

**Study on the Evolution Characteristics and Collaborative  
Governance Strategies of "Production-Living-Ecological" Space  
at county level in Loess Hills and Gully Areas--Taking Huangling  
County as an Example**

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### **Abstract**

With China's rapid economic development and continued urbanisation, the contradiction between urban expansion and land resource use has become increasingly prominent. The study site is located in the gully area of the Loess Plateau, where soil erosion is a prominent problem. The acceleration of urbanisation further complicates the spatial contradiction between production, life and ecology. In the context of ecological civilisation construction, it is crucial to study the spatial evolution of production-life-ecology in the county. The study indicates that the production space in Huangling County is fragmented, the living space is inefficient and the ecological space is fragile. Consequently, a comprehensive management strategy to protect the production space, optimise the living space and regulate the ecological space is proposed.

### **Keywords**

Production-Living-Ecological space; Spatio-temporal evolution; Collaborative governance; PLUS model

### **Full text**

## **0 Introduction**

The rapid development of China's urbanisation is often more concerned with the economic benefits that can be gained, often neglecting the improvement of the comprehensive benefits of land resources(Liu and Sun 2020). The Loess Plateau, as a typical soil and water loss region, not only faces long-term ecological pressure for urban development, but also the complex topographic environment severely restricts the rapid advancement of urbanisation. In 2019, the Ministry of Natural Resources explicitly proposed that territorial spatial planning should be aimed at building intensive and highly efficient production space, livable and moderate living space, and unspoiled and beautiful ecological space. With the gradual entry into the transition of urban development in China, the optimisation of the “production-living-ecological” space coordination in the loess plateau region at the development stage has gradually received hot attention from planning academics(Wang, Sun et al. 2020, Liu, Huang et al. 2023).

The collaborative governance of county “production-living-ecological” space is directly oriented towards solutions, and is an important aspect of the coordination and optimization of national spatial resources. Currently, studies on the collaborative governance of county “production-living-ecological” space often start from the two core aspects of classification system and optimal spatial layout, and have formed a diverse research system(Zou, Wang et al. 2018, Cui, Zhu et al. 2020, Gao, Yang et al. 2022). From the perspective of research content, although the current research generally attaches importance to the scientific proof of the coordination of the “production-living-ecological” space, most of the research focuses on the use of the established results to analyse the current situation, while the “production-living-ecological” space often takes a certain amount of time to unfold, so it is important to carry out collaborative governance on the basis of analysing the evolutionary patterns and future development trends of the “production-living-ecological” space in a long time series.

## **1 Data sources and research methodology**

### **1.1 Overview of the study area**

Huangling County has a total area of 2,292 square kilometre, and the geomorphological types within the regional scope are complex and diverse. The eastern loess plateau surface area is part of Luochuan tableland, which is the main area of agricultural activities in the county, and more than 70 percent of the production space is distributed here; the western mountainous area belongs to loess hills and soil and rocky mountainous areas, and more than 80 percent of the ecological space, which is dominated by forests, is concentrated here; and the river valley and

river channel area, which is mainly the valley of the Discouragement River and its terraces, is the living space. It is the main distribution area of living space. In recent years, as the urbanisation process continues, more and more urban construction activities have begun to encroach on cultivated land and grassland in an uncontrolled manner, and under the influence of a series of policies such as "grain for green project" and "cultivated land requisition-compensation balance", structural imbalance has begun to appear in the internal development of the region.

## 1.2 Data sources

The land use data used in this paper come from the publicly released 30m-resolution land cover dataset by the team of Professors Yang Jie and Huang Xin of Wuhan University, which is based on 5,463 visually decoded samples and has an overall accuracy of more than 80%; for the spatial environment data, the population distribution, GDP, spatial interpolation of mean annual temperature, spatial interpolation of mean annual precipitation, and distribution of soil types are from the Resource and Environment Science and Data Centre (<https://www.resdc.cn/>); road data and watershed data are from the National Geographic Information Resources Catalogue Service System (<http://www.webmap.cn/>); and DEM data are from the Geospatial Data Cloud (<http://www.gscloud.cn/>).

