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Landscape ecology: the theoretical foundation of sustainable agrolandscape planning and design*

Wang Yanglin

Department of Geography, Peking University, Beijing100871, China

Fu Bojie

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

Abstract — The theoretical focuses of emerging landscape ecology are spatial heterogeneity and ecological holism. The ultimate aim of agrolandscape sustainability is the harmonious relation between man and his environment, that is, the human ecological holism. The study on agrolandscape sustainability deals with an extensive area, and the realization of agrolandscape sustainability must depend on a spatial approach. Therefore, landscape ecology could be taken as a theoretical foundation of agrolandscape planning and design.

Keywords: landscape ecology; sustainable development; agrolandscape; sustainability.

1 Landscape ecology

European scientists have long ago recognized the important value of systematical landscape study and have applied it successfully to a number of local and national plannings(Ahern, 1991). The working Group of Landscape Eco-Planning which has been established recently by IALE (International Association of Landscape Ecology) encourages the application of landscape ecology to land use decision. American scientists have founded their landscape ecology on the basis of biology within recent ten years. A lot of landscape architects, regional planners and policy makers have currently discovered the value of the landscape ecological perspective to planning and design researches and practices.

Landscape ecology is different from the ecosystem ecology with spatial and temporal scales. To landscape ecologists, landscape refers to a cluster of ecosystems with a repeating patten in a heterogeneous area. Its spatial scale is significantly large than that of ecosystem ecology and similar to that of the regional planning practice. Although the primary scope of landscape ecology is the landscape scale, the discipline also considers other systems with larger or smaller scales.

Hierarchy theory studies of several levels and the relations among elements on each level or

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between levels. The function of each element contributes to and is controlled by the large systems. When hierarchy theory is applied to landscape studies, the function of landscape as a mosaic system could be predicted by its component parts. Some ecological processes present only at larger spatial and temporal scales, for example, the movement of many species among various landscape parts. This process studies are the theoretical basis of the landscape eco - planning and design.

It is an universal means for describing the landscape mosaic that classified, landscape spatial units into patch, corridor and matrix, and it facilitates the landscape studies by other disciplines (mathematics, information theory and so on). The matrix present a landscape spatial element with a extensive space, and has the main role in determining landscape function. The corridor is a linear spatial element of landscape, its function is the effects on various landscape ecological processes. The patch is a non - linear spatially element of landscape, and its function provides habitat island for species. This spatial classification facilitate to describe landscape spatial structure, analyze the relation between landscape pattern and process by GIS (Geographical Information System) and modelling.

The study of landscape function is the main part of landscape ecology. The function is the flows of energy, species and nutrients between landscape elements. These flows are natural or artificial. The landscape functional analysis is a useful means of the effects of land use changes. The flows between landscape elements are the essential part of integrated landscape. If they are interrupted by human activities, some negative effects will be produced. For example, soil erosion is a natural process that provides needed energy and nutrients to lowlands and fluvial ecosystems. But when land uses disrupt this process, rates of flow can become excessive, resulting in siltation of lowlands and fluvial ecosystems. A key challenge in landscape ecology is to design optimal landscape pattern on the base of process studies, and to realize sustainable land use.

Landscape and its mosaic changes forever. So, landscape ecologists must study landscape structure, function and their relation with dynamic process. This is one of the study characteristics in theoretical and applicational landscape ecology.

2 Pattern - landscape spatial structure

Landscape pattern, generally refers to its spatial pattern, is an arrangement of various landscape element which have different sizes and shapes. It presents the landscape heterogeneity is the consequence of different ecological processes on different scales. The contemporary ecological and environmental problems demand systematic recognitions about the larger areal units and their spatial heterogeneity. In landscape ecology, the studies on ecological functions at landscape are based on the assumption that the spatial arrangement of landscape elements has special implications. For example, landscape pattern may influence the dispersion of various disturbances, the movement and location of species, flows of nutrients, net primary productivity, runoff and erosion(Fu, 1994).

The relationship between landscape pattern and process is a focus of landscape ecology. It includes changes of landscape pattern, control factors of landscape pattern, effects of landscape patterns on the dispersion of disturbances, measuring landsccape pattern, modelling and predicting

landscape changes and so on. Clearly, landscape pattern should be measured and described before the relation between pattern and process is recognized. Landscape ecology develops rapidly in this aspect in the USA(Table 1).

