chemical structures which have different functions and utilization orientation. By the structure of regional ecosystem we mean the space scale and its order grade. What is called function of a regional ecosystem is mainly exchange of matter, energy and information in the system or between the system and the external world, and different changes and characteristics within the system as affected by the exchange. Study on structure and function of ecosystem has an important significance for planning regional ecological construction and protecting regional environment.

2.2 Quality monitoring and assessment of regional ecosystem

Regional ecology is a research field of multimedia, multi - interface and complex system. In order to recognize directly the component, structure and quality of regional ecosystem, population, resources, economy, environment and their changes caused by human activities, a study on quality monitoring and assessment of regional ecosystem must be conducted, including design and establishment of regional ecological monitoring station network, data collection, establishment of data base and assessment models and quality evaluation. This type of study can supply regional eco - environmental prediction and management with basic information and scientific basis.

2.3 Simulation and prediction of regional ecosystem

Regional ecosystem is a system with three phases (gaseous, liquid and solid) and four dimensions (longitudinal, lateral, vertical and time). The outstanding characteristics of this system is changeable with the lapse of time. The system state sometimes can be monitored directly. This situation needs to be simulated and predicted more accurately in order to understand the development tendency of the system.

2.4 Management and protection of regional ecosystem

Regional ecosystem is a comprehensive territory resource for sustainable development of a region. For the sake of utilizing these resources sustainable and strengthening function of the system, measures must be adopted to protect the regional eco - environment, including technical, engineering, policy and management. Among them management is an economical and effective measure.

The above - mentioned study contents relate to three stages of regional economic develop

ment. They are study on ecological problems in earlier stage of regional economic development; study on ecological problems of territory realignment in an economically developed region; study on ecological problem prediction and warning in future developments of a region.

3 Theoretical fundamentals of regional ecology

Owing to the fact that regional ecology is a multi - disciplinary comprehensive subject, its fundamental theory is also diversified.

3.1 General ecological theory

Because regional ecology is one of the main branches of ecology, it should follow general ecological theories which include biological evolution and diversity theories. The general ecological theory places emphasis on macro - ecological points of integration, comprehension, harmonization, stabilization and protection to lead to ecological evolution theory, the character of which is that biology and environment make a joint evolution.

The symbiosis of human society and nature is an important theory for recognizing nature and its own position in universe.

3.2 Normal site theory

The normal site exists opposite internormal, extranormal and paranormal sites. What is called normal site is a smooth location which can reflect water and warm conditions of large climate and can develop soil and vegetation suitable to the climate. The normal site theory is very important for regional ecological classification and can link vertical and longitudinal structures of an ecosystem in order to recognize ecosystem space interaction and time evolution.

3.3 Dissipative structure theory

Regional ecosystem is an open system which can be described by dissipative structure theory. This theory says that elements of the system are in a non - sequential stochastic state when the system is in a thermal and chemical equilibrium state; the system is linear non - equilibrium when it is in a near thermal and chemical equilibrium; and the system is in a nonlinear and stochastic uncertain state when it is far from the thermal and chemical equilibrium. This nonlinear stochastic state can become a new dynamic steady sequential state structure because of the self - organization of the system.

3.4 Theory of integrated macro - chemistry

As an important branch of integrated chemistry, biogeochemistry play an important role in regional ecological research. The biogeochemistry is developed on the basis of organic chemistry, biochemistry and geochemistry. The core is cycle, evolution and equilibrium theories of biogeochemistry which aims at conducting study on transportation, concentration, dispersion and biological effect of chemical elements in the earth's surface of a region.

4 Methodology characteristics of regional ecology

Regional ecology is a comprehensive study field of which the research method must also be comprehensive. To sum up, it is the combination of macroscopic and microscopic studies, integration of software and hardware scientific researches and union of qualitative and quantitative

studies. Some of the methodological characteristics of regional ecology are as follows.

4.1 Regional character

Division of region in regional ecological research should consider both administrative, natural and economic units. Regional ecology can study ecological problems of a region with the aid of geographical research methods, such as remote sensing technology, map - making technology and GIS (geography information system). The emphasis of the character of these methods is on the scale effect and selection which depends on the object of study and the problems solved.

4.2 Comprehensive character

Ecological and environmental problems of a region frequently involve several disciplinary methods, such as chemistry, biology, geography and so on. So the research method of regional ecology should have a comprehensive character.

Complexity of regional ecological problems requires comprehensiveness of methodology. Practices show that only by using various technologies and administrative measures integrately, can each single method exist itself efficiently. In brief, study on regional ecology is a synthetical system of comprehensive survey, assessment, treatment and management.

Fig. 1 shows an example of the total flow in the Cone Spring ecosystem (Tilly, 1968). This is a simple example of a method of systematic analysis .

