A Probe into the Dynamic Change of Land Use in the Southern Loess Plateau

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Abstract In order to reveal the characteristics of land use change in the south loess plateau, this paper tentatively divided Loess Plateau into North and South under the support of GIS, and then introduced land use spatial temporal dynamic model, analyzed land use dynamic change in provincial scale. The results showed: during the 25 years, construction land area increased from 3 555.99 km^2 to 4 794.28 km^2, unused land decreased by 0.02 percentage points, forest land area increased from 51 011.31 km^2 to 51 066.79 km^2, waters increased of 0.01 percentage points, farmland area decreased to 98 561.57 km^2 from 100 004.79 km^2, grassland area increased by 0.08 percentage points. Land use change important values in province scale on each were not identical, showed obvious regional differences.

Key words Land use and land cover change, Dynamic change, Southern Loess Plateau, RS, GIS

1 Introduction

LUCC (land use/cover change) is one of the main reasons for global changes[1]. Since the 1990s, LUCC research has become a hot topic of global change[2-3]. LUCC affects the interaction between ecosystem and the surrounding air, water and land system, resulting in a substantial impact on the structure and function of whole ecosystem, thereby affecting the supply of ecosystem services and improvement of human well-being[4-8]. The topography is complex in the southern Loess Plateau, and there are varied land landscape types. Compared with other regions of Loess Plateau, the cities cluster in the densely populated southern regions. Unreasonable land use patterns bring land ecosystem under enormous pressure. For a long time, the domestic and foreign scholars have done a lot of researches on Loess Plateau and made a series of achievements, but there are few research results on the southern Loess Plateau[9-20]. In this paper, with the southern Loess Plateau as the study area, through the field survey, we use "3S" technique, and apply the landscape ecology theory to discuss the characteristics of land use change in the southern Loess Plateau, in order to lay a foundation for further research on the ecological security, land landscape pattern and ecological processes in the southern Loess Plateau.

2 Overview of the study area

Considering the natural and geographical factors in Loess Plateau (DEM, isohyet, normalized vegetation index, aridity index, humidity index, accumulated temperature greater than or equal to 10 ℃ and the average annual temperature), we adopt spatial overlaying analysis to divide Loess Plateau into northern and southern parts in support of ARCGIS, according to the differences in the spatial distribution of natural factors. The specific method is to rank each grid layer, then carry out map calculation of various layers according to the weights, and finally carry out reclassification of grid based on the computed score to tentatively divide the line. Loess Plateau is divided into northern and southern parts, and the boundary between the two is roughly in the vicinity of 400 mm isohyet, basically overlapping the aridity index line 1.5. The northern landform types of this line are mainly loess hilly areas, and the average annual precipitation is below 400mm. The vegetation cover is mainly the grassland, desert and steppe desert, with low vegetation coverage. The accumulated temperature is lower than that of southern regions, and the average annual temperature is below 8 ℃, but the solar radiation is higher than in the south. The landform types in the south of the line are mainly the loess tableland and valley plains, and the annual average precipitation is more than 400 mm. The vegetation cover is mainly based on forest and forest steppe, with high vegetation coverage. The accumulated temperature is higher than in the north, and the average annual temperature is above 8℃. It is not difficult to find this line is basically identical to the Chinese arid and semi-arid sub-humid boundary line. From social and human point of view, compared with the northern Loess Plateau, it is densely populated in the southern Loess Plateau where the economy is developed and social and human factors have a great impact on land use. Each indicator layer is shown in Fig. 1, and the scope of the study area is shown in Fig. 2.

3 Research methods

3.1 Data processing The data sources of this article are as follows: U. S. Landsat image, TM and ETM + sensor and access

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time (1980, 2000, 2005); the southern Loess Plateau DLG includes administrative divisions, rivers, roads, railways, lakes, towns, *etc.*; 1:50 000 DEM; soil type map, landform map, NDVI map; land use map, GPS field sample data and fieldwork data. Remote sensing image pre – processing includes data format conversion, image stitching, image cropping, geometric correction, projection transformation, band fusion, the best band selection, and image enhancement. The image pre – processing and interpretation are carried out in ERDAS9.2, and the land use data in 1980, 2000, 2005 are derived after importing ARCGIS10.0.

3.2 Dynamic change of land use Based on the characteristics of the southern Loess Plateau, Land Use Survey Technical Regulations in 1984 and Land Use Classification in 2007, this article divides land use/land cover into six categories (namely, woodland, grassland, arable land, construction land, water area and unused land)[22].

Land use change includes the change in the area of land use type, the spatial distribution change in the land use type, and the change in the land quality[27]. This paper uses the land use database established by ARCGIS9.2 to measure the total area of various land use types, and draws on the spