Environment, Resource and Ecology Journal (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/erej.2024.080112
ISSN 2616-3756 Vol. 8 Num. 1

Study on Eco-Environmental Effects of Land Use Function Transition in Dingxi City from the Perspective of "Production-Living-Ecological Space"

Jiayao Li, Xiaoping Zhang*, Tingting Zhao, Hu Chen

College of Geography and Environmental Science, Northwest Normal University, Lanzhou, China
*Corresponding author

Keywords: Land use function transition; Production-Living-Ecological Spaces; Eco-environmental Effects; Sustainable Cites and Communities; Life and Land

Abstract: Land use function transition significantly impacts eco-environmental change. Understanding regional land use transitions is crucial for addressing eco-environmental issues. This study analyzes land use transition and eco-environmental quality in Dingxi City from 1990 to 2020 using remote sensing data and the "production-living-ecological space" perspective. Key findings include: (1) Ecological space increased by 519.54 km^2, while production space decreased by 642.95 km^2, and living space expanded by 123.93 km^2. (2) Transition directions varied, with agriculture encroaching on ecological land from 1990 to 2000, and grassland and forest encroaching on agriculture from 2000 to 2020. (3) Eco-environmental quality exhibited a "U" trend, with higher quality in the south, lower in the middle, and medium in the north, influenced by mutual transitions between agriculture and forest land.

1. Introduction

Land serves as the foundational element for human production and living activities, with land use playing a fundamental role in socio-economic development. As industrialization, urbanization, and environmental protection policies advance, land use functions undergo diverse development, leading to profound transitions and spatial reconstructions. Land use transitions alter land cover statuses, impacting regional atmospheric, hydrological, and soil conditions, as well as landscape patterns, thereby influencing ecosystem service functions and eco-environmental quality[1]. While existing studies have extensively explored theoretical hypotheses, research frameworks, driving mechanisms, and ecological effects of land use transitions, less attention has been given to land use function transition (LUFT). LUFT refers to the dynamic reallocation of land resources among production, living, and ecological (PLE) functions, reflecting regional economic and social transition stages.

Research focusing on LUFT based on the "production-living-ecological space" (PLES) can address gaps in understanding the ecological functions of land use, facilitating rational regional PLES layout and coordinated development of production, living, and ecological functions. Thus, linking the spatial evolution of PLES with land use transition is crucial for exploring the ecological effects of regional LUFT.

Traditionally prioritizing production over life and construction over ecology, China's territorial space development has resulted in chaotic development, with extensive and unreasonable activities encroaching on and damaging ecological spaces, sacrificing the environment for economic growth, leading to settlement deterioration, ecosystem function degradation, and regional ecological insecurity. The 18th National Congress of the Communist Party of China emphasized promoting ecological civilization construction, optimizing territorial space development patterns, and promoting "intensive and efficient production space, livable and moderate living space, and beautiful ecological space". Consequently, Chinese scholars have explored LUFT's eco-environmental effects based on the PLES model, primarily in developed eastern regions, with limited focus on economically underdeveloped and ecologically sensitive arid areas in northwest China. Given natural, locational, and socio-economic differences, land use patterns, transition mechanisms, and eco-environmental effects differ from those in developed eastern regions. Therefore, this study focuses on Dingxi City in Gansu Province, northwest China, to analyze the spatial and temporal characteristics of land use transition modes and eco-environmental effects from 1990 to 2020, using land use transfer matrices and eco-environment quality indices. This study aims to provide insights for sustainable land resource utilization and eco-environmental protection in arid regions of northwest China[1].

2. Study area

Dingxi City, located in the central part of Gansu Province (103 °~105 °E, 34 °~35 °N), features undulating terrain with mountains, hills, and river valleys. The climate varies from dry and less rainy in the central and northern parts to cold and humid in the south. Despite once being considered the "most barren place in the middle of Gansu," Dingxi has undergone significant transformation due to the implementation of the "Western Development" strategy and the "Belt and Road" initiative. It has become a pivotal city in the "Belt and Road" initiative and a key hub in western China, serving as a gateway to Lanzhou and the surrounding economic circles.

