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Research Progress on the Functions and Values of Watershed Ecosystem Services

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Abstract: As a region with strong interaction between natural processes and human activities, watershed has complex ecosystem structure and diverse service types, and has the closest relationship with human production and life. Firstly, the basic concept, function and value of watershed ecosystem services were reviewed, and it was found that the theory of ecosystem services was gradually enriched. Secondly, the current research on ecosystem services not only focuses on the composite research of multiple functions, but also focuses on the change of a single function and its affected mechanism. In addition, some new models based on geographic information technology (such as InVEST model, CASA model and RUSLE model) have been introduced into the evaluation methods of ecosystem service value except the equivalent factor method.

Keywords: Watershed; Ecosystem Service; Literature Review.

1. Preface

The formation of ecosystem services depends on the ecosystem structure and process on a certain time and space scale, and its significant role can only be shown on a specific time and space scale [1]. Land use/cover change (LUCC) is one of the most critical factors concerned deeply with landscape structure, function and dynamics. Land use landscape pattern changes affect the matrix and structure of landscape types in the region, and have an important impact on the structure, function and specific ecological process of the ecosystem, which eventually leads to the change of the supply and maintenance of the ecosystem service function [2]. The impacts of LUCC on ecosystem services vary with scales, and even in the same process, the impacts on ecosystem services at different scales are different. Watershed ecosystem is a social-economic-natural complex ecosystem, which has ecological integrity. When the ecosystem is disturbed by various natural or man-made factors and exceeds its adaptive capacity, irreversible damage or degradation, productivity decline, biodiversity decrease, and environmental regulation ability decline will inevitably occur in some aspects. Ecosystem services are closely related to human well-being and sustainable development. At present, the study of watershed ecosystem services based on land use has been paid more and more attention by academic circles. This paper mainly reviews the related literature, and discusses the research progress of ecosystem services function and value in the study of watershed ecosystem services based on land use.

2. Basic Concepts of Watershed Ecosystem Services

The MA assessment report pointed out that land use change (LUCC) is a key factor causing the change of ecosystem type and landscape pattern, and is the direct driving force of ecosystem service change in the past 50 years. There are great differences in land use/cover status, cognition level of actors on the relationship between LUCC and ecosystem services, and decision-making management mode of organizations at different spatial scales. There are large scale differences in the process, mode and mechanism of LUCC impact on ecosystem services [3]. Watershed is an important part of land and water ecosystem. Watershed forms a relatively independent and complete spatial unit through the boundary of natural water system. River, as a continuum, bears the main ecological functions such as material flow, energy exchange and information transmission between upper, middle and lower reaches [4]. Therefore, the special geographical and ecological characteristics of the watershed should be fully considered in the study of ecosystem services at the watershed scale.

Ecosystem service function refers to the natural environment conditions and their utility formed by ecosystem and ecological process to maintain human survival. The concept of ecosystem services was born in the 1960s and was first proposed and used by King et al. In 1997, Costanza's team from the University of Maryland first constructed a framework for quantifying natural assets and services, which was the first to quantify the value of global ecosystem services. The achievement was published in the journal Nature, in which Costanza et al. divided 16 different biological communities in the world, summarized the ecosystem service functions into 17 categories, and evaluated the value, which is of milestone significance for the quantitative research of global ecosystem service value [6]. In 2001, the Millennium Ecosystem Assessment (MA) defined ecosystem services as "the benefits that humans derive from ecosystems", which paid more attention to the relationship between ecosystem services and human welfare, driving factors of change, evaluation scales, evaluation techniques and methods. In China, the research on ecosystem services started late. The book <Research on Ecosystem Service Function> edited and published by Li Wenhua summarizes the progress of ecosystem service research. Ouyang Zhiyun and other scholars proposed that the ecosystem service function is mainly to provide rich species and genetic resources needed for the preservation of biological evolution, solar energy, carbon dioxide fixation, organic matter synthesis, etc [5]. Combined with the actual situation of our country, scholars have explored the relationship between ecosystem services and sustainable development strategy, the role of ecosystem services in natural disasters, the theory and practice of ecological forest compensation, and made some

progress.