## 1.3 Research methodology

### 1.3.1 Classification of “production-living-ecological” space

The classification method based on land use type is more suitable for analysing the spatial and temporal evolution of “production-living-ecological” space, and the study area is divided with reference to the classification system of the dominant function method, combined with the actual situation of territorial spaces in Huangling County (Liu, Liu et al. 2017, Jiao, Yang et al. 2021)(Table 1).

Table 1. Land use classification system of “production-living-ecological” space.

Spatial categorisation	Dominant function	Land use type
Production space	Agricultural production activities	Cultivated land
Living space	Urban and rural living activities	Construction land
Ecological space	Regulation and maintenance of regional ecological security	Woodland, Shrubland, Grassland, Water area

### 1.3.2 PLUS model

The PLUS model can effectively simulate the complex evolution of multiple land classes. Based on various types of acquired data on land use drivers in Huangling County, the Land Expansion Analysis Strategy (LEAS) and the CA model based on multiple types of stochastic patch seeds (CARS) are used to simulate the land use types of Huangling County in 2025 and 2030, and the combination of land use data of each year can show the “production-living-ecological” space of Huangling County in its entirety history and future changes.

### 1.3.3 Land use transfer matrix

The land use transfer matrix describes the quantitative structure and spatial distribution characteristics of regional land use type changes. According to the relationship between the changes in land use data of Huangling County from 1995-2030, a number of two-dimensional matrices are obtained, and by analysing the obtained transfer matrices, the transformation

between different land categories is obtained, which can be used to analyse the land categories that have changed in different years, as well as the location and area of change.

#### *1.3.4 Spatial conflict model*

The spatial conflict model is often used to quantitatively characterise the state of conflicts between land uses, and according to the quantitative analysis of three dimensions of the spatial complexity index, spatial vulnerability index and spatial stability index of the six periods of land use data in the study period in Huangling County, the spatial conflict intensity index is obtained through comprehensive calculation, which can be used to assess the degree of coordination of the “production-living-ecological” space. The lower the spatial conflict intensity, the higher the degree of coordination.

## **2 Characteristics of spatial evolution in Huangling County**

### **2.1 Spatial aggregate characteristics of staged evolution**

The results of the evolution of the total amount of “production-living-ecological” space in Huangling County show that the production space is decreasing, the living space continues to grow, and the ecological space is relatively stable in the time period of the study. The study is divided into three phases based on the increase and decrease of each type of space (Figure 1).

The first phase was from 1995-2005, during which the changes in the “production-living-ecological” space were relatively stable, with production space and living space continuing to grow and ecological space continuing to decrease. The ecological space decreased by 4.37 square kilometre while the production space increased by 2.33 square kilometre, and both the decrease in ecological space and the increase in production space were the largest in the study period, which shows that the urban development of Huangling County in this period was mainly based on agricultural production, and the additional cultivated land caused a large amount of damage to the ecological space.

The second stage is from 2005-2010, in which the “production-living-ecological” space changes drastically, the production space decreases and the ecological space starts to increase, while the living space increases further. During the study period, the total amount of production space decreased for the first time by 10.03 percent and the total amount of ecological space increased by 1.22 percent, which indicates that along with the rapid advancement of urbanisation, the urban development of Huangling County has adjusted its dominant production mode and paid more attention to the protection of the ecological environment.

The third stage is from 2010-2020, in which the evolution of the “production-living-ecological” space has intensified, and the changes in production space and living space have gradually increased, while the ecological space has maintained its growth. After 2010, the average annual decrease in production space reached 2.43 percent, and the average annual increase in living space reached 45.82 percent, both of which were the largest in the study period. At this time, the total difference between the “production-living-ecological” spaces in Huangling County becomes more and more obvious.