Dingxi is now a core area for traditional Chinese medicine industry development and potato seed breeding. Efforts are underway to establish it as "China's medicine capital," "China's potato capital," and "China's western grass capital," along with becoming a national characteristic seed industry base. The city has improved its eco-environment quality through terracing, afforestation, and converting farmland back to forests and grasslands[2].

With a total area of approximately 1.9×10^4 km², Dingxi comprises one district and six counties. As of 2020, it had a permanent resident population of about 2.521 million, with an urbanization rate of 38.39% and a regional GDP of 44.136 billion yuan. Rapid economic and social development has led to enhanced living standards, improved urban infrastructure, and increased activity in land resource development and occupation. The demand structure for production, living, and ecological land has also evolved significantly over time[3].

3. Data and methods

3.1 Data source and processing

Remote sensing data for land use in Dingxi City from 1990, 2000, 2010, and 2020 were sourced from the Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences. The data, derived mainly from Landsat remote sensing imagery with a 30m resolution, underwent manual visual interpretation to identify primary land use types, including cultivated land, forest land, pasture land, water area, construction land, and unused land, along with 25 secondary land use types.

By analyzing and integrating these land use types, a PLES land use classification system was developed, considering natural attributes and land cover perspectives. This classification system includes three Class-I land use types (production, living, and ecological land) and eight Class-II land use types (see Table 1).

Table 1: Land use classification of PLES and eco-environmental quality index

Categories	Subcategories	Eco-environmental quality index
Productive land	Agricultural production land	0.2500
	Industrial and mining land	0.1500
Ecological land	Forest ecological land	0.6628
	Pasture ecological land	0.3983
	Water ecological land	0.5715
	Other ecological land	0.0378
Living land	Urban Living Land	0.2000
	Rural Living Land	0.2000

3.2 Methods

3.2.1 Land use transfer matrix

Land use function transition is analyzed using a land use transfer matrix, a tool derived from system analysis principles. ArcGIS software is utilized to spatially overlay land use data from two periods, generating land use type transfer matrices for each study period. These matrices serve as the foundation for structural and directional analyses, providing insights into the structural characteristics and changes in land use function types. The formula is as follows:

$$S_{ij} = \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{21} & \cdots & S_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{bmatrix} \quad (1)$$

where S_{ij} is the state of land use change at the beginning and end of the study period, and n is the number of land use types.

3.2.2 Eco-environmental effects

The eco-environmental effects of LUFT can be expressed by regional eco-environmental quality index and ecological contribution rate of land use function transition.

(1)Ecological quality index

The regional eco-environmental quality index offers a comprehensive assessment of ecological conditions and land use distribution within the study area, allowing for quantitative analysis of ecological quality. Drawing from previous research and tailored to Dingxi City's PLES land use, this study assigns eco-environmental quality values to secondary land types (Table 1). This enables the calculation of eco-environmental quality indices across different time periods.

$$EV_t = \sum_{i=1}^{n} \frac{A_{ki}}{A_k} R_i \quad (2)$$

Where EV_t is the eco-environmental quality index of the study area in period t; A_k is the total area of the region; R_i is the ec-environmental index of the i land-use type; A_{ki} is the area of the i land-use type in the study area in period t; and n is the number of land-use types.

(2)Ecological contribution rate of LUFT

The ecological contribution rate of land use function transition measures the change in regional ecological quality resulting from shifts in a specific dominant land use function. It helps quantify the impact of mutual conversions between dominant land use functions on regional eco-environmental quality, facilitating the identification of key factors driving regional ecological changes (Liu et al. 2003). The equation is as follows:

$$\mathrm{LEI} = (\mathrm{LE}_1 - \mathrm{LE}_0)\mathrm{LA}/\mathrm{TA} \tag{3}$$

Where LEI is the ecological contribution rate of LUFT; LE_1 and LE_0 respectively represent the ecological environment quality index of the initial and final stages of land use change reflected by a certain type of land use change; LA is the area of the change type; TA is the total area of the region.

