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Structural patterns of land types and optimal allocation of land use in Qinling Mountains

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Abstracts: The case study based on Qinling Mountains in Shaanxi Province of China, in virtue of the information from TM image, classifies the land types and analyzes their spatial and temporal differential law, and puts forward three structural patterns of land types in mountainous areas, namely, spatial, quantitative and qualitative structures of mountainous land types. Furthermore, it has been noticed that the analysis of structural patterns can disclose the heterogeneity and orderliness of combination of land types, which can lay the theoretic foundation for comprehensively recognizing ecological characteristics and succession law of structure and function of land types. After the all-around comparative analysis, an optimal allocation of land use in Qinling Mountains has been put forward according to the principle of sustainable development and landscape ecology, which can lay the scientific foundation in practice for the structural adjustment and distribution optimization from the macro level to micro level.

Structural patterns of land types and optimal allocation of land use in Qinling Mountains LIU Yan-sui, DENG Xiang-zheng (Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) 1 Introduction Mountains?as one of the huge ecosystems in the world, play a significant role during human evolution and development[1]. As the treasury of ecological resources[2], mountains have faced the challenge of the degradation of their eco-environment and the difficulty in their regional poverty relief because of human unsuitable exploitation. The 53rd Conference of United Nations has claimed the year 2002 as the International Mountains Year and called on each country to pay attention to the mountain resources and environmental problems. Qinling Mountains in China are the dividing line between the warm-temperate zone and subtropical zone in East Asia. They are also among the highest and east-west trending mountains and one of the most poverty-stricken areas in the middle and western parts of China. Their ecological reconstruction and sustainable economic development should not only obey the natural law of mountain evolution and development but also drastically change the situation of excessive cultivation and deforestation that has been formed for a long period of time. Particularly, the exploitation and utilization of land resources should base on different land types, and land use planning and structural adjustment should be carried out according to the suitability of land types and their structural patterns and following the principles of sustainable development and landscape ecology so as to promote the optimal allocation and sustainable use of mountainous land[3,4]. Land type is not only controlled by regional physical differentiating factors but also influenced by human economic activities in the past and at present. The difference of the geomorphologic processes in Qinling Mountains has led to the different geomorphologic characteristics and climate conditions, based on which relevant soils and vegetations, were formed and then different kinds of land types. Land types are also the outcome and objectives of human activities[3], which, therefore, has made them some social and economic attributes. Different spatial combination forms and comparison in quality and quantity of land types in a certain region lay the foundation for evaluating ecological conditions and adjusting land use patterns in Qinling Mountains. It will open a new way for the optimal allocation of land use among various industries as well as different regions in mountainous area to suitably match and adjust land types in quantity, quality and function based on the structural pattern of mountainous land types and according to the present using circumstances and their dynamic succession of land types, which has been disclosed in positive research[5,6]. The case study is based on the northern slope of Qinling Mountains, which covers an area of 1.295⊙104 km2 including Baoji, Xianyang, Xi ˇan and some counties south of Weinan in Shaanxi Province of China. 2 Regional differentiation of land types in mountainous areas