Table 1 Measurement indexes of landscape pattern (Turner, 1990)

Index	Description
Pk	Proportion of the landscape occupied by each category
s,l	Size (s) and perimeter (l) of each patch
d	Fractal dimension of each patch
Ei,j	Edges between each pair of category
Qi,j	Probabilities of adjacency (vertical and horizonal) between category
H	Diversity index
D	Dominance index
C	Contagion index

There are a lot of measurement indexes and methods of landscape. However, the current indexes focus on three kinds, diversity(H), dominance(D) and contagion(C) from the information theory.

$$H=-\sum_{i=1}^{m}(P_k)\log(P_k)$$

$$D=H_{max}+\sum_{i=1}^{m}(P_k)\log(P_k)$$

$$C=K_{max}+\sum_{i=1}^{m}\sum_{j=1}^{m}(Q_{i,j})\log(Q_{i,j})$$

where, P_k is the proportion of k category, m is the number of all categories. The greater H value, the more landscape diversity. Higher values of D indicate a landscape that is dominated by one or a few categories, and low values indicate a landscape that has many categories represented in a proximately equal proportions. The index is not useful in a completely homogeneous landscape (i. e., $m=1$) because D then equals zero. C is the contagion index. $K_{max}=2m\log(m)$ when $m=1$, $C=0$; when $m\geqslant 2$, value of C approaching 1 will indicate a landscape with a cluster pattern of landscape units.

The studies (Turner, 1988) show that there are greater fractal dimensions diversities and patchiness in mountain area, and there are a greater dominance and contagion value in the plain area. So, landscape pattern is controlled by the physiogeography to a greater extent.

3 Pattern and process - the key of theoretical studies on landscape ecology

The processes on the landscape scale which include natural and artificial aspects have a determinant effect on landscape structures. Relevantly, the formed structures has also a controlled effect on ecological processes or flows (Turner, 1990). Flows which result from factors, such as wind, water, animal and human activities are the essential structural parts - functional relations.

In fact, it is various ecological processes that constitute the holism theory of landscape ecology.

A agrolandscape pattern is a spatial mosaic with many patches, corridors and matrixes. To a great extent, the characteristics of patches are determined by the effects of neighboring environment. For example, the amount and types of insects and birds in a farming patch are related to surrounding forest networks and forest lands.

Forman and Gordon(Forman, 1986) have put forward five driving forces such as wind, water, flying animals, ground animals and human activities of ecological flows between landscape units. To landscape ecology studies, this is a good beginning, however, the more important task is analyzing the integrating features of a whole landscape with concrete conditions and their general implications. Studies of flows on landscape scale can recognize following ideas of landscape ecology, all flows change with long - and short - term, studies about long - term changes are more important, the interaction between long - and short - term flows is very important, landscape ecology, especially emphasizes the flows which are caused by natural and artificial factors ; ecological studies on the landscape scale are based on concepts of structure and function and so on.

Peterjohn *et al.* (Peterjohn, 1984) have investigated the changes of N, P, K within water flows through a farming river basin. The result is as expected, the N cycle is much higher in a riverside forest(89%) than in a farming land(8%); P has similar results(80%, 41%) as N. The important phenomenon is that they have different ways through landscape. Underground water flow are the main of N transformation and losses, and surfacial water flows are the main way of P transformation and losses. These results demonstrate some assumptions of landscape ecology: the spatial mosaic of landscape units can affect various flows; different landscape units have different effects on nutrient transformation; different nutrients, such as N,P,K and so on, have different transformation ways in a landscape.

Landscape ecology is now moving past the early, descriptive stages, which focused on the structure of landscape, to analysis of the processes in landscape systems. Although most of studies on ecological flows or processes are empirical, it is these empirical information that will be the foundation of principles of future landscape ecology. Next development of landscape ecology will depends on the establishment of concepts and principles systems and the improvement of technologies.

4 Sustainable development

There are more and more evidences which demonstrate that human demand to environment has been greater than the biosphere capacity. In high degree, the present model of economic growth and social development has been damaging the sustainable stability of biosphere. The isolated pursue to ecological sustainabilities could not resist the deteriorated trend of global environment. It is the considerations to for human beings in the future that result in such concepts as sustainability and sustainable development.

Sustainable development is a concept which has its origins in the natural resource conservation movement in the past 25 years. Unlike earlier conservation paradigms, primarily based on environmental factors, the sustainable development paradigm recognizes the critical interdepen-

dence of environmental, social and economic factors. Sustainable development offers a challenge to the current economic paradigm of growth - based economic development: economic growth, social equity, and environmental stability are complementary and not incompatible. On the other hand, while growth - based models may result in environmental degradation, technology will solve these problems before the viability of the biosphere is ultimately threatened. The cost of environmental degradation is a basic part of the sustainable development paradigm which is always neglected by the traditional economic model. Without the long - term environmental and social benefits, there will be not real economic growth.