4. Result and Analysis

4.1 Temporal and spatial patterns of land use change

Using the PLES land use classification system (Figure 1), we analyzed land use data from Dingxi City in 1990, 2000, 2010, and 2020 to understand the spatial pattern and structural changes (Table 2). Over this period, ecological land dominated, increasing by 519.54km^2 (4.3% growth), while production land decreased by 642.95km^2 (8.7% decrease). Despite being the smallest category, living land grew significantly by 123.93km^2 (44.10% increase). Pasture and water ecological land initially declined but rebounded, while forest ecological land showed a fluctuating trend. Agricultural production land increased initially but decreased later, while industrial and mining production land surged by 2209.7%. Both urban and rural living land consistently expanded, with urban areas growing faster, up by 156.76%.

Table 2: Land use structure and change in Dingxi City from 1990 to 2020 (km^2)

Type	Production		Ecology				Living	
Year	APL	IMPL	FEL	PEL	WEL	OEL	ULL	RLL
1990	7356.67	1.13	1950.09	9855.76	81.11	86.5	25.11	255.93
2000	7399.62	1.23	1947.31	9798.57	77.96	86.50	31.91	269.21
2010	6863.46	12.41	2173.83	10026.24	79.50	81.46	48.71	326.70
2020	6688.75	26.1	2137.19	10170.80	98.51	86.03	64.48	340.49
1990-2000	42.95	0.10	-2.78	-57.19	-3.15	0.00	6.80	13.28
2000-2010	-536.16	11.18	226.52	227.67	1.54	-5.04	16.80	57.49
2010-2020	-174.71	13.69	-36.64	144.56	19.01	4.57	15.77	13.79
1990-2020	-667.92	24.97	187.10	315.04	17.40	-0.47	39.37	84.56

*APL: Agricultural Production Land; IML: Industrial and Mining Land; FEL: Forest Ecological Land; PEL: Pasture Ecological Land; WEL: Water Ecological Land; OEL: Other Ecological Land; ULL: Urban Living Land; RLL: Rural Living Land

The ecological land has the widest distribution, followed by production land, with living land having the smallest proportion.From a spatial standpoint, Pasture, agricultural, and forest ecological lands were widespread. Pasture land was mainly in Anding District, Lintao County to the north, and Minxian County to the south, with increasing coverage. Agricultural land was primarily in Anding District, Lintao County to the north, Tongwei County, and Longxi County in the middle, showing reduced distribution. Forest land was mostly in Zhangxian and Minxian counties to the south, and

Weiyuan County in the middle, with significant expansion. Water and other ecological lands had limited distribution due to natural factors. Water land was concentrated in the Tao River, Wei River, and their tributaries, while other ecological lands were scattered across various districts and counties in central and northern Dingxi City. Urban and rural living areas were mainly in urban zones of Anding District, Longxi County, Lintao County, and Min County. Rural living areas correlated with agricultural land, influenced by natural conditions and socio-economic development levels[4-6].

