

Core concepts of landscape ecology

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Abstract—People from different backgrounds may have various opinions and methods dealing with landscape ecology. As a basic ecology theory for decision making in land use planning and resource management, it should provide sound scientific principles, which means some core concepts for landscape ecology need to be established. This paper attempts to introduce some core concepts for landscape ecology, with brief analysis, including: the integrity of landscape system and the heterogeneity of landscape elements; scale in landscape ecology; mosaics of landscape structure; spatial aggregation and spread of ecological flow; physical cultural nature of landscape; the irreversible and human dominated landscape evolution; the multi-value of landscape.

Keywords: landscape ecology, core concept, mosaic, ecological flow, multi-value.

1 Introduction

Landscape ecology is a newly emerged transdisciplinary subject. This multi-discipline characteristic brings benefits to its development. People from different backgrounds may have various opinions and methods dealing with landscape ecology. For instances, researchers may emphasize on the large scale effect of landscape ecology, involving effects of land mosaics on ecological phenomenon; while planners prefer to combine ecological principles with economics and sociology, and apply it into land use planning. Still there are some others interested in between. This difference provides opportunity for solving the common problem in landscape dynamics and its effect. Now we should face the challenge to generalize and develop landscape ecology, instead of emphasizing on the difference we have (Wiens, 1996). In the mean time, the construction of landscape ecology is needed, so that it can evolve from an application discipline into a so called science subject with its own theory and methodology. As a basic ecology theory for decision making in land use planning and resource management, it should provide sound scientific principles, which means some core concepts of landscape ecology need to be established. And afterwards, it will become more powerful in combination with the widely used biology, earth science and human studies.

There are already some general principles of landscape ecology. Although provided by different scholars, the contents are more or less similar with each other. Risser(Risser, 1984) pointed out 5 principles: (1) spatial pattern and ecological process; (2) spatial and temporal scale; (3) effects of heterogeneous to flow and disturbance; (4) pattern transformation; (5) framework of natural resource management. In 1987, he explained in another way: (1) heterogeneity and disturbance; (2) structure and function; (3) stability and change; (4) nutrient redistribution and (5) hierarchical structure. Forman and Godron(Forman, 1986) proposed 7 principles: (1) landscape structure and function; (2) biodiversity; (3) species flow; (4) nutrition redistribution; (5) energy flow; (6) landscape change; (7) landscape stability. In 1995, Forman expanded them into 12: (1) landscape and region; (2) patch-corridor-matrix; (3) large natural vegetation patch; (4) patch shape; (5) interactions among ecosystems; (6) dynamics of meta-population; (7) landscape resistance; (8) grain size; (9) landscape change; (10) mosaic series; (11) aggregate with outliers; (12) essential pattern. Xiao(Xiao, 1996) expressed 9 principles: (1) landmosaic and landscape heterogeneity; (2) scaling and layers; (3) interactions and feedbacks of landscape structure and function; (4) spatial flow of energy and nutrition; (5) species migration and succession; (6) landscape change and stability; (7) effects of human activity-disturbance, reformation and

construction; (8) spacial disposition in landscape planning; (9) landscape visual diversity and ecological aesthetics. In addition, Farina suggested 9 key topics when he summarized the advancement of landscape ecology in 1995: (1) spatial and temporal scaling of processes and patterns; (2) hierarchical system organization; (3) land classification (from geographical unit to ecological unit); (4) disturbance process; (5) land mosaic heterogeneity; (6) forest fragmentation; (7) characteristics and functions of ecotone; (8) neutral model; (9) landscape dynamics and evolution.

System theory has also been introduced into landscape ecology, emphasizing on the combination of bio-sphere and techno-sphere. Naveh (Naveh, 1995) talked about the concept of human ecosystem, which can be classified into three categories: open landscape, architecture landscape, and human landscape. Based on the theoretical frame work above, this paper attempts to introduce some core concepts for landscape ecology, with grief analysis. Hopefully more discussion will come afterwards so that the landscape theory may get more perfect.

2 Core concepts of landscape ecology

2.1 The integrity of landscape system and the heterogeneity of landscape elements

Landscape is a system which consists of many interactive elements with hierarchical structure. It is also a geographical entity with independent functions and visual characteristics (clear boundaries often). The word "landscape" is the combination of two meaning: one is for the restrictive area, and another is for the total visible scenes on the ground surface. Considering the integrity of a landscape system, the study on its structure, function and change will be more deep going, with the methods of analysis and synthesis, induction and deduction. And the conclusion will also be more logical and precise. The comprehensive model of a landscape system can be derived via approaches like structure analysis, function evaluation, process monitor and dynamic prediction, and can be expressed with formula language, diagrams, and mathematics models.

Landscape system is open and far from equilibrium, with characteristics of self organization, self similarity, randomness, and order. Self organization comes from the instability of symmetres separation, which leads to the appearance of patches, and provides stability for lager scales.

Landscape is made up of heterogeneous elements, which has been one of the basic topics of landscape ecology. Heterogeneity has a close relation which resistance, rehabilitance, stability and bio-diversity. High heterogeneous landscape can encourage symbiosis, while discourage rare inner species. Organisms, water, nutrients and energy flowing through a landscape are mostly affected by landscape pattern, i. e., the heterogeneity of landscape. Godron (Godron, 1995) measured landscape heterogeneity with negative entropy and information theory methods. He integrated vertical vegetation structure, scale, the relatively open bio-system with landscape heterogeneity, and pointed out that the heterogeneous pattern of landscape is caused by input of negative entropy from its environment. The higher the entropy value is, the more random the landscape will be, and vice versa. If we can manipulate the energy input from outside, then we can change the landscape pattern into a more comfortable living space.

2.2 Scale in landscape ecology

Scale is the spatial and temporal dimension of an object or process. It can be described as resolution and range, which indicate in how much detail the object or process has been understood. In ecology, spatial scale means the area of the ecosystem, while temporal scale refers to the interval of dynamic change. Landscape ecology corresponds with meso-scale, that is, from kilometers to hundreds of kilometers, and from years to hundreds of years. As for the scales of ecosystem unit, large scale or macro-scale usually reflects the global climate zones; meso-scale tells about the structure division of the earth surface, and micro-scale means the difference in soil, vegetation and micro-climate.

The spatial and temporal scaling of pattern and process is one of the main topics of nowadays landscape ecology (Farina, 1996). Scale analysis and scale transformation are of great importance in landscape ecology. With the help of landscape modeling and GIS, optimum scale can be selected according to the purpose of study and results in fine scale can also be transformed into broad scale, or other way around. Grain size is a significant index in landscape structure.

The correspondence and coordination of spatial and temporal scale are very important, usually the larger the study area is, the longer the temporal scale is. Eco-equilibrium is a kind of natural coordination in dynamics, depending on scales. In microscale, ecosystem often behaves as non-equilibrium, or "transient dynamic" (Loucks, 1970), while in macro-scale it behaves like equilibrium. Landscape system can overcome some instability caused by local bio-feedback.

Scale is also closely related with continuity. Small scales minimize the possibility of continuity, and individual ecosystems may even have intensive dynamics. On the contrary, natural process in large scale can provide more stability. In larger scales, chaos stands opposite to meta-population distinction. Chaos can keep the continuity of landscape system. Large scale spatial pattern includes land use and land cover change, habitat fragmentation, introduced species spread, regional climate, catchment hydrology, and so on. In even more large scale regions, landscape is the basic unrepeatable structural unit with sharp contrast, and coarse pattern. Both landscape and region are within "human scale", that is, within the frame of human perception. This is important for understanding the effect of landscape management on ecosystem process. In temporal scale, landscape ecology concerns the human being span, i.e., tens of years.

2.3 Mosaics of landscape structure

Mosaic, the structurally integrated elements, exists all over the natural world. The heterogeneity of landscape and region has two forms: gradient and mosaic. The characteristics of mosaic is that objects are aggregated with clear boundaries, and the continuous space is broken. Land mosaic is the main feature of landscape and region ecology. Forman's landscape structure model (Forman, 1995) with patch-corridor-matrix gives a good explanation of this feature.

Patch is entirely composed of geographic, climatic biological and human factors. It's an input/output unit for energy, material and information, varied in size and shape. Corridor differentiates in curvature, width and continuity. Matrix is even more various, from continuation to percolation, from aggregation to scattered.

Landscape structure, the combination pattern of patch-corridor-matrix, is usually the decisive factor of function flows in the landscape, while structure itself is the result of former flows. The interactions and feedback between structure and function, pattern and process are mostly concerned in landscape ecology.

There are many aspects that can describe lands mosaics, such as diversity, edge, central patch and patch pattern, etc. Indexes like diversity, dominance, relative evenness, fractal dimension, patch isolation, accessibility, dispersion and contagion, are all very popular. In addition, net theory, central position theory, percolation theory, random spatial model are also introduced into landscape structure research.

Landscape can be classified into coarse and fine mosaics according to the patch grain size measured by average patch diameter. Pure coarse or fine landscape is dull. Only coarse landscape with fine segments has the best large patch effect, which provides enormous resources and conditions for man and other multi-habitat species (Forman, 1995). The combination of many spatial factors in lands mosaic, such as corridors, barriers and high heterogeneity areas, contributes to the landscape resistance.

2.4 Spatial aggregation and spread of ecological flow

Ecological flow reflects the ecological process, including the flow of species, nutrients, energy and other materials among spatial elements. Affected by landscape pattern, the flow can be

aggregated or spread, crossing ecosystems horizontally. Any material movement is accompanied by a series of energy transformation. Material flow between patches can be regarded as ordered movement at different energy levels. The energy level characteristic of patch is decided by its spatial position, components, biological factors and other environment factors. The speed of species and nutrient flow in landscape elements is positively related to the intensity of disturbance. Energy and species flow cross boundaries increases with heterogeneity. Without disturbance the horizontal structure of landscape tends to be homogeneous, while the vertical structure will become complicated. All the energy, nutrient and species can move from one landscape element to another. These movements or flows have five media: wind, water, flying animals and human beings. In landscape scales there are 3 driving forces for movement. The first is dispersion, which is closely related to landscape heterogeneity. Another is transpiration of materials, i. e., the species changes its position with its own energy. Dispersion needs little energy, and only has its effects at smaller scales, while transpiration and movement are main driving forces in most of the landscape scales. Water erosion, transportation and deposition are one of the most active processes in landscape. Movement mainly refers to the movement of flying animals, ground animals and human beings. The specific ecological characteristic of this kinds of movement is that the movers are highly aggregated in the target landscape unit.

Edges often behave as "semi-penetrable membrane" to ecological flows and have important effects on ecological flows. In addition, neighboring elements may become source and convergence if they are in different development status.

2.5 Physical cultural nature of landscape

Landscape is not only a physical integrity. It often incorporates human cultural characteristics. According to the extent of human activities, landscape can be classified into natural, managed and artificial categories(Forman, 1986). In modern times less and less pure natural landscapes exist, while various kinds of artificial natural landscapes(e. g. agriculture) form the main part of the world. Biodiversity and bio-productivity are important in both kinds of landscapes. The prosperous landscape is a combination of ecosystems with high biodiversity and bio-productivity, low energy need and high resistance and rehabilitance.

Artificial or human cultural landscape did not exist originally. Huge amount of artificial buildings become landscape matrix instead of the original natural appearance. Wherever man is a main ecological element, the landscape is often characterized by regular spatial pattern, highly specialized function division and extensive energy and material flow. Here the landscape diversity reflects the cultural character of landscape. Man is affecting and affected by landscape. Cultural customs strongly affect artificial landscapes and managed landscapes. Landscape appearance reflects different cultural opinions of local people(Nassauer, 1995). Since landscape has both character of nature and culture, landscape ecology becomes a transdisciplinary subject between natural science and human studies.

2.6 The irreversible and human dominated landscape evolution

Like the other natural systems, landscape is irreversible in its macro movement process. The open system becomes ordered via introduction of negative entropy from environment. Landscape has fractal structure, that is, the whole is a mosaic structure of its self-similarity parts. The system develops along the cycle from chaos to ordered and to chaos again.

The motivation of landscape development has two aspects: natural disturbance and human activity. Human activity has overwhelmingly and deeply affected the environment, and thus becomes a leading factor in landscape evolution. Man is possible to guide the landscape into certain sustainable stages through controlement on its changing direction and speed.

Under continual affect of human activities on biosphere, landscape has become fragmented and land form has changed a lot. If human activity can be called "disturbance" in natural landscapes,

then it should be called "reform" in managed landscapes, and "construct" in artificial landscapes. Build and destroy are two aspects of the man-nature relationship. Man can positively affect the landscape evolution by designing the landscape following the symbiosis rule.

Landscape stability is decided by the resistance and rehability of landscape structure. The threshold of landscape system can afford to human activity is called landscape bearing-capacity. It is decided by the counter-reaction from environment, such as crowdedness of spatial structure, stability of main ecosystems, extent of renewable resources utilization, environment quality and human psychological feeling and so on.

The evolution pattern of landscape system has two possibilities: positive feedback and negative feedback. Negative feedback is advantageous to self-adaptation and self-organization of the system, and thus keeps its stability. This is the main way of natural landscape evolution. But during the transformation from natural to artificial landscape, positive feedback dominates. According to the theory of dissipative structure, unequilibrium are the main source of organization and orderliness, by way of fluctuation.

2.7 The multi-value of landscape

Landscape is the mosaic of different lands units, or a geographical entity with obvious visual features. It has mixed values of economics, ecology and aesthetics, which constitute the basis of landscape planning and management. The economic value of a landscape is obvious in bio-productivity and land resource exploitation, while the ecological value is reflected by bio-diversity and environmental functionality. The aesthetic value of a landscape is profound and wide. People's aesthetic standard changes with time: artificial landscape is the embody of industrial productive forces, followed by urbanization; but after a long time of living among concrete buildings and noisy streets, they want to come back to nature again. Different nations and cultures have different aesthetic standards for landscape, so that is why Chinese garden is different from its European counterpart.

The optimistic value of landscape is the basic for landscape planning and management. An acceptable landscape for human beings should has the following characteristics: good accessibility, economically constructed, ecological stable, clean, uncrowded and beautiful and so on. In landscape designing, the shape, connectivity, density and accessibility of landscape elements are as important as the material components.

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