

A Review of the Interaction Between Land Use Change and Ecological Environment

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Abstract. The utilization of land cover change is the most core way for human disturbance of regional ecology. Under the rapid urbanization, the extensive development of land has led to problems such as the fragmentation of ecological land, soil erosion, the degradation of biological habitats, and the intensification of ecological risks. However, ecological carrying capacity and ecological sensitivity will in turn restrict the scale and layout of land development. The two form a complex relationship of bidirectional coupling and dynamic feedback. This paper reviews the driving paths of land use on the ecological environment, as well as the multiple constraint mechanisms formed by the ecological environment from natural background, ecological pattern, disaster feedback, and policy control. It also summarizes the three mainstream research hotspots of spatio-temporal evolution, ecological service trade-offs, and multi-factor coupling. And clarify the multi-level mutual feedback laws of natural and human driving factors. The research finds that the existing achievements generally have five major shortcomings. Based on this, it is proposed that future research should focus on areas quantifying ecological security thresholds, enhancing multi-scale analyses, and establishing a long-term monitoring system to better support sustainable land development.

Keywords: Land use change, Ecological environment, Coupled mutual feedback, Ecological risk

1. Introduction

Land use cover change is the core human-induced cause of ecological deterioration, and extensive development has led to a two-way restrictive relationship between land and ecology [1]. Since the 1990s, a large number of regional studies on the three-life space have been carried out in China. However, the existing research focuses more on the one-way impact of land on ecology. Most of the existing studies only analyze the one-way effect of land on ecology, lacking systematic exploration of the two-way mutual feedback between the two. There are also problems such as the difficulty in connecting studies of different scales and the lack of local adjustment of models. This leads to the difficulty for relevant theories to be implemented and guide actual governance.

This article reviews the bidirectional interaction mechanism between land use and the ecological environment, summarizes the existing research hotspots, driving factors and shortcomings through empirical cases, improves the human-land coupling theory, predicts the future research and

development direction in this field, and can also provide theoretical basis and improvement ideas for land planning and ecological protection and governance. This research enriches the theory of the coupling of human-land relationship and provides theoretical support for the fine control of territorial space and the coordinated and sustainable development of regional human and nature.

2. Theoretical basis

The research on the interaction between land use and ecological environment relies on the interdisciplinary theories of geography, ecology, land science, systems science, etc. After long-term development, it has formed a logically complete theoretical system. This system comprises five complementary sections: core foundation, pattern process correlation, quantitative assessment, regulation and optimization, and system mutual feedback analysis, providing support for the analysis of the coupling mechanism of LUCC.

The theory of human-land coordination is the core foundation, originated from Wu Chuanjun's theory of the regional system of human-land relationship, explaining the unity of opposites between human land development activities and the natural ecological environment, and laying the foundation for the research paradigm of human-land regulation and sustainable development [2].

Landscape ecology analyzes spatial heterogeneity by means of indicators such as patches, corridors, and substrates, opening up research channels for land spatial patterns and ecological evolution processes, and is often used for ecological risk and habitat fragmentation analysis.

The ecosystem service theory, combined with the InVEST and SAORES models, can quantitatively measure the ecological value changes of functions such as water conservation, carbon sequestration, and soil and water conservation [3].

The theory of sustainable development takes into account the three-dimensional balance of economy, society and ecology, and can guide practical work such as territorial space planning and ecological restoration, which is in line with the current development needs of ecological civilization construction.

3. The driving mechanism of land use change on the ecological environment

Land use change is the core anthropogenic driving factor that triggers the evolution of the ecological environment. It mainly occurs through three paths: land use type transformation, spatial pattern reconstruction, and disturbance of utilization intensity, triggering a chain response of the regional ecological environment. It is the core dominant dimension of the interaction between the two systems.

The ecological and environmental effects of land use type conversion. The focus of cultivated land is on grain production, while forests can conserve water and soil, regulate climate and protect biodiversity. Wang, relying on methods such as ecological contribution rate and land transfer matrix, studied Wutai County and found that the conversion of forest land into grassland and subsequent development into construction land was the main cause of ecological deterioration. The expansion of local construction land squeezed cultivated land, grassland and water areas [4].