Mountain is a kind of natural integrated complex with altitude and gradient. In spatial dimension, mountains take three series of differentiation patterns including region, zone and type, which further form differentiation of the altitudinal zone, whose basic zone lies in a natural geographical region at a certain level in the macroscopic aspect. In different zones, the differentiation of land types arises from the difference in the terrain, slopes direction, soil types and vegetation. Regarding the 1998-10-30 false color photograph with 1:10,000 scale of Landsat TM 4, 7, 3 (R, G, B) as the basic information source, the altitudinal zonal spectra can be divided in Qinling Mountains. The differentiation in geomorphology, terrain and climate between the northern and southern slopes in Qinling Mountains is formed owing to the difference of modern geomorphic processes in history there. Table 1 Land types and its characteristics on northern slope of Qinling Mountains The northern slope, located in the warm-temperate and sub-humid zone and its basic zone lying in the areas of cinnamon soil and yellowish brown soil with mixed coniferous and evergreen broad-leaved forests of the warm-temperate zone, forms two sorts of differentiation series resulting from regional differentiation: in the spatial dimension, various groups of land types, which are different in mechanism and attribute but associated with each other among different altitudinal zones or within a single zone, has been formed adaptable to the change of altitude; in temporal series, a succession series, which can mutually transform between the evolution and devolution of the land types, has come into existence as a result of the continuous change of natural environment and the intense influence of human economic activities (see Figure 1). So, in this sense, the structural patterns of mountainous land types are just the instantaneous representation[6] in its successive series. Therefore, the classification of mountainous land types is based on a certain temporal and spatial range and ought to be implemented according to regional differentiation. Firstly, on the basis of the horizontal natural region, the characteristics and rules of the altitudinal differentiation ought to be analyzed and the altitudinal zonal spectrum ought to be divided mainly according to the middle and large geomorphologic types. For example, there ought to be five altitudinal physical zones (the first level of land types) to be divided in Qinling Mountains including the river valley and gully (I), the hill and terrace (II), the low mountains (III), the middle mountains (IV), and the sub-alpine mountains (V)[7], appearing continuous and zonal distribution. Secondly, the difference of the regional factors affecting the differentiation, in which the small and middle geomorphologic types, vegetation, soil and models of land use are included and ought to be analyzed; the land types within each zone (the second level of land types) ought to be classified at the same time. For example, there ought to be 40 kinds of land types in total on the northern slope of Qinling Mountains (see Table 1), appearing a series of zonal distribution. The mastery of the mechanism and rules of regional differentiation in land types lays the significant theoretic foundation for further analysis of the structural pattern of the regional land use and its function. 3 Structural patterns of land types Structural patterns of land types fundamentally represent the orderliness of land types in space and function within a certain zone, which mainly include spatial and quantitative structural patterns. Otherwise, the combination of land types in suitability for different kinds of industries based on the qualitative evaluation of land types is also named after the qualitative structural patterns of land types. 3.1 Spatial structures of land types Spatial structures are the spatial form of the combination of land types under the control of the rules of regional differentiation. Virtually, they reflect the combining relationship between the main land types, which are conterminous and can carry out the material transportation, energy transition and information transfer with each other, which can be represented by the conceptual model. For example, the altitudinal differentiation of land types is obvious on the northern slope of Qinling Mountains: the basic zone belongs to the warm-temperate zone and the mixed coniferous and broad-leaved forests?the mountain burozem soil and mountain drab soil zone, above it, there comes the deciduous broad-leaved forests and forests steppe?the drab-soil low mountain zone, the coniferous and broad-leaved mixed forests and mountain podzolized-burozem middle mountain zone?the shrubs and meadow and desert vegetation?high mountain meadow soil and initial soil zone in turn. Each zone contains many kinds of sub-types. In the typical high mountainous areas, concentric hierarchic structural patterns have been formed owing to the effect of altitudinal zonal differentiation (see Figure 2A). The land types are diversiform and the land structures are complex in the hill and terrace and low-middle mountain zone because of excessive cultivation and deforestation and comprehensive exploitation of the agriculture and forestry respectively, which generally form the structural patterns of large areas inlaid and symmetrical distribution along rivers (see Figure 2B). A certain structural pattern is formed by the dominant types among and within zones via their internal relations (see Figure 3). It ought to be noticed that the analysis of spatial structures of land types is fundamental for the recognition of physical attributes and distribution characteristics of mountain land and the adjustment to local conditions in the layout of all kinds of industries. 3.2 Quantitative structures of land types Quantitative structures of land types disclose the contradistinctive relation of land types in different zones, which can be represented by the indexes of area proportio