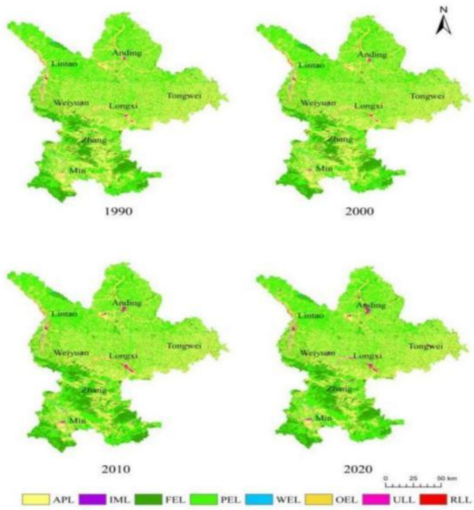

Figure 1: Spatial pattern of PLES in Dingxi City from 1990 to 2020

4.2 Land use transition mode

To study LUFT, we used ARCGIS10.2 to analyze land use data from 1990-2000, 2000-2010, and 2010-2020, creating transfer matrices (Table 3-5). From 1990 to 2000, pasture shifted to agriculture, indicating outdated practices. Rural and urban expansion mainly used agricultural land. During 2000-2010, agriculture converted to pasture and forest due to the "Western Development" strategy, while urbanization intensified. Pasture and rural lands also transitioned to agriculture. Similar shifts occurred from 2010 to 2020, with increased mutual transitions among agricultural, pasture, forest, and urban-rural lands[7-10].

Table 3: Transition matrix of land use in Dingxi City from 1990 to 2000 (km^2)

	APL	IML	FEL	PEL	WEL	OEL	ULL	RLL	Total (1990)
APL	7332.49	0.10	0.77	3.60	0.40	0.00	5.23	14.07	7356.67
IML	0.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	1.13
FEL	4.49	0.00	1944.71	0.89	0.00	0.00	0.00	0.00	1950.09
PEL	59.01	0.00	1.83	9794.08	0.00	0.00	0.00	0.83	9855.76
WEL	3.56	0.00	0.00	0.00	77.55	0.00	0.00	0.00	81.11
OEL	0.01	0.00	0.00	0.00	0.00	86.49	0.00	0.00	86.50
ULL	0.00	0.00	0.00	0.00	0.00	0.00	25.11	0.00	25.11
RLL	0.05	0.00	0.00	0.01	0.00	0.00	1.56	254.31	255.93
Total (2000)	7399.62	1.23	1947.31	9798.57	77.96	86.50	31.91	269.21	19612.31

Table 4: Transition matrix of land use in Dingxi City from 2000 to 2010 (km^2)

	APL	IML	FEL	PEL	WEL	OEL	ULL	RLL	Total (2000)
APL	6651.19	6.40	124.96	520.18	2.65	3.33	16.52	74.39	7399.62
IML	0.01	1.22	0.00	0.00	0.00	0.00	0.00	0.00	1.23
FEL	10.17	0.24	1916.91	16.59	0.97	0.16	0.30	1.98	1947.31
PEL	167.09	4.33	130.62	9484.24	1.10	0.76	0.67	9.78	9798.58
WEL	2.34	0.08	0.06	0.57	74.70	0.01	0.01	0.18	77.96
OEL	6.93	0.00	0.06	2.32	0.00	77.06	0.00	0.12	86.50
ULL	0.86	0.00	0.12	0.01	0.01	0.00	30.52	0.38	31.91
RLL	24.87	0.15	1.11	2.34	0.05	0.15	0.67	239.86	269.21
Total(2010)	6863.46	12.41	2173.83	10026.24	79.50	81.46	48.71	326.70	19612.32

Table 5: Transition matrix of land use in Dingxi City from 2010 to 2020 (km^2)

	APL	IML	FEL	PEL	WEL	OEL	ULL	RLL	Total (2010)
APL	5007.72	15.63	140.84	1510.91	31.09	24.39	16.46	116.43	6863.47
IML	2.89	5.77	0.64	2.10	0.14	0.19	0.11	0.57	12.41
FEL	124.62	0.14	1642.38	398.75	1.65	1.72	0.42	4.16	2173.83
PEL	1405.73	2.26	342.69	8191.62	13.32	20.02	1.85	48.78	10026.27
WEL	19.24	0.17	3.17	11.18	41.77	0.07	1.20	2.69	79.50
OEL	20.20	0.59	0.77	11.48	7.71	38.37	0.13	2.21	81.46
ULL	3.75	0.35	0.44	0.57	0.06	0.14	41.76	1.63	48.71
RLL	104.60	1.18	6.27	44.20	2.76	1.12	2.56	164.01	326.70
Total (2020)	6688.75	26.10	2137.19	10170.80	98.51	86.03	64.48	340.49	19612.35

4.3 Eco-environmental effects of land use transition

4.3.1 Temporal variation characteristics of eco-environment quality

The ecological environment quality index was computed for Dingxi City in 1990, 2000, 2010, and 2020, revealing a slight increase from 0.3653 in 1990 to 0.3720 in 2020, with fluctuations in between. Despite improvements, the overall quality remained relatively stable due to simultaneous enhancement and degradation factors.