The gradient ecological effect of land use intensity disturbance. By using tools such as ArcGIS and dynamic land use attitude, Yang concluded that the dynamic land use attitude in the basin increased from 0.33% to 0.72% from 2000 to 2020, and human development intervention continued to strengthen [5].

4. The reverse constraint mechanism of ecological environment on land use

Ma coupled the GMOP and PLUS models to explore the land use laws in arid areas [6]. The shortage of water resources and the fragile grassland ecology in arid areas naturally restrict the disorderly expansion of towns and cultivated land. In mountainous earthquake-prone areas with superimposed geological disaster risks, it is necessary to divide control zones and strictly control the scale and spatial distribution of various types of development land.

Core ecological Spaces such as water conservation areas, wetlands and biological habitats form a rigid ecological bottom line, restricting the disorderly expansion of cultivated land and construction land. The essence of ecological red lines and ecological networks is to transform the demand for ecological integrity into land control rules. Li took the Changsha-Zhuzhou-Xiangtan metropolitan area as an example and confirmed that the ecological security pattern established based on the MCR model can curb the encroachment of urban land on ecological sources and adjust the boundaries of urban expansion [7]. Xu Xibao proposed in his research on the Yangtze River Delta that there is a critical value for connectivity in regional ecological patches and corridors [8]. Excessive urbanization would disrupt the ecosystem and reduce ecological services. Therefore, it is necessary to reduce the development scale within corridors and optimize the urban spatial structure.

Land development that exceeds ecological thresholds can trigger disasters such as soil erosion and landslides, increase governance costs, and force the optimization of land use methods. The promotion of returning farmland to forest through the reclamation of steep slopes in the Loess Plateau is a typical example. Liu's research indicates that regional soil erosion continuously deplets cultivated land, promoting the return of sloping farmland to forest and grassland and optimizing the land use structure [9].

The degradation of the ecological environment has given rise to various ecological control policies. Systems such as ecological red lines, fallow farmland, and the integration of multiple plans have transformed ecological restrictions into legal control rules. In 2019, the national spatial planning policy clearly prioritized ecological conservation and strictly controlled high-pollution and high-consumption development projects in land approval. This type of system fixes ecological feedback as a long-term constraint and is currently the most effective way to coordinate the contradiction between humans and the land.

5. Research on the coupling mechanism of multiple driving factors

Most existing studies have selected the urban-rural transition zone, ecologically fragile areas and river basins to conduct empirical research, revealing that there is a significant spatial differentiation in the coupling relationship between land use and the ecological environment. Ecosystem services are at the core of coupled analysis. The research focuses on exploring the impact of land patterns on multiple ecological services and their trade-off synergy effects, providing support for the optimization of territorial space [10-12].

5.1. Classification system of multiple driving factors for land use change

Natural factors form the inherent basis of the regional land use spatial pattern and are rigid natural constraints that land development activities cannot break through. They are classified into the following three categories. The basic background elements include topography and geomorphology, climatic conditions, soil properties, water resource endowment, geological structure and disaster risk, which determine the suitability of regional land and naturally delineate the basic boundaries of

urban, agricultural and ecological Spaces [13]. The constraint elements of ecological carrying capacity include ecological fragmentation, ecological connectivity, critical threshold of ecosystem services, upper limit of ecological carrying capacity, and upper limit of regional land development intensity. When land development exceeds the ecological threshold, it will trigger negative feedback of ecological degradation [14]. Sudden natural disturbance factors include extreme climate change, earthquakes, landslides, floods, droughts, and soil erosion, which drastically alter the surface cover in a short period of time and force the passive adjustment of land use structure [15].

Urbanization, economic industries, land policies, and technological cognition are the core drivers of the drastic changes in land use in recent decades. Human-driven factors can transform and reshape the natural base conditions, which can be classified into the following four categories. Population and location factors, including population concentration and transportation location, promote urban expansion and reshape the land development pattern [16]. Economic development and industrial transformation squeeze ecology and arable land, driving the change of land use [17]. Land-related policies rely on compulsory control to balance development and protection [18]. Progress in various engineering, agricultural technologies and ecological concepts has continuously transformed land development models and land use structures [19].