n, multi-degree, multiplicity of land types and so on. Multiplicity of land types represents the complex degree of la nd type combination in different zones, which can be illustrated with the Shannon model ; area proportion represents how different land types make up of a certain zone in constitution while multi-degree discloses how often a given lan d type appears in a certain and single zone. It is noticed by the research that they correlate with each other with t he trend of parabola (see Figure 4)[8], i.e., when the area is a constant, the high value in multi-degree in zones I, II and III discloses reverent land types apparently exists with high frequency, small blocks and complex combinati on form while the low value in IV and V discloses the reverse information of relevant land types. The parabola also d irectly denotes the rapidity of the correlated changes of the area proportion and multi-degree: when the quadratic co efficient is positive and its absolute value is high, the correlated change will be sensitive and vice versa. The dif ference of quantitative structures of land types in different altitudinal zones and within a certain zone is mainly r ooted from the physical factors and the model and intensity of human economic activities. Quantitative structures of land types, in some sense, are the significant premise to optimize the structures of land use in agriculture, forestr y, animal husbandry and so on. 4 Qualitative evaluation of land types 4.1 Evaluative indexes system Based on the comp rehensive analysis of the physical factors in Qinling Mountains, an evaluative index system has been set up, includin g 4 evaluation factors and 15 resources potential sub-factors that definitively affect land types in quality. It is m ade up of climate (mean January temperature, ?10oC accumulated temperature, annual average rainfall, annual desiccati on degree), hydrology (water abundance in loose rocks, annual runoff discharge of surface water), soil (suitable for agriculture, suitable for agriculture and forestry, suitable for agriculture and stockbreeding, suitable for forestr y and stockbreeding, suitable for stockbreeding, unsuitable for use) and vegetation (covering degree of vegetation, p otentiality of vegetation resources). 4.2 Evaluation model Evaluation model comprehensively represents the structur e, function, change and other information, which comprise the evaluation model of single ecological factor and all-ar ound ecological factors. A kind of factor has different effect levels, which determines that it should have differen t proportions for different evaluations. The evaluation model is as follows: In the model, W represents environmenta l factor value (1 to 100); k is the order codes of different environmental factors (1 to 4); i is the order codes of different environmental sub-factors (suppose sub-factors number is p); j represents the grading numbers of factors (s uppose their total grade amount is g); ? is the ecological effect weight value of factors (0 to 1); S represents the area proportions of different grades; and F represents grading value of factors. Based on the resources potential val ues of environmental factors and their effect on local environment, it is necessary to compute them by proportion, ge t the qualitative potential value of land types unit that can represent their levels in quality. The evaluation mode l is as follows: In the model, En represents the qualitative value of unit n, n is the order number of units; ?k is t he proportion of factor k; and Wkn represents the grading value of factor k in unit n. 4.3 Procedure and methods (1) It should take land types units as evaluation object, refer to designed evaluation index system and evaluation model [9], respectively to evaluate different factors and represent them by different values, and use the software Foxpro 2.5 to create attribute database. (2) After digitizing land types map (scale: 1:100,000), a spatial database ought t o be created and connected to the former attribute database in the platform of Arc/Info. (3) The above evaluation mod el should be applied to analyze the total values of units that determine their homogeneous zones according to their a ccumulation and scattering. (4) It should carry out the merger of each kind of land types units in quality according to the main purposes of each kind of land types and get the different suitable grades of land types (namely qualitati ve structural patterns; see Table 2), which further provide the foundation for scientific decision-making in the opti mal allocation of land use, structure and layout[9,10]. Table 2 Synthetic quality evaluation results of land types o n northern slope of Qinling Mountains 5 Optimal allocation of land use based on land types 5.1 Principle of optimal a llocation of land use Once being used, land will become an ecological and economic system in which man and nature ar e closely related, which of course will be comprehensively affected by the factors including nature, economy, societ y, technology and so on. The basic characteristic of land lies in what is profitable in economy and can be adjusted a nd controlled during the course of use, which is the fundamental premise to implement the optimal allocation in regio nal land use. As a controlling means, the central allocation is to optimally adjust and arrange the structure of reso urces utilization that is against the natural ecological structure in order to get the rational structure and layout of land among industries and regions and attain to the objective that land use system tend to be optimized[11], whic h ought to be implemented by the adjustment and control of human technology according to the ecological suitability o f land types and the difference of their structural patterns. Mountain, a vulnerable terrestrial ecological system, h as not only diversified surface and the tendency to bring about the factitious environmental problems, but also has a ltitudinal zones and complexity in its landscape distribution[12,13], which determined the necessity and speciality i