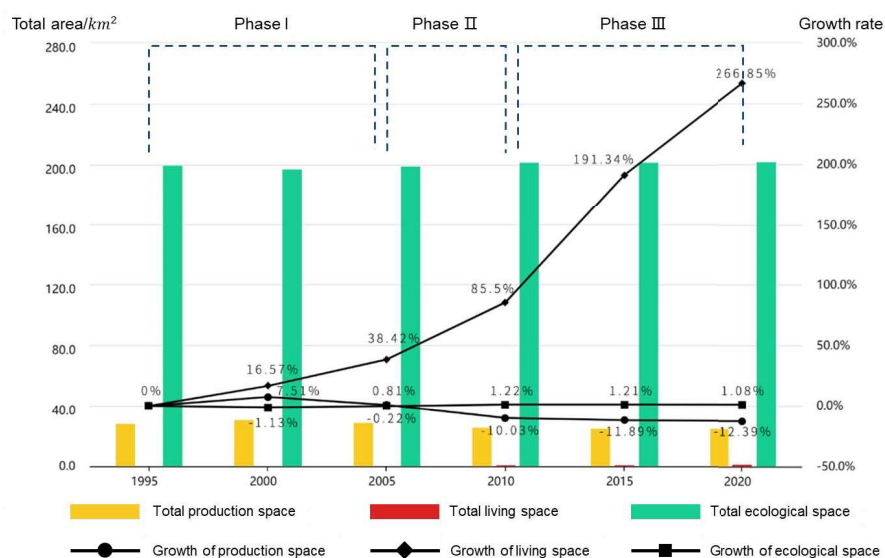


Fig.1. Evolution of spatial aggregates from 1995 to 2020.

## 2.2 Characteristics of spatial transformations dominated by production space

According to the five-period land use transfer matrix of the “production-living-ecological” space in Huangling County during the study period, the Sankey diagram of spatial transfer was drawn, from which it was found that the production space played an important role in the process of mutual transformation of the “production-living-ecological” space, and that the interchange between production space and ecological space, as well as the conversion of the production space to the living space, were the main spatial interaction modes (Figure 2).

From 1995-2010, the total amount of production space transferred to ecological space remained at a relatively large stage, with a cumulative transfer of 129.18 square kilometre during the study period; unlike this, the transfer of ecological space to production space experienced a process of growth, then decrease and then growth of the total amount of transfer, with a cumulative transfer of 60.28 square kilometre, which suggests that the early stage of urban development focuses on ecological environment maintenance, while the importance of cultivated land is gradually increased as urban problems gradually come to the forefront. From 2000-2015, the transfer of production space to living space in Huangling County increased period by period, reaching the peak in 2015, and then the transfer dropped, which shows that the construction speed of urban development is gradually slowing down, and the production space has been protected to a certain extent.

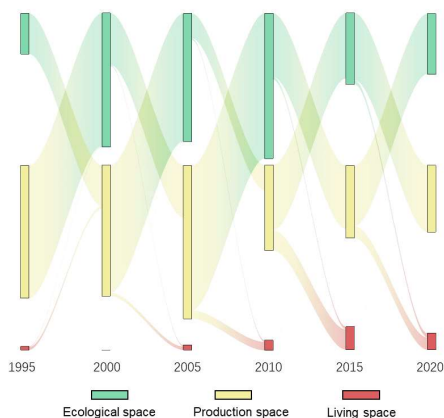
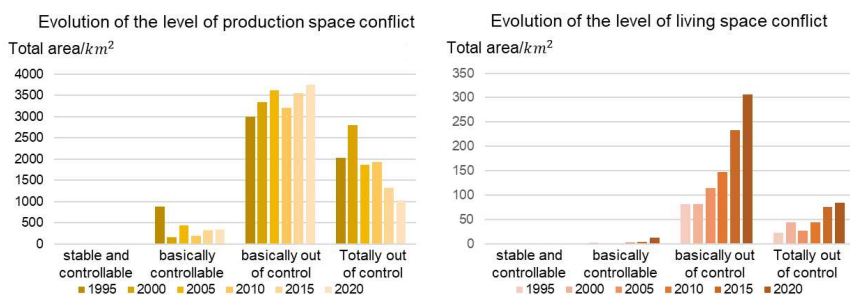


Fig.2. Evolution of the spatial transition from 1995 to 2020.