5.2. Internal coupling mechanism of multiple driving factors

The synergistic promotion of coupling is manifested in the fact that superior terrain, water sources and soil conditions give birth to contiguous high-quality cultivated land, and the well-connected ecological foundation can support moderate development [13]. The coupling of constraints and checks and balances is manifested in the fact that high-risk areas of drought and geological disasters impose rigid restrictions on urban expansion. Once the intensity of land development exceeds the ecological threshold, disasters such as floods and soil erosion will in turn restrict development activities.

The four major driving factors of human beings have a coupling chain of layer-by-layer transmission and linkage amplification. Economic development promotes urbanization and population concentration, while urban construction encroaches on cultivated land. Disorderly development has led to ecological problems and given rise to various spatial control policies. With technological progress and the enhancement of ecological awareness, extensive development has been restricted, promoting the transformation of land use towards intensive and ecological conservation.

5.3. Cross-system coupling and mutual feedback mechanism between natural driving factors and artificial driving factors

The natural base and human activities do not act independently. Instead, they form a bidirectional circular coupling system of "nature constraining human development — human transformation of the natural base — natural feedback constraining human activities", which is divided into two major coupling paths: positive promotion and negative constraint.

Positive adaptation coupling refers to the natural base supporting artificial land development. Reduce the costs of urban construction and agricultural production and development, attract population concentration and industrial settlement, and promote the expansion of regional land development scale. Good ecological connectivity and complete ecosystem services can support higher-intensity economic construction activities and achieve short-term synergy between development and ecology [9, 13].

Negative feedback coupling refers to the ecological backlash triggered by excessive development that exceeds the ecological threshold. When the disorderly expansion of population and towns exceeds the regional carrying capacity, the reclamation of cultivated land triggers soil erosion and drought, urban construction cuts off ecological corridors and destroys biological habitats, and disasters such as floods and landslides occur frequently, damaging urban and rural land. This will force localities to adjust their land use structure, tighten development control, carry out ecological restoration, and rebalance development intensity with ecological carrying capacity [20].

Policies for the protection of national territory, ecology and cultivated land are key means to coordinate the driving forces of nature and human activities. The policy designates three zones and three lines in combination with the regional background and ecological carrying capacity, and controls the upper limit of development. At the same time, land use indicators should be allocated based on economic and population demands to balance ecological constraints and development needs and alleviate the contradiction between population and land [1].

6. Conclusion

The land system and the ecological environment form a nonlinear, bidirectional feedback human-land complex system, creating a complete closed loop of "development disturbance — ecological degradation — control and optimization". The multi-layer driving factors of nature and human beings are coupled with each other, resulting in obvious spatial differences in the coupling relationship between the two. Ecosystem services serve as the core medium for analyzing the interaction between humans and the land, and provide a critical pathway to connect theoretical research with land governance. Although China has accumulated a large amount of local regional empirical evidence, research still suffers from deficiencies in exploring two-way mutual feedback mechanism and multi-scale linkage analysis.

There are five prominent problems in the current field: First, most research focuses on the one-way impact of land on ecology, neglecting the reverse constraints of ecology on development, and the analysis of the system evolution mechanism is incomplete, Second, the research is limited to a single scale and lacks a mature cross-scale analysis framework, making it difficult for macro conclusions to guide grassroots governance. Thirdly, the parameters of mainstream simulation models lack local correction, resulting in insufficient regional simulation accuracy. Fourth, the research is overly focused on theoretical calculations and lacks practical and implementable plans for optimizing territorial space. Fifth, it is challenging to forecast long-term evolution hazards due to the predominance of static cross-sectional data and the dearth of long-term continuous dynamic monitoring studies.

Overall, the research on the coupling of land use and ecological environment, as a core branch of human-land system science, will continue to move towards systematic mechanism analysis, multi-scale comprehensive analysis, intelligent simulation and prediction, and practical governance applications in the future. By improving the two-way mutual feedback theory and optimizing quantitative technical tools, Provide solid theoretical and technical support for the precise control of territorial space, the guarantee of regional ecological security, and the harmonious and sustainable development of human and nature.

References

- [1] Geng, X., Hu, S., Xiao, Y., et al. (2022). Optimization and evaluation of land use pattern in Northeast agro-pastoral ecotone based on ecosystem service value. *Journal of Natural Resources*, 37(7), 1799–1814.