In many different definitions of sustainable development, there are a number of points:

(1) Option for reasonable utilization of regenerative resources, and ensuring regenerative resources not to deteriorate.

(2) The utilization of non - regenerative resources should facilitate a stable transition from the present utilization to sustainable unitization of regenerative resources.

(3) One objectives of the biosphere ecosystem or a region exploitation is the improvement of human living standards.

(4) Encouraging various social - equity policies, such as the equity among different countries or regions, the equity between present and future humanities and so on.

The first objective of sustainable development is not an isolated conservation of natural environment. Its development model is to alleviate as far as possible human environmental deterioration and damage. The aim of sustainable development invalves securing more material products for the human society, to adjust various contradictions in natural resources exploitation, to equilibrate ecological costs and benefits which result from human activities, and to reach a harmonious situation between man and his environment.

Sustainable development is a global problem as well as a regional one. The biosphere is a spatial mosaic of regions or landscape units, so its sustainability is to depend on the sustainabilities of its parts. Generally, the effectiveness of a planning and management is greater with smaller study - scales. A sustainable management of landscape units with facilitate the achievement of the whole biosphere sustainability. Therefore, " think globally, act locally " is becoming a common principle of sustainable development.

Sustainability and sustainable development are such concepts that it is difficult to give definition in practice. The comprehensive, complex and interdisciplinary characteristics make the sustainable development study a multi - fields and multi - levels one. It is one of those studies that base on landscape ecology - emphasizing agrolandscape sustainability and sustainable development.

5 Agricultural sustainability

In the past decade, agricultural sustainbility and sustainable agriculture, being sustainability and sustainable development concepts, are also becoming familiar terms at home and abroad. However, sustainable agriculture is considered an alternative model of the modern conventional agriculture which is described as highly specialized and capital intensive, heavily dependent upon synthetic chemicals and other off - farm inputs (Donglass, 1984).

The ideal of sustainability, at least in the agriculture and natural resource fields, is not creative. Through out world agricultural history, human being has not always escaped the contradiction between food production and environmental protection(Schaller, 1993). In recent times, interests in agricultural crises and health hazards. These problems, such as contamination of ground and surface water from agricultural chemicals and sediment, hazards to human and animal health from pesticides and feed additives, adverse effects of agricultural chemicals on food safety and quality, loss of genetic deversity in plants and animals, reduced soil productivity due to soil erosion and loss of soil organic matters, and over - reliance on non - renewable resources and so on, have the pursue of an alternative model for the conventional agriculture a practical option.

Sustainable agriculture can become a popular concept duc to is integrating environmental interacts, health farming, economic and social factors(Farshad, 1993). It is not only an objective, but also a special farming practice to reach the objective. As an objective, agricultural sustainability has a clear meaning but is difficult to be given a simple definition as are equity and truth. Also, it is not easy to determine which farming is the most sustainable farming due to different sites and environments. In effects, a lot of problems could have different answers at different times. It has extensively been recognized that the alternative management, human wisdom and isolated conservation for natural environment can enhance agricultural sustainability. For example, crop rotation can break the cycle of pest living and maintain soil nutrients, integrated pest management can protect crops from plant deseases and insect pests without chemical materials. These methods may be incorporated into a sustainable farming. Certainly, an ideal sustainable farming must depend on much more and new information of agricultural technologies.

Since researchers have different knowledge backgrounds and value ideas, there are two viewpoints about agricultural sustainability. Thc first one is that the sustainable agriculture is a conventional agriculture with intensive management. The conventional agriculture is an essential stage of agricultural development, and includes a lot of sustainable factors. These problems, such as environment, health and food safety, which result from the conventional farming will be fully solved by various agricultural technologies. Economic benefits are the main parts of agricultural production forever. The second is that a sustainable agriculture is entirely to reform a conventional agriculture, from ideals to technologies. The main problem of a conventional agriculture is to neglect the importance of social and environmental benefits. The social value judgement, equity idea, eco - ethics and technology development all are essential parts of a sustainable agriculture. Various problems of a conventional agriculture result from not only technology but also ideas of agricultural development, the latter is more important. If took the first as a question of " how to reach the agricultural sustainability ", the second as " what is the agricultural sustainability ", we would find that this two ideas are not contradictions.