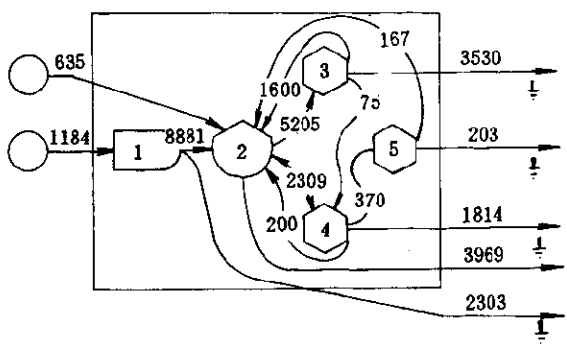

Fig. 1 Energy flow in Cone Spring ecosystem, kcal/(m^2. a)

1: autotrophs 2: detritus 3: bacteria 4: detritus feeders

5: carnivores, ground symbols represent losses to respiration

The input - output analysis (IOA) has been fashioned by economists to answer questions about indirect effects of initial supplies or final demands upon sectors of the economy. Until now the mathematical framework of IOA has been applied intact by ecologists to study indirect effect in ecosystems. The actual amounts of direct and indirect flows between compartments may be portrayed explicitly as the components of a matrix of total flow.

A satellite design for integrated regional environmental modelling is a structure analysis method with qualitative information (+ or −) which comes from a matrix. It has become an

important tool in analyzing complex integrated model and is useful for identifying directional effective relation of variables. Fig. 2 indicates the simple situation of the analysis (Brouwer, 1987).

4.3 Systematic character

A systematic theory treats the region involved as a complex system. At first, the large system can be resolved into several subsystems or less sub-subsystems, then the systems are analyzed and composed integrately on the basis of systematic science ideas and methods of systematic analysis so that we can obtain comprehensive countermeasures for protecting eco-environment.

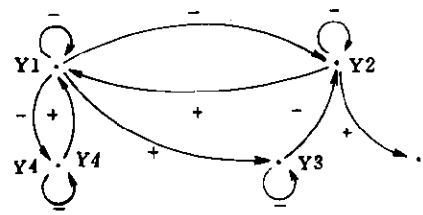

Fig. 2 An example of satellite design

Systematic analytical methods have been applied to regional ecological studies more and more today. Systematic dynamics and satellite design for integrated regional environmental modelling are the methods most in use at the present.

4.4 Optimal character

Optimal combination of regional treatment methods, such as optimal blend of resources and optimal benefit of eco-environment, and beneficial optimization, especially integrated optimization, are major characteristics of regional ecology.

One way of evaluating ecological models is to determine the impact of the model on management decisions relating to the ecological system. To achieve this evaluation, the ecological model can be translated into or coupled with an optimization model to determine whether changes in the ecological model results in the selection of different management strategies (Jameson, 1987). Optimal methods in common use are linear programming, dynamic programming and systematic dynamic ones.

A standard linear programming formulation can be written as follows:

$$\begin{aligned} &\text{maximize} && z=c^{u}x \\ &\text{subject to} && Ax=b, \qquad x\geqslant 0, \end{aligned} \tag{1}$$

where z is total benefits; vector c is the benefits of harvest; x is a vector representing the state of the system; u is a vector of controls; A is a matrix composing of the coefficients of x and u, and b is a vector of other elements.

The dynamic programming formulation is generalized as:

$$\begin{aligned} &\text{maximize} && z=f(x,u) \\ &\text{subject to} && x_{k+1}=F_k x_k+u_k+w_k, \end{aligned} \tag{2}$$

where $f(x,u)$ is some (possibly nonlinear) function of x and u; F_k is some (possibly nonlinear) matrix of state translation functions; w_k is random effects which are unknown.

4.5 Quantitative character

In point of quantization is quantitative presentation of regional ecological index, quantitative description of regional ecological characteristics and quantitative relationship of regional ecological elements. Development of various mathematical models of regional ecology, including simulation,

description, prediction and management models is needed. Vieira and Lijikeima (Vieira, 1989) applied the model of regional water quality management to the River Ave Basin in Portugal.

4.6 Practical character

Due to objective requirement of regional economic development and eco-environmental construction, the study of regional ecology is more and more practical.

Regional ecology is not a purely fundamental and experimental science, so its methodologies must consider convenience and operability in its practical application.

5 The study on regional ecology in China

Because of objective requirements of regional economic construction and social development, regional ecology has been studied in China since the beginning of 1980s. These studies include regional ecological characterization of composite ecosystem and pollution control (Zhuang, 1986); regional economic development and its impact on eco-environment (Ye, 1991; Guan, 1991); ecological regionalization and planing (Wang, 1994); regional macro-ecological chemistry (Su, 1993; Ye, 1994); basin ecology and regional water resources (Guo, 1993; Ye, 1989; Yin, 1992); acid rain and its ecological effects (Chen, 1991). Quality assessment and management of regional environment have been emphasized in recent years.

Nevertheless due to theoretical study falls short of the demands in practice, enhancement of regional ecology research level has been handicapped in China. There needs to strengthen theoretical and applied study on regional ecology in the future. The study on regional ecological theory in China includes mainly index system of regional ecology, mathematical models and application of remote sensing and geographical information system technologies in regional ecology researches.

6 Conclusion

Regional ecology is a research field of multi-disciplinary integrated subject which is based on regional economic development and eco-environmental protection. It has definite contents, intentions and methodology characteristics. The theory and conception of regional ecology are still developing and perfecting up to the present. The research on regional ecology in China is conducted from an advanced footing since its inception.

From the view point of advanced ecology, the development tendency of regional ecology study should explore the impact of regional economic development on regional eco-environment and restriction of regional ecology on regional development. The focal points of regional ecology are studies on regional and global eco-environment, development of macro-eco-chemistry, especially global and regional cycling of pollutants.

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