### 2.3 Spatial conflict characteristics of asynchronous change

Based on six periods of land use data in Huangling County, the conflict index of the “production-living-ecological” space is calculated, and the change process of the degree of coordination of the “production-living-ecological” space in a long period of time is analysed. It is found that the degree of coordination of the “production-living-ecological” spaces is inconsistent, with the production space and living space in a long-term uncontrollable state, and the ecological space in a long-term controllable state (Figure 3).

During the study period, the production space has the lowest degree of coordination, 60.61 percent of which is in a long-term basically uncontrollable state and does not change, and 32.51 percent of which is in a completely uncontrollable state but has been alleviated year by year since 2000; the degree of coordination of living space is also poor, with the long-term basically uncontrollable and completely uncontrollable spaces occupying 75.02 percent and 23.11 percent respectively and deteriorating year by year during the study period; the degree of coordination of ecological space is relatively good, with 76.37 percent of the space in a long-term basically controllable state and remaining relatively stable, but 23.62 percent of the space in a long-term out-of-control state cannot be ignored.



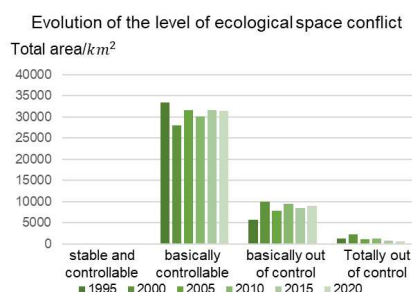


Fig.3. Evolution of "production-living-ecological" spatial conflict from 1995 to 2020.

### 3 Summary of spatial evolution mechanisms and Issues in Huangling County

#### 3.1 Mechanisms of spatial evolution

##### 3.1.1 Progressive development period (1995-2000)

The period from 1995-2000 was the period of progressive development of the “production-living-ecological” space in Huangling County. Although urban development had already begun in this period, the low level of development and the complex topography of loess gullies limited the agglomeration capacity of the city, and therefore, the integration of production space and living space, which was mainly based on traditional farming, remained the mainstream in this period.

With the rapid growth of population in Huangling County, on the one hand, a large number of labourers carried out residential construction in the areas around the towns, and faced with the disorderly construction, the county government strictly regulated the living space in that period, which made the living space decrease and revert to the production space; on the other hand, the income of the new labour force mainly comes from agricultural production activities, so land reclamation is more frequent in this period, and the production space expands while the ecological space decreases. As the total amount of high-quality cultivated land in the Loess Plateau region itself is limited, the selection of new cultivated land is very difficult, with part of the new cultivated land choosing to encroach on ecological space around towns and cities and subsequently being forced to fallow, and the other part of the cultivated land being concentrated in loess gullies, resulting in the complication of the overall pattern of production and ecological space, and a decline in spatial coherence.

##### 3.1.2 Period of fluctuation (2000-2010)

The period from 2000-2010 was a period of fluctuating development of the “production-living-ecological” space in Huangling County, during which industrial production, mainly coal mining and processing, gradually became the main driving force for urban development, and a large number of surplus agricultural labourers began to move to non-agricultural industries, with urban construction activities becoming more and more active.

Around 2000, the first round of grain for green project was launched in Huangling County, and the land with poor farming conditions was gradually transferred to ecological space, which increased the ecological space and improved the overall coordination between production space

and ecological space, but along with the gradual widening of the gap between urban and rural areas, the excess rural population began to concentrate in the urban areas, the negative impacts of rapidly advancing urban construction activities on the coordination of production and ecological space have gradually become obvious. On the one hand, the loss of population in rural areas has led to the abandonment of cultivated land, and on the other hand, with its favourable geographic environment, the valley area has become the focus of land development, and a large amount of high-quality arable land has been occupied, additional cultivated land is often cultivated on the sidewall of loess gully, loess tableland surface, and loess gully by villagers as a unit. As a result, a large number of fragmented ecological and production spaces appeared, leading to another reduction in spatial coordination. Supplementary cultivated land in this period was far less than the reduction of activities such as urban construction as well as abandonment of land, so the total amount of production space declined.