6 Agrolandscape and its sustainability

Landscape is a concept of areal entity, a structural land - functional unity with human and natural factors in a spatial unit. As an areal entity, landscape do not have a determinate scale, and it follows the spatial hierarchical rule, that is, a landscape unit is not only a part of a higher

-level landscape but also a spatial mosaic of lower-level landscapes. Landscape is a complex systematic unity, and has a series of factors or elements. So, there are two divisional approaches to landscape structure, the factoral and elemental approaches. The factoral approach takes landscape parts as geology, geomorphology, vegetation, soil, hydrology, climate and human products and so on. The elemental approach takes landscape part as various spatial units with lower-levels. Agrolandscape is an extensive landscape type on the earth surface and has common characteristics of general landscapes. It will be one of the main researching direction of global sustainable development that agrolandscape sustainability and sustainable development are studied on the basis of landscape ecology.

An agrolandscape is a spatial expression of agricultural activities and their products. The objective of a sustainable agrolandscape also includes three aspects, that is, environmental, social and economic. In detail: (1) economic benefits of farmers; (2) the sustainable conservation of natural resources; (3) the tiniest negative effect on the environment; (4) a little other input(non-agricultural); (5) to meet the food and other products needs of the people; (6) a favorable rural social environment.

From landscape ecology, a sustainable agrolandscape must have following features: diversity, hierarchy, heterogeneity, and harmonious relations between various spatial units. Since a natural landscape is often considered sustainable, the comparison of the natural landscape to the agrolandscape is a fine way to reach the agrolandscape sustainability(Table 2).

Table 2 The structural and functional attributes of natural and agrolandscapes

Attributes	Natural landscape	Agrolandscape
Net productivity	Low to medium	High
Food webs	Complex	Simple
Biodiversity	High	Low
Stability	High	Low
Sustainability	High	Low
Nutrient cycles	Closed	Open
Spatial heterogeneity	Complex	Simple
Phenology	Seasonal	Synchronized
Ecotone(edges)	Obscure or clear	Clear

7 Conclusions

Landscape ecology belongs to the macro-scale ecological study, its theoretical focuses are the spatial heterogeneity and ecological holism(Golley, 1991). The ultimate aim of agrolandscape sustainability is the harmonious relation between man and his environment, that is, the human ecological holism. The study on agrolandscape sustainability deals with an extensive area, and the realization of agrolandscape sustainability must depend on a spatial approach. Therefore, landscape ecology could taken as the theoretical foundation of agrolandscape planning and design.

In the sustainable agrolandscape planning and design, the effects of landscape ecology are as follows: (1) landscape ecology provides the planners and designers with a conceptual framework,

and with a lot of landscape ecological principles, especially the spatial and temporal scale, hierarchy, and interactions between landscape patterns and processes. (2) landscape ecology provides a set of tools, methods, data and experiences to the planners and designers. For example, fractional geometry can be applied to landscape boundaries, the interactions between shape and size.

The planning and disign of sustainable agrolandscapes are a comprehensive procedure (Haber, 1990). Its content includes four interrelated parts, studies on agrolandscape patterns and processes, an ecological assessment of agrolandscape units, a reasonable arrangement of agrolandscape patterns and managing proposals for a sustainable agrolandscape. These relate to all aspects of theoretical and applied landscape ecology.

References

Ahern J. Landscape and Urban planning, 1991; 21: 131

Dounglass. Sustainability in a changing world order. Westivew Press. Boulder. 1984: CO: 3

Farshad A, Zinck JA. Agriculture, Ecosystem and Environment, 1993; 47; 1

Forman RTT, Godron M. Landscape ecology. New York Willey. 1986

Fu Bojie, Gulinck H. Land Degradation & Rehabilitation, 1994; 5(4): 261

Golley FB, Bellot J. Landscape and Urban Planning, 1991; 21; 3

Haber W. Changing landscape: an ecological perspective(Ed. by Zonneveld IS and Forman RTT). New York; Springer - Verlag. 1990: 217

Peterjohn WT, Correl DL. Ecology, 1984; 65(5): 1466

Schaller N. Agriculture, Ecosystems and Environment, 1993; 46: 89

Turner MG. Landscape Ecology, 1990; 4(1): 21

Turner MG, Gardner RH. Quantitative methods in landscape ecology. New York; Springer - Verlag. 1990: 536

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