The study of ecosystem service value originated in the first half of the 20th century. In 1925, Belgian scholars first proposed that the economic value of wildlife should be measured by the cost of human recreation around it. Based on the theory and method of ecological assets assessment, many models of ecological assets assessment have been developed by integrating the decision support techniques of ecology, economy and geography. The research on the value of ecosystem services in China began in the 1990s, including the measurement of economic losses caused by environmental damage and the evaluation of biodiversity value. Recent studies have paid more attention to ecosystem services and their evaluation. Gaodi Xie et al. estimated the service value of different ecological assets in Qinghai-Tibet Plateau by correcting biomass and other factors with reference to some results of global ecosystem service value assessment by Costanza et al. [7]. Domestic scholars have also studied the service functions of different types of ecosystems, such as wetlands, farmland, forests, grasslands, etc. Yuechen Li et al. established the evaluation model and method of the importance of ecosystem service function, and conducted a comprehensive study on the ecosystem service function in Chongqing section of the Three Gorges Reservoir Area [8]. Many experts and scholars in the field of ecosystem service value research and try to provide an opportunity for the development of ecological compensation, environmental damage value assessment and other topics, including the construction of ecological civilization has laid a good economic value foundation.

3. Research Progress on Ecosystem Services

Rivers and floodplains, wetlands, and lakes are among the most complex and dynamic ecosystems, playing a key role in freshwater supply, water purification, flood regulation, biodiversity conservation, and food supply [9]. As a region with strong interaction between natural processes and human activities, watershed has complex ecosystem structure and diverse service types, and has the closest relationship with human production and life. The basin has typical ecosystem structure characteristics and unique ecosystem functions, and its dynamics is very high, and the ecological process is easily disturbed and affected [10]. With the development of landscape ecology, scholars pay more attention to the dynamic assessment of the temporal and spatial changes of watershed ecosystem services. Based on InVEST model and CASA model, Kexin Du et al. quantified the typical ecosystem services of Heihe River Basin in 2018 by using multi-source remote sensing data from four aspects of ecosystem support service, regulation service, supply service and cultural service, and analyzed the gradient effect of each ecosystem service in combination with altitude, slope, topographic relief and topographic niche index factors, i.e., analyzed the ecosystem service function. Spatial heterogeneity [11]. Different from the above, Siyu He et al. used InVEST simulation to analyze the four ecosystem service functions of water supply, habitat quality, carbon storage and soil conservation in Wangkuai Reservoir Basin from 2005 to 2010, and further explored the changes of ecosystem service functions and the trade-off/synergy between them based on land use change [12].

At present, a large number of scholars from a certain point of view or the comprehensive role of multiple factors, targeted analysis of a certain ecosystem services or changes in the affected situation. For example, Siying Zhang et al. selected Longxi River Basin in Chongqing City, which is located in the important ecological barrier in the upper reaches of Yangtze River, as the research object, and studied the spatial and temporal change characteristics of water ecosystem services such as water production, water quality purification and soil conservation services in Longxi River Basin in recent 20 years and their influence by different land use types by using InVEST model [13]. It is not difficult to find that Siying Zhang and other scholars put the ecosystem services based on water cycle and water ecology(eco-hydrology) process as the research focus, and discussed the flow law of material, energy and information in the ecosystem in Longxi River Basin. Different from the former, Miao Qing et al. used the land use data from 1980 to 2020 in Shiyang River Basin, and used InVEST model and FLUS model to explore the impact of land use change on carbon storage in Shiyang River Basin in the past 40 years and in the future under three scenarios of natural change, ecological protection and cultivated land protection. The results show that the carbon storage of Shiyang River Basin presents obvious spatial differentiation, and the areas with high carbon storage are mainly distributed in the upper Qilian Mountains and the oasis areas in the middle and lower reaches, which is closely related to the spatial distribution of land use types in the basin [14]. This study also analyzes the carbon storage function of ecosystem from different scenarios or different angles, so as to provide a strong basis for the protection or governance of ecosystem. Some scholars also consider the factors that will affect the ecosystem service function, and analyze the impact on the ecosystem service function after dealing with them. For example, Qijie Zeng et al. analyzed the spatial and temporal variation characteristics and influencing factors of soil conservation function, a single ecological service function, in Yiluo River Basin from 2010 to 2020 by using the modified universal soil erosion equation (RUSLE) and statistical methods in consideration of comprehensive factors such as land use, vegetation, climate and soil [15].

4. Research Progress on the Value of Ecosystem Services

The concept and content classification of ecosystem services lay a theoretical foundation for its value assessment. Ecosystem service value assessment has a wide range of objects, including various ecological elements or their subsystems [16]. With the continuous enrichment and innovation of relevant research theories, the attention of scholars in the evaluation of ecosystem service value has shifted from the early large-scale single natural ecosystem to the multi-type of small and medium-scale such as watershed, forest, wetland, and the evaluation of its ecosystem value is also being further developed. There are many methods for watershed assessment, but there are mainly two methods for ecosystem service value assessment, value method and material quantity method.