n the optimal allocation of mountainous land use. The optimal allocation of mountainous land is to regard the principle of landscape ecology and sustainable development as its guide and the steady improvement of biology productivity and attainment of much environmental benefit as its aim, on the basis of the present use structure of mountainous land adaptable to the altitudinal zone, to bring forward the ecological model and means in the land using structure and layout. In spatial dimension, based on the physical zones, the optimal allocation of mountainous land use ought to make all kinds of land types its operational units; in temporal series, considering the rules and characteristic of historical succession of land types in mountain, the allocation ought to be limited in 15 to 20 years in time span; in strategic decision-making, beginning with the adjustment of industries structure, it is necessary to apply biologic technology and rationally assign human economic activities to promote the evaluative succession of land types and assure the continuation of mountainous land use in temporal series in order to realize the sustainable use of mountainous land. 5.2 Model of optimal allocation in land use The model of optimal allocation in mountainous land use is some kind of generalization and description to the systematic structural characteristic and functional attribute of mountainous land use. In spatial dimension, it can be divided into three-level models, namely, macro-level, mid-level and micro-level. Considering the vulnerable eco-environment and obvious difference of different land types in quality in Qinling Mountains together with the significance in ecological sustainability[14] in the course of economic development, in macro-level, its allocation mode ought to emphasize the sustainability in eco-environment and the regionality in economic development, find a foothold in ecological suitability of mountainous land in different zones, make fun of the spatial and temporal differences of light, temperature and water and the supplement in diversity of vegetation, then to work out the regional pattern in professional use and protection of mountainous land; basing itself upon the layout and adjustment of industrial structure, at middle-level, the model of allocation ought to hunt for the suitable land types within different zones according to the needs of ecological function of different industries in land use, analyze systematically structural pattern in mountainous land use, bring about the improved measures in the model of land use which answer for the needs of natural ecological structure, go along with the way of constructing the ecological base which promotes the development of intensive and specialized industries; at micro-level, it ought to emphasize the implementation of practical use of mountainous land and hunt for using model which centralizes with the further development of its resources and the protection of local environment (see Table 3). Although the three kinds of models with different emphasis and using objectives, their implementations have internal relationship that are all affected and limited in a certain social and economic environment. 5.3 Solution of optimal allocation in mountainous land use Solution of optimal allocation is that the reification and integration reflection on the optimal allocation models in mountainous land use[9,10]. Its outline ought to be in terms of the distribution of land types, regard all the land types as its operative unit, obey the differential rule of land types and the macro allocation model of land use in different zones, analyze and affirm the suitability of the present land use model, identify the unsuited using model for the local conditions and bring about the adjustable direction, put forward the practical solutions adaptable to the present use structure of mountainous land in order to realize the optimal allocation at last. Given this, a practical solution of mountainous land use optimal allocation has been put forward in the paper based on the northern slope of Qinling Mountains (see Table 4). Table 3 Vertical allocation models of land use on northern slope of Qinling Mountains With the following evaluative succession of land types as its essential premise, the solution of optimal allocation has been designed. On the basis of assuring the grains production, it emphasizes the ecological suitability for exploitation and use of land resources, and the economic speciality of mixed farming and the comprehensive development of forestry and stockbreeding. Considering the vulnerable environment in mountainous areas and the necessity of ameliorating soil erosion, it calls on reusing the land which is unsuitable for agriculture to develop forestry and animal husbandry on the northern slope of Qinling Mountains, namely reusing 5.07 % of land for other purposes except for agriculture and increasing forestry land, grassland, interlaced land for forestry and animal husbandry by 4.74 %, 1.01 %, 3.13 % respectively. In the low mountainous areas with the altitude of from 1,000 to 1,300 m, it ought to be encouraged to intercross agriculture and forestry. For example, the low northern slope with drab soil (664.25 km2 in total) is exploited comprehensively for agriculture and forestry in Qinling Mountains. Even such height on the slope comes to the upper limit for agriculture, part of land has to be used for the grains needs of large population in the local area within the 5 to 10 years, but it will be reused as forestry land in future. Moreover, the implementation of optimal allocation solution in land use depends on the rational plan and management in land use at micro-level[15], for example, it will improve the efficiency in land use and promote the consistent and sustainable development of local nature, economy and society via the implementation of the production model of intercrossing grains and forestry, forestry and grassland and specialized production in different zones. 6 Conclusions 1) The differentiation of lan

d types in mountainous areas has its own spatial and temporal speciality. In spatial dimension, with the change of altitude, the altitudinal differentiation of land types is formed, which represents different zones in a series; in temporal series, owing to the continuous change of natural environment and the influence of human economic activities, a reversible successive series in land use has been produced. The speciality in space and time brings about the theoretic foundation of the optimal allocation of land use in mountainous areas. 2) Structural patterns obviously disclose the spatial combination and the quantitative and qualitative comparison of different land types, which involves three kinds of structures, namely spatial, qualitative, quantitative structures. The analysis of structural pattern can disclose the heterogeneity and orderliness of land types in structure and function, and then bring forward the theoretical foundation for the design of allocation model in mountainous land use. 3) The physical zonality, vulnerability in environment, multilevel and complexity of landscape determine the necessity and speciality in the land use optimal allocation based on the mountainous land structural pattern. The optimal allocation of mountainous land use ought to obey the theory of landscape ecology and sustainable development, comprehensively analyze the ecological suitability in present land use, suitability of land types and the scientific decision-making in the ecological design of mountainous land use, bring forward the ecological model and measures to optimize the structure and layout in mountainous land use. 4) The optimal allocation model of land use, in some sense, generalizes and describes the systematic structural characteristic and functional attribute of mountainous land use. In spatial dimension, it consists of three models in detail, namely macro regional, middle industrial and micro operational models. The solution of optimal allocation is the concrete representation of the optimal allocation model in mountainous land use, which virtually, is the optimization of industrial land use structure and layout, and is suitable and practical in mountainous land use. Its implementation, however, ought to be brought into the all-round and special layouts of regional land use, and gets the support of the economic and social factors including the investment, technology and labor as well as the conversion of ethical ideology in land use. Acknowledgements The authors wish to thank Jay Gao, a Ph.D from Department of Geography, University of Auckland, for many helpful and necessary suggestions in our research. The authors also are grateful to Prof. WU Chuanjun, academician of CAS, for his warmhearted guidance. References

关键词： land types; succession of land types; structural patterns; optimal allocation; Qinling Mountains