- [2] Li, X., Wang, Z., Liu, D., et al. (2023). Simulation and control of construction land evolution in the Changsha-Zhuzhou-Xiangtan metropolitan area under the constraint of ecological security pattern. *Journal of Environmental Engineering Technology*, 13(1), 348–358.
- [3] Yang, J., Zhou, P., Yuan, S., et al. (2022). Research on ecosystem service functions of Dongting Lake Ecological Economic Zone based on InVEST model. *Bulletin of Soil and Water Conservation*, 267–272, 282. <https://doi.org/10.13961/j.stbctb.2022.01.035>
- [4] Zhang, Y., Li, F., Zhang, R., et al. (2025). Spatio-temporal evolution and trade-off/synergy analysis of ecosystem services in the Xi'an section of the Qinling Mountains. *Remote Sensing of Natural Resources*, 37(6), 191–200.
- [5] Zhang, H., Yuan, S., Dong, K. (2026). Analysis on the dynamic changes of land use landscape pattern in Xiangtuo Mountain Area, Guangdong Province by topography. *Remote Sensing of Natural Resources*, 38(2), 209–218.
- [6] Deng, F. (2024). The impact of land use change on ecological environment. *Heilongjiang Environmental Bulletin*, 37(5), 123–125.
- [7] Li, T., Qiao, Z., Feng, W., et al. (2024). Grazing intensity and temporal variation characteristics of ecosystem services on the Loess Plateau under restrictions. *Journal of Ecology and Rural Environment*, 40(3), 313–324. <https://doi.org/10.19741/j.issn.1673-4831.2023.0317>
- [8] Yang, H., Xu, Y., Zhou, K., et al. (2023). Evaluation of the suitability, adaptability and reserve potential of construction land on the Qinghai-Xizang Plateau. *Acta Geographica Sinica*, 78(9), 2128–2146.
- [9] Fu, B., Liu, Y., Cao, Z., et al. (2023). Ecological protection and high-quality development on the Loess Plateau: Current situation, problems and suggestions. *Proceedings of the Chinese Academy of Sciences*, 38(8), 1110–1117. <https://doi.org/10.16418/j.issn.1000-3045.20230525001>
- [10] Chen, L., Fu, B., Zhao, W. (2006). "Source" and "sink" landscape theory and its ecological significance. *Acta Ecologica Sinica*, (5), 1444–1449.
- [11] Ma, K., Fu, B., Li, X., et al. (2004). Regional ecological security pattern: Concept and theoretical basis. *Acta Ecologica Sinica*, (4), 761–768.
- [12] Zhang, W., Wang, C., Lyu, X., et al. (2003). The coupling relationship between land use change and industrialization and urbanization in the Pearl River Delta. *Acta Geographica Sinica*, (5), 677–685.
- [13] Zhang, H., Li, Z., Li, Y. (2019). Research on the sustainable land use model of mountain towns based on ecological security: A case study of Dali City, Yunnan Province. *Geographical Research*, 38(11), 2681–2694.
- [14] Central Committee of the Communist Party of China & The State Council. (2019, May 24). Several opinions on establishing a national spatial planning system and supervising its implementation [Newspaper article]. *People's Daily*, p. 001.
- [15] Liu, J. (2019). *The process of vegetation cover change and future distribution prediction on the Loess Plateau after returning farmland to forest* [Doctoral dissertation]. University of Chinese Academy of Sciences.
- [16] Long, H., & Tu, S. (2018). Land use transformation and rural revitalization. *China Land Science*, 32(7), 1–6.
- [17] Zhao, W., Liu, Y., Feng, Q., et al. (2018). Ecosystem services under the framework of human-earth system coupling. *Progress in Geography*, 37(1), 139–151.
- [18] Kong, D., Chen, H., & Wu, K. (2021). Evolution characteristics, ecological environment effects and influencing factors of "three living spaces" in China. *Journal of Natural Resources*, 36(5), 1116–1135.
- [19] Fu, B. (2017). Geography: From knowledge, science to decision. *Acta Geographica Sinica*, 72(11), 1923–1932.
- [20] Fan, J., Tao, A., Chen, T., et al. (2008). The fundamental role of resource and environmental carrying capacity evaluation in post-Wenchuan earthquake recovery and reconstruction planning. *Proceedings of the Chinese Academy of Sciences*, (5), 387–392. <https://doi.org/10.16418/j.issn.1000-3045.2008.05.002>