In order to reveal the impact of land use transition on regional eco-environment quality, the ecological contribution rate of land use transition in Dingxi City was calculated (Table 6). The results showed that from 1990 to 2000, the conversion of agricultural production land to pasture ecological land and pasture ecological land to forest ecological land was the main factor promoting the improvement of eco- environment quality, and the contribution rate reached 67%. While the conversion of ecological land such as forest and pasture into agricultural production land was the main reason for the deterioration of eco-environment quality, with a contribution rate of 82.23%. Compared with 1990-2000, from 2000 to 2010, the contribution rate of conversion of agricultural production land into pasture and forest ecological land increased while the contribution rate of conversion of pasture ecological land into agricultural production land decreased significantly, indicating that the ecological benefits of returning farmland to forest and grassland were gradually prominent, and the continuous deterioration of eco-environment quality was curbed. Compared with 2000-2010, from 2010 to 2020, the contribution rate of conversion of agricultural production land into pasture ecological land was still on the rise, while the contribution rate of pasture ecological land to agricultural production land had little change, resulting in continuous improvement of eco-environment quality[11].

Expansion of production and living areas at the expense of ecological space primarily drove eco-environmental degradation. Quality improvement relied on conserving and expanding pasture and forest lands.

Table 6: Major land use transition and ecological contribution rates influencing eco-environmental quality in different periods

	1990-2000		Rate (%)	2000-2010		Rate (%)
	Major types of land use transition	LEI		Major types of land use transition	LEI	
Positive ecological effect	APL-PEL	0.00003	33.33	APL-PEL	0.00393	45.64
	PEL-FEL	0.00003	33.33	APL-FEL	0.00263	30.52
	APL-FEL	0.00002	22.22	PEL-FEL	0.00176	20.45
	APL-WEL	0.00001	11.11	OEL-APL	0.00008	0.87
	Subtotal	0.00009	100	Subtotal	0.0084	97.48
Negative ecological effect	PEL-APL	-0.00045	67.28	PEL-APL	-0.00126	55.02
	FEL-APL	-0.0001	14.95	FEL-PEL	-0.00022	9.76
	WEL-APL	-0.00006	8.97	FEL-APL	-0.00021	9.32
	APL-RLL	-0.00003	4.49	APL-RLL	-0.00019	8.28
	APL-ULL	-0.00001	1.50	PEL-RLL	-0.00010	4.31
	Subtotal	-0.00198	97.18	Subtotal	-0.00198	86.69
	2010-2020		Rate (%)	1990-2020		Rate (%)
	Major types of land use transition	LEI		Major types of land use transition	LEI	
Positive ecological effect	APL-PEL	0.01143	54.29	APL-PEL	0.01372	52.71
	PEL-FEL	0.00462	21.96	APL-FEL	0.00584	22.45
	APL-FEL	0.00296	14.08	PEL-FEL	0.00456	17.53
	APL-WEL	0.00051	2.42	APL-WEL	0.00056	2.13
	Subtotal	0.01952	92.75	Subtotal	0.02468	94.82
Negative ecological effect	PEL-APL	-0.01143	54.73	PEL-APL	-0.01100	54.79
	FEL-PEL	-0.00462	22.14	FEL-PEL	-0.00438	21.83
	FEL-APL	-0.00296	14.20	FEL-APL	-0.00221	11.02
	PEL-RLL	-0.00049	2.36	PEL-RLL	-0.00051	2.56
	PEL-OEL	-0.00037	1.76	APL-RLL	-0.0004	1.99
	Subtotal	-0.01987	95.19	Subtotal	-0.01851	92.20