### *3.1.3 Green transformation period (2010-2020)*

The period from 2010-2020 is the period of greening transformation of the “production-living-ecological” space in Huangling County, during which the problems of environmental pollution and food security in the process of urbanisation have gradually come to the fore, and with the proposal of new urbanisation in 2012, the importance of the production and ecological space has been significantly increased, and the traditional development mode, which is mainly based on industrial production, has begun to change.

In the process of rapid urbanisation, the expansion of living space has increased the encroachment on production space and ecological space. On the one hand, the more complex spatial patterns have led to a continuous decline in the coordination of living space; on the other hand, although the supplementary cultivated land is still unable to make up for the loss of cultivated land, the county government has begun to pay attention to the protection of the quality of new cultivated land, and inefficient cultivated land, such as sloping cultivated land, has gradually been replaced by ecological space under the policy of grain for green project. In contrast, the coherence of ecological space in this period declined to a certain extent, mainly due to the fact that the grain for green project that lasted for more than ten years had seriously changed the local vegetation structure, and the single species of forest land and the loss of a large amount of shrubland and grassland had caused the development of ecological space to be stagnant.

## **3.2 Summary of space issues based on development projections**

Through the analysis of the evolution characteristics and evolution mechanism of the “production-living-ecological” space in Huangling County, it can be found that its development is the result of the long-term accumulation of natural, social and economic factors under the leadership of policy factors, so the prediction and analysis of the development evolution of the “production-living-ecological” space is one of the necessary steps in the collaborative governance of the “production-living-ecological” space.

In order to verify the reliability of the simulation results of the PLUS model, firstly, the land use data of Huangling County in 2017 and 2020 were used to give the relevant driving force data and parameters to obtain the simulation results of land use in 2023, and compared with the status quo situation in 2023, and the Kappa coefficient was greater than 0.7, which indicated that the model had a high degree of credibility. Therefore, further using the current land use data in 2023 to simulate the land use results in 2025 and 2030 under the natural development

scenario, the study found that the problems in the long-term evolution of the “production-living-ecological” space in Huangling County from 1995-2030 are mainly concentrated in the following three aspects.

### 3.2.1 Evolution of production space fragmentation

In the long-term development of production space in Huangling County, since the Loess Plateau region itself has less high-quality arable land, a large amount of supplementary arable land is concentrated in loess gullies, loess gully slopes, and loess plateau borders, etc. It is found that in the future, Huangling County will still maintain an average annual reduction of production space of 1.73%, and the production space in loess gulleys and loess plateau borders will further increase. However, on the one hand, the shortage of agricultural labour cannot be effectively improved in the short term, and the long-term cultivation of new cultivated land cannot be guaranteed; on the other hand, the complex topographic conditions of loess gullies and the soil and water environment of loess plateau borders, which are prone to erosion, will continue to affect the farmers' motivation to cultivate, so that these long-term unavoidable production problems will seriously affect the spatial stability of the development of the space. Combined with the time-space distribution of spatial conflicts and the comparison of satellite maps, the spatial coordination between loess gullies and loess plateau areas has not been effectively alleviated, and the new cultivated land has continued to appear in a complex spatial pattern under the requirement of the annual target of the total amount of cultivated land, and has been intermittently abandoned under the long-term negative impacts of the natural environment and other factors, so that the production space in these areas will continue to evolve in the direction of fragmentation in the future (Figure 4).