Value assessment uses value theory to highlight the importance of natural assets and is applied to regional ecological compensation and other fields [17,18]. The use value and non-use value of ecosystem services are estimated through value coefficients of different landscape types [19,20]. Equivalent factor method and functional value

method are both value assessment methods. The former calculates the total value of ecosystem services of land type area based on the service value equivalent of unit area, while the latter further quantifies the price of ecosystem services combined with economic market price. The equivalent factor method based on the assumption that "the value of ecosystem services of the same unit land is the same" is greatly affected by the spatio-temporal heterogeneity of ecosystem services, and is more suitable for the service value assessment of small-scale regions. In addition, it is summarized in the literature [21,22, 23,24] that the application of the equivalent factor method is more in the study of this scale of river basin. Based on the land use, natural environment and socio-economic data of Dongjiang River Basin from 2010 to 2020, combined with hot spot analysis tools and local spatial autocorrelation analysis method, and referring to the revision of equivalent factor table of Dongjiang River Basin by relevant scholars, Haixia Yu et al. calculated the ecosystem service value of one standard equivalent factor of Dongjiang River Basin, and then obtained the service value per unit area of different land types of ecosystems in Dongjiang River Basin. Finally, comprehensive analysis of spatial and temporal evolution of ESV in Dongjiang River Basin, the spatial differentiation mechanism of ESV in Dongjiang River Basin was explored under the support of geographic detector tools [25]. Based on the long-term research and national equivalent factor table published by Gaodi Xie and other scholars, Jie Jin used the equivalent factor evaluation method to calculate the ecological service value of land use in Dianchi Lake Basin from 1974 to 2016(ESV), and using remote sensing, GIS technology and extensible stochastic environmental impact assessment model(STIRPAT) combined with geographically weighted regression method (GWR) to analyze the spatial and temporal variation and influencing factors of ESV in the basin during the five periods from 1974 to 2016[26]. Chen Xiangbiao et al (Dianchi Lake, Fuxian Lake, Xingyun Lake, Qilu Lake and Yangzonghai Lake) as the research unit, based on the remote sensing land use data of 2000,2010 and 2020, the land use structure and change process were analyzed by using the single land use dynamic degree, land use degree comprehensive index model and land use transfer matrix. Based on the revised ecosystem service value equivalent and ecosystem service value calculation model, The change characteristics of ecosystem service function value in lake basin from 2000 to 2020 were analyzed [27].

With the development of geographic information technology, physical assessment, which reflects ecosystem functions and processes, is becoming more and more important, and tends to be integrated with spatial explicit landscape pattern simulation. The material quantity method mainly evaluates the services provided by the ecosystem as a whole from the perspective of material quantity, and objectively reflects the impact of land use landscape process on watershed ecosystem services [20]. The emergy method combines the energy system theory to reveal the physical basis and formation mechanism of ecosystem services with emergy indicators, reflecting the energy flow and regional differences of ecosystem services [16]. The model method measures the quality of ecosystem services through the integrated model. The structure of watershed ecosystem has spatial heterogeneity, and the uneven distribution of the total value of ecosystem services will be ignored obviously if the total value of ecosystem services is estimated only. Therefore, assessment models based on ecological processes, remote sensor data and socio-economic ecosystem data play an increasingly important role in research. At present, most of the studies on the application of model method to the evaluation of ecosystem service value [29] are based on InVEST model, CASA model and RUSLE model. Wang Yuchun et al. used meteorological, land use, NDVI, soil and other data, based on InVEST model, CASA model and RUSLE model, with the help of correlation analysis method to quantitatively calculate and analyze the water yield, NPP and soil conservation services and their trade-offs and synergies in Shiyang River Basin from 2003 to 2018, and proposed a method to identify the comprehensive relationship between various ecosystem services, and studied the spatial differentiation characteristics of the comprehensive relationship of ecosystem services in Shiyang River Basin. And the driving mechanism was revealed by the geo-detector method [30]. Based on InVEST model, CASA model and RUSLE model, Zizheng Zhang et al. estimated the value of grain supply, net primary productivity (NPP), soil conservation and water production services in Qingjiang River Basin from 2000 to 2020, and then analyzed the trade-off synergy relationship between them by using correlation analysis, root mean square deviation and other methods, and analyzed the determinants affecting ecosystem service trade-off by using geographic detector [31]. In addition, in view of the unique geographical environment conditions of the study area, Zhixiong Tang et al. considered the effects of land use change, rainfall intensity and surface runoff on soil erosion, and adopted SWAT model for large and medium-scale watershed developed by Agricultural Research Center of US Department of Agriculture to simulate soil erosion in the study of ecosystem services in Jinghe River Basin of Loess Plateau, so as to evaluate the soil conservation function of ecosystem. Studies have shown that the model has high applicability in this region [32]. InVEST model includes terrestrial, marine and freshwater ecosystem modules, which can better evaluate the value of support, regulation and supply services of these three types of ecosystems, and can be found from the current research results that it is widely used, but it is not suitable for cultural service value assessment.