4.3.2 Spatial distribution characteristics of eco-environment quality

To depict Dingxi City's eco-environmental quality accurately, a grid of 1km×1km cells was meticulously analyzed, resulting in nearly 1.9×10^4 cells. Using Equation (2), the eco-environmental quality index for each unit in 1990, 2000, 2010, and 2020 was computed and categorized into five levels: low (≤0.28), medium-low (0.28-0.35), medium (0.35-0.42), medium-high (0.42-0.53), and high (>0.53) (Figure 2). The analysis revealed that medium and lower quality areas dominated Dingxi City's eco-environment, constituting about 75.6% of the area. These differences were pronounced, forming a south high, middle low, and north medium distribution pattern. High-quality regions, rich in forest and grass resources, were mainly found in

Zhangxian, Minxian, and Weiyuan County. Medium-quality areas were prevalent in Anding District and Lintao County, primarily featuring pasture ecological land and agricultural production land. Conversely, low and lower quality areas, mainly used for agricultural production and urban-rural living, were concentrated in the north.

Regarding temporal changes, from 1990 to 2000, aside from a decline in eco-environment quality in Longxi and Weiyuan County, other regions remained relatively stable. Subsequently, from 2000 to 2020, overall eco-environment quality improved across Dingxi City, notably in Weiyuan, Anding, and Longxi counties. This positive shift was attributed to national policies promoting returning farmland to forests and grasslands, effectively reversing the trend of deteriorating ecological quality.

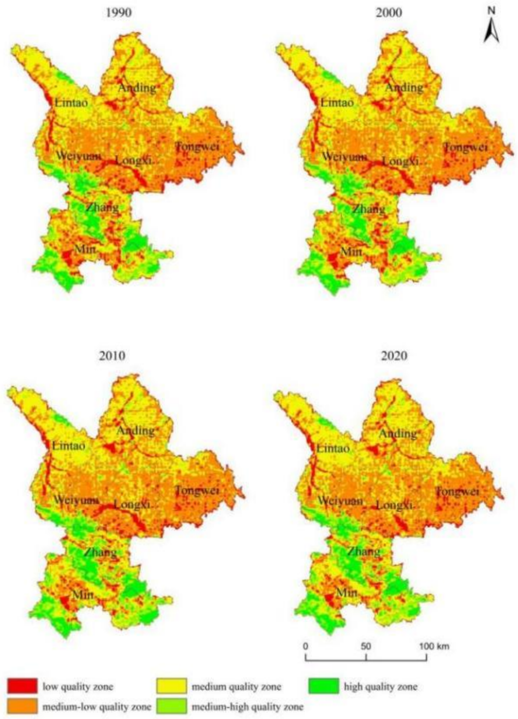

Figure 2: Spatial pattern of eco-environment quality in Dingxi City from 1990 to 2020

5. Conclusion

This paper analyzes the spatio-temporal evolution of land use transition's eco-environmental effects in Dingxi City from 1990 to 2020, using land use remote sensing data and eco-environment quality index from a PLES perspective. The key findings are:

(1)Significant differences in PLES land use types were observed from 1990 to 2020. Ecological land expanded widely, mainly in northern Anding District and Lintao County, and southern Zhangxian and Minxian counties. Production land decreased, mainly in Tongwei and Longxi counties, as well as Anding District and Lintao County. Living land, although the smallest, exhibited noticeable expansion, scattered in urban and suburban areas[13-16].

(2)Land type transitions varied across stages. From 1990 to 2000, agricultural land encroached on ecological land severely, while after 2000, agricultural land loss shifted towards ecological and urban-rural living land.

(3)Dingxi City's eco-environment quality fluctuated from 1990 to 2020, showing a "U" shaped evolution with both improvement and deterioration. The decline from 1990 to 2000 resulted from agricultural land encroachment on ecological land. Post-2000, ecological policies like returning farmland to forests and grasslands led to ecological land expansion and improved eco-environment quality. Spatially, the eco-environment quality displayed a pattern of higher quality in the south, lower in the middle, and medium in the north[17-19].