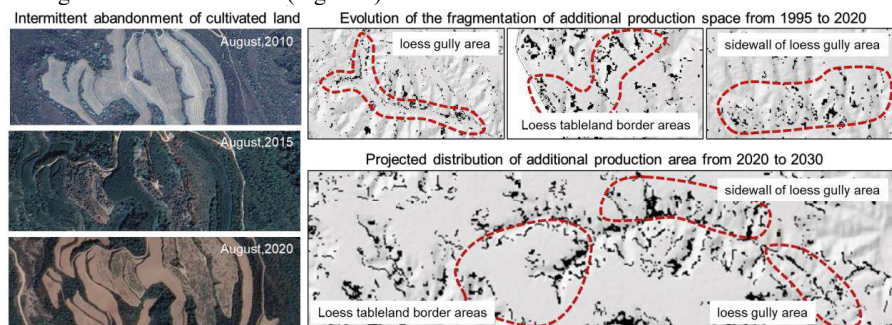


Fig.4. Evolution of production space fragmentation.

### 3.2.2 Non-stable expansion of living space

In the process of construction of living space in Huangling County, the rapidly developing urban economy and urban construction activities are closely related. Valley area has become the first choice for urban development by virtue of its flat terrain and dense river distribution, because the limited construction space in valley area cannot be reasonably matched with the rapid increase in the construction demand, so the living space along the valley area spreads continuously to form a long and narrow belt-shaped space form, and even part of the living space is connected with the ditch bank of the valley, which not only leads to the disorderly distribution of the living space but also seriously affects the overall stability. In the future urban development, the living space in the valley area will further increase, the expanding narrow space not only makes the urban spatial layout inefficient, at the same time, linear elements such

as rivers, high voltage lines and railway lines seriously damage the integrity of the urban form, coupled with the construction of land to change the catchment environment of the valley, the valley ditch bank suffers from more serious rainwater erosion, thus affecting the safety of the living space itself. Therefore, the living space in these areas is destabilised for future development(Figure 5).

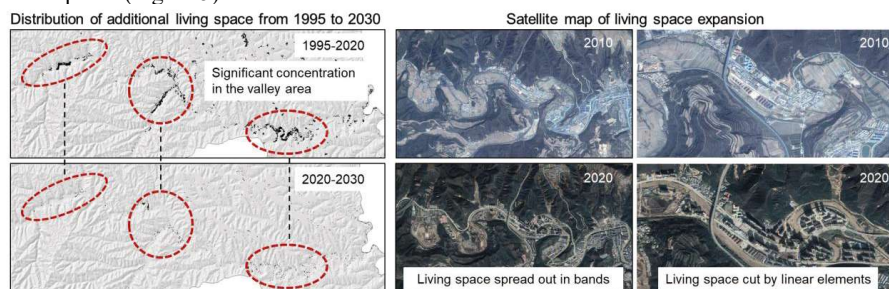


Fig.5. Non-stable expansion of living space.

### 3.2.3 Binary polarisation of ecological space

Huangling County is located at the southern edge of the Loess Plateau, with the eastern loess area being part of the Luochuan tableland, and the western mountainous area belonging to the loess hills and soil and rocky mountains; since soil erosion is more serious in the eastern area, more than 70 percent of the increase in ecological space in Huangling County in the period 1995-2020 under the impetus of the grain for green project will be concentrated in the eastern side of the county. Local fast-growing tree vegetation, mainly acacia, is more suitable for planting and simple to maintain, so through long-term forestry activities in the eastern part of Huangling County, a relatively single vegetation structure dominated by trees has been formed, which has greatly reduced the species richness in the eastern part of the county, and for a long time, not only are the ecological differences caused by the topography and soil environment faced by the eastern and western parts of the county, but also the dichotomy of species diversity resulting from the grain for green project has also become more and more obvious. These factors have intensified the formation of the ecological border zone, and the development of the ecological space located in the ecological junction zone in the central part of Huangling County has obviously stagnated. In the future, the growth of ecological space will be further concentrated on the eastern side of the county, which will lead to more obvious ecosystem differentiation, and the overall stability of ecological space will continue to decrease(Figure 6).