5. Conclusion

The contradiction between ecological environment problems and social and economic development of river basins is mostly closely related to the unreasonable utilization of river basin resources and the unreasonable human activities, which makes it one of the key points of earth system science to seek answers to these problems from the perspective of river basins. Firstly, the basic concept, function and value of watershed ecosystem services were reviewed, and it was found that the theory of ecosystem services was gradually enriched. Secondly, the current research on ecosystem service function not only pays attention to the compound research of multi-function, but also pays more attention to the in-depth analysis of the change of a single function and its affected mechanism. Although the current functional value analysis covers the support, regulation and supply services of ecosystem, the research on the content, evaluation and evaluation of its cultural services is very limited. On the other hand, most of the researchers are based on the relationship between landscape type and ecosystem service value, and use the value equivalent factor table to evaluate the ecosystem service value of each landscape type. However, the research on the relationship, formation process and mechanism of

regional ecosystem services is relatively few. In addition to the equivalent factor method, some new models based on geographic information technology (such as InVEST model, CASA model and RUSLE model) are also introduced.

References

[1] Wang Guangcheng, Li Zhongcai. Ecosystem service function based on spatio-temporal scale and benefit relationship [J]. Acta Ecologica Sinica, 2007 (11):4758-4765.

[2] Wang Yinghui, Ding Jianli, Li Xiaohang, Zhang Junyong, Ma Guolin. Impact of LUCC on ecosystem service value in Yili River Basin: Based on intensity analysis model [J/OL]. Acta Ecologica Sinica, 2022 (08):1-13[2022-06-23].

[3] Zhang Yushuo, Wu Dianting, Lu Xiao. Impact of land use/cover change on ecosystem services: Review of the research on spatial scale perspective [J]. Journal of Natural Resources, 2020, 35 (05):1172-1189.

[4] Liu Yang, Bi Jun, Lv Jianshu. A review on classification of ecosystem services and its reclassification at watershed scale [J]. Resource Science, 2019, 41 (07):1189-1200.

[5] Ouyang Zhiyun, Wang Rusong, Zhao Jingzhu. Ecosystem services and their eco-economic value [J]. Chinese Journal of Applied Ecology, 1999 (05):635-640.

[6] Costanza R, Darge R, De Groot R, et al. The value of the world's ecosystem services and natural capital. Nature, 1997, 387(6630): 253-260.

[7] Xie Gaodi, Lu Chunxia, Leng Yunfa, et al. Valuation of ecological assets in Qinghai-Tibet Plateau [J]. Journal of Natural Resources, 2003 (02):189-196.

[8] Li Yuechen, Liu Chunxia, Min Jie, et al. Evaluation on the importance of ecosystem services in the Three Gorges Reservoir Area [J]. Acta Ecologica Sinica, 2013, 33 (01):168-178.

[9] Li Shuangcheng. Geography of Ecosystem Services. Beijing: Science Press, 2014:26-42.

[10] Xue Xinghua, Qian Hua. Development and current core issues of river landscape ecology [J]. Advances in Water Science, 2018, 29(06):887-897.

[11] Du Kexin, Zhang Fuping, Feng Qi et al. Terrain gradient effect and ecological regionalization of ecosystem services in Heihe River Basin [J]. Desert of China, 2023, 43 (02):139-149.

[12] He Siyu, Zhang Lei. Evaluation of ecosystem services and trade-off/synergy relationship in Wangkuai Reservoir watershed based on InVEST model [J]. Hydroelectric Energy Science, 2022, 40 (11):60-63+81.

[13] Zhang Siying, Chen Rongrong, Cheng Xian. Spatial-temporal evolution of aquatic ecosystem services and its response to land use change in Longxi River Basin, Chongqing [J]. Chinese Journal of Soil and Water Conservation, 2023, 37 (04):173-183.

[14] Qing Miao, Zhao Jun, Feng Chao et al. Response of ecosystem carbon storage services to land use change in Shiyang River Basin from 1980 to 2030 [J]. Acta Ecologica Sinica, 2022, 42 (23):9525-9536.