References

[1] Avila FB, Pitman AJ, Donat MG, Alexander LV, Abramowitz G. Climate model simulated changes in temperature extremes due to land cover change. J. Geophys. Res-atmos. 2012.117(D4).

[2] Chen WX, Li JF, Zeng J,Ran D, Yang B. Spatial heterogeneity and formation mechanism of ecoenvironmental effect of land use change in China. Geogr. Res. 2019.38(9):2173-2187.

[3] Chen J, Shi PJ.Discussion on Function Land Use Classification system. [J]. Beijing Normal Univ. (Nat. Sci.). 2005.41(5):536-540.

[4] DAI WY, JIANG FQ, Huang WL, LIAO LH, Jiang K.Study on Transition of Land Use Function and Ecosystem Service Value Based on the Conception of Production, Living and Ecological Space: A Case Study of the Fuzhou New Area. J. Nat. Resour. 2018.33(12):2098-2109.

[5] Dong D, Luo Y, Gu KK. Spatio-temporal differentiation and driving forces of Eco-environmental effects of Land use transformation in the Yangtze River DeltaEconomic zone: A perspective of "ecological-production living"spaces. Resour. Environ. Yangtze Basin. 2023.32(08):1664-1676.

[6] Gao X, Liu ZW, Li CX, Cha LS, Song ZY, Zhang XR. Land use function transformation in the Xiong'an New Area based on ecological-productionliving spaces and associated eco-environment effects.Acta Eco. Sin. 2020.40(20): 7113-7122.

[7] Ge DZ, Long HL, Zhang YN, Ma L, Li TT. Farmland transition and its influences on grain production in China. Land Use Policy, 2018.70(C):94-105.

[8] Huang JC, Lin HX, Qi XX. A literature review on optimization of spatial development pattern based on ecological-production-living space. Prog. Geogr.2017. 36(03):378-391.

[9] Li XB. . Theoretical Hypotheses about Agricultural Land Use Changes and the Relevant Propositions about Environmental Impacts. Adv. Earth Sci. 2008.23(11):1124-1129.

[10] Long HL, Li XB. Analysis on regional land use transition: A case study in Transect of the Yangze River. J. Nat. Resour. 2002.17(2):144-149.

[11] Long HL. Land use transition and land management. Geogr. Res. 2015.34(9): 1607-1618.

[12] Li T, Long HL,Liu YQ, Tu SS. Multi-scale analysis of rural housing land transition under China's rapid urbanization: The case of Bohai Rim.Habitat Int. 2015.48:227-238.

[13] Li CX, Wu, JY. Land use transformation and eco-environmental effects based on production-living-ecological spatial synergy: evidence from Shaanxi Province, China. Environ. Sci. Pollut. Res. 2022.29(27):41492-41504

[14] Mather AS. The forest transition. Area. 1992.24(4):367-379.

[15] Song XQ. Discussion on land use transition research framework. J. Geogr. Sci. 2017.72(3):471-487.

[16] Wu YJ, Yang YZ, Yang L, Zhang C, You Z.Land spatial development and suitability for city construction based on ecological- living- industrial space—take Ningbo City as an example. Resour. Sci. 2016.38(11):2072-2081.

[17] Yang QK, Duan XJ, Wang L, Jin ZF. Land Use transition Based on Ecological-production-living Spaces and Associated Eco-environment Effects: A Case Study in the Yangtze River Delta. Sci. Geogr. Sin. 2018.38(01):97-106.

[18] Zhu HY, Li XB. Discussion on the Index Method of Regional Land Use Change. Acta Geogr. Sin. 2003.58(05):643-650.

[19] Zhang ZL, Zhao QY. Eight Dimensional Space Ideology in Land Use. Hum. Geogr. 2018. 33(06):9-17.