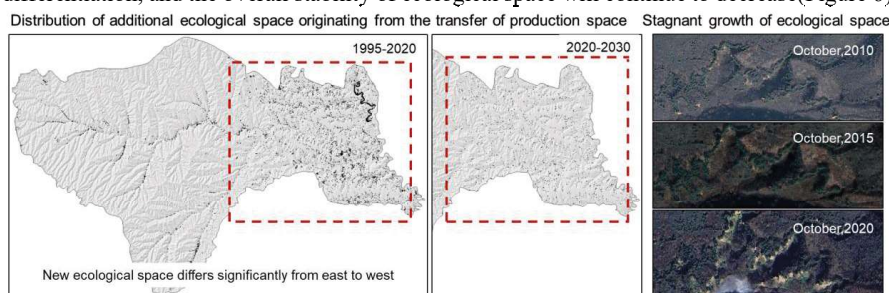


Fig.6. Binary polarisation of ecological space.

## 4 Spatial collaborative governance strategy for Huangling County

#### **4.1 Connecting production space to improve the quality**

In Huangling County's long-term development process centred on urban construction, a large amount of high-quality cultivated land has been replaced by construction land, and the quality of cultivated land has inevitably declined in the production space. Aiming at the scattered distribution of new cultivated land and the intermittent abandonment of cultivated land, which has led to the reality of the evolution of the fragmentation of the production space, the study puts forward the strategy of connecting production space to improve the quality.

Firstly, taking the territorial spatial planning of Huangling County as the basis, integrating and optimising the overall pattern of production space, higher quality cultivated land in the valley area should be prioritised into permanent basic farmland to strengthen the protection of high-quality cultivated land, and when cultivated land has to be occupied for urban expansion, less suitable cultivated land should be selected first, while cultivated land with higher cost of use and higher ecological risk should be designated into the ecological protection red line, and cultivated land will be launched in an orderly manner, so as to continuously harmonising the interrelationships among the “production-living-ecological” space. Secondly, the policy of “cultivated land requisition-compensation balance” needs to be linked to the construction of agricultural infrastructure. On the one hand, new cultivated land must adhere to the principle of “quantity-quality-ecology” balance in the selection of replenishment areas, and compensation measures need to be proposed for the phenomenon of “occupying the best and replenishing the worst”. On the other hand, the relatively poor quality cultivated land in loess gullies and loess tableland borders need to invest more public resources in the construction of agricultural infrastructure to improve the conditions for the use of the production space continuously. Finally, it is necessary to optimise the rural settlement system, adjust the distribution relationship between population and arable land, and guide the integration of fragmented cultivated land resources for contiguous development.

#### **4.2 Saving living space and making it suitable for the location**

The rapid expansion of living space has long been spreading in the form of a long and narrow belt, which not only causes the inefficiency of living space, but also has a serious negative impact on the production and ecological space in the vicinity. Aiming at the unstable development of living space and thus leading to the decline of spatial coordination, the study proposes the solution strategy of saving living space and making it suitable for the location.

Firstly, the expansion of living space needs to strictly comply with the requirements for the coordination and integrity of the “production-living-ecological” space, and in the dual evaluation stage of territorial spatial planning, the key protection areas of production and ecological space should be identified in advance, so as to take the lead in protecting them and preventing the disorderly encroachment of living space. Secondly, the ever-expanding living space needs to respect the natural geographical conditions of the Loess Plateau region. On the one hand, the urban construction should be adjusted from a long and narrow belt to a continuous group, forming a relatively independent and complete living space, changing the current inefficient development mode, and gradually forming a “finger” urban structure by linking up the surrounding gully areas through the newly built roads. On the other hand, the grouped spaces should be interspersed with continuous ecological and production spaces, so as to reduce the environmental risks in the valley area. Thirdly, in the process of rapid development, there are a lot of inefficient urban spaces in Huangling County that need to be improved, so it is

important to actively promote urban renewal to ensure the efficient use of the stock of living spaces.

#### **4.3 Regulating the ecological space into a stable and healthy system**

The evolution of ecological space needs a long time process to appear the effect, for a long time Huangling County grain for green project to relatively single fast-growing vegetation planting forestry activities, although a significant increase in the total amount of ecological space, but at the same time, also greatly changed the overall stability of the ecological environment, for the construction of ecological space ignoring the ecological functions of the local adaptability, thus leading to the development of ecological space binary polarisation of the reality of the problem, the study proposes a solution strategy for the regulating the ecological space into a stable and healthy system.

In terms of technical support, Huangling County is located at the southern edge of the Loess Plateau, and its topography, soil and climate are all special to the area, so the construction of ecological space needs to set up a special research team, and on the basis of the ecological zoning of the territorial spatial planning, it should adjust the proportion of planting structure of trees, shrubs and grasses based on native plant species according to the actual conditions, so as to ensure stable and healthy development of the ecological space. In terms of policy support, the construction of ecological space requires long-term and stable local policies and regulations. The government of Huangling County should carry out long-term planning for the development of ecological space, and allocate funds in instalments according to the construction period and the maintenance period, so as to guarantee the funding requirements for long-term coordinated management. For the ecological space located in the ecological border zone, its own vulnerability is high, so it is necessary to reduce the intervention of external factors through planning, on the one hand, to reduce the concentration of new cultivated land in these areas, and at the same time, put forward more stringent control measures for the production activities; on the other hand, to minimise the intervention of short-term human activities in plantation areas through the closing hillsides to facilitate afforestation.

#### **5 Conclusion**

The construction of “production-living-ecological” space with harmonious integration of production, living and ecology is an inevitable requirement for urban development in the context of ecological civilisation, and also a key issue for the transformation of urban development in Huangling County in the new period. The analysis of the “production-living-ecological” space in Huangling County in a long time sequence can not only clarify the implementation of the previous plan, but also has practical significance in identifying the problems of urban development. Although there are some limitations, this paper conducts collaborative governance research based on the spatial and temporal evolution of the “production-living-ecological” space, which provides a guideline for the optimisation of the “production-living-ecological” space in Huangling County in the future, and also provides a scientific reference for the transformation of urban development in the Loess Plateau region.

#### **Bibliography**

Cui, S., P. Zhu, G. Zhou, H. Zhang and X. Deng (2020). "Urban Spatial Function Change and Regulation Path from the Perspective of Production-Living-Ecological": Taking Changsha City as An Example." *Resources and Environment in the Yangtze Basin* **29**(8): 1733-1745.

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- Gao, S., L. Yang and H. Jiao (2022). "Changes in and Patterns of the Tradeoffs and Synergies of Production-Living-Ecological Space: A Case Study of Longli County, Guizhou Province, China." *Sustainability* **14**(14).
- Jiao, G., X. Yang, Z. Huang, X. Zhang and L. Lu (2021). "Evolution characteristics and possible impact factors for the changing pattern and function of "Production-Living-Ecological" space in Wuyuan county." *Journal of Natural Resources* **36**(5): 1252-1267.
- Liu, J., Y. Liu and Y. Li (2017). "Classification evaluation and spatial-temporal analysis of "production-living-ecological" spaces in China." *Acta Geographica Sinica* **72**(7): 1290-1304.
- Liu, P. and B. Sun (2020). "The spatial pattern of urban production-living-ecological space quality and its related factors in China." *Geographical Research* **39**(1): 13-24.
- Liu, X., M. Huang and W. Lei (2023). "SPATIOTEMPORAL EVOLUTION OF LAND USE IN ECOLOGICALLY FRAGILE AREAS OF THE LOESS PLATEAU IN NORTHERN SHAANXI." *Journal of China Agricultural Resources and Regional Planning* **44**(3): 47-57.
- Wang, Q., P. Sun, X. Liu, Y. Liu, W. Hai and X. Zhang (2020). "ANALYSIS ON SPATIAL-TEMPORAL PATTERN OF TRADE-OFFS AND SYNERGIES OF "PRODUCTION-LIVING-ECOLOGICAL" FUNCTION IN LOESS HILLY AND GULLY REGION—A CASE STUDY OF WUSHAN COUNTY." *Journal of China Agricultural Resources and Regional Planning* **41**(11): 122-130.
- Zou, L., J. Wang and X. Hu (2018). "An Classification Systems of Production-Living-Ecological Land on the County Level: Theory Building and Empirical Research." *China Land Science* **32**(4): 59-66.