[15] Zeng Qijie, Li Shuangquan, Ma Yufeng et al. Dynamic changes of soil conservation ecosystem service function in Yiluo River Basin [J]. Soil and Water Conservation Bulletin, 2023, 43 (02):350-360.

[16] Chen Dongjun, Zhong Linsheng. Review on the valuation and realization mechanism of ecosystem services [J]. Chinese Journal of Agricultural Resources and Regionalization, 2023, 44 (01):84-94.

[17] McNeely J A, Miller K R, Reid W V, Mittermeier R, Werner T B. Conserving the World's Biological Diversity. Gland, Switzerland: International Union for Conservation of Nature and Natural Resources, 1990:1-39.

[18] Pearce D W. Blueprint 4: Capturing Global Environmental Value. London: Earthscan, 1995:1-20.

[19] Costanza R, De Groot R, Sutton P, Van Der Ploeg S, Anderson S J, Kubiszewski I, Farber S, Turner R K. Changes in the global value of ecosystem services. Global Environmental Change, 2014, 26:152-158.

[20] Liang Youjia, Liu Lijun. A review on the integration of ecosystem services and landscape pattern [J]. Acta Ecologica Sinica, 2018, 38 (20):7159-7167.

[21] Wang Yinghui, Ding Jianli, Li Xiaohang et al. Impact of land use/cover change on ecosystem service value in Yili River Basin based on intensity analysis model [J]. Acta Ecologica Sinica, 2022, 42 (08):3106-3118.

[22] Yang Qiangqiang, Xu Guanglai, Li Aijuan et al. Evaluation and trade-off of ecosystem services in Qingyi River Basin [J]. Acta Ecologica Sinica, 2021, 41 (23):9315-9327.

[23] WU Zhaopeng, ZHANG Jinyan, WANG Juanjuan et al. Spatial-temporal changes of land use and ecosystem service value in oasis of Jinghe River Basin [J]. Journal of Ecology and Rural Environment, 2021, 37 (09):1168-1175.

[24] Wu Cuixia, Feng Yongzhong, Zhao Hao et al. Study on ecosystem service value of the Yellow River Basin in Gansu Province based on land use change [J]. Chinese Desert, 2022, 42 (06):304-316.

[25] Yu Haixia, Wang Yuxiao. Spatial-temporal evolution and spatial differentiation mechanism of ecosystem service value in Dongjiang River Basin [J/OL]. Chinese Journal of Applied Ecology:1-12[2023-08-11].

[26] Jin Jie. Spatial-temporal variation of ecosystem service value in Dianchi Lake watershed based on land use and its impact [J]. Soil and Water Conservation Research, 2022, 29 (06):344-351.

[27] Chen Xiangbiao, Ding Wenrong. Land use change and ecosystem services in lake basins of central Yunnan Plateau [J]. Soil and Water Conservation Research, 2022, 29 (03):205-212.

[28] Tang Yuzhi, Shao Quanqin, Cao Wei, Yang Fan, Liu Lulu, Wu Dan, Zhou Shugui. Comparison of Ecosystem Services and County Differences in Southern Guizhou Based on Material Quality Assessment. Geographical Sciences, 2018, 38(1): 122-134.

[29] Xu Jing, Yang Guishan, Xu Chen et al. Trade-off and multi-objective optimization of ecosystem services in water source areas of lakes and reservoirs: a case study of Tianmu Lake watershed [J]. Yangtze River Basin Resources and Environment, 2023, 32 (01):62-70.

[30] Wang YC, Zhao J, Fu JW, et al. Spatial differentiation and driving factors of integrated relationship of ecosystem services: a case study of Shiyang River Basin [J]. Soil and Water Conservation Research, 2023, 30 (02):274-284.

[31] Zhang Zizheng, Zhang Lei, Sun Guiying et al. Spatial-temporal effects and driving factors of ecosystem services trade-off in Qingjiang River Basin [J]. Chinese Journal of Applied Ecology, 2023, 34 (04):1051-1062.

[32] Tang Zhixiong, Zhou Zixiang, Bai Jizhou et al. Scale heterogeneity of trade-off/synergy of ecosystem services in Jinghe watershed [J]. Soil and Water Conservation Research, 2023, 30 (04):318-326.

[33] Gong J, Liu Dongqing, Gao BL, et al. Trade-off and synergy of ecosystem services in western mountain watershed: a case study of Bailong River watershed in Gansu Province [J]. Chinese Journal of Applied Ecology, 2020, 31 (04):1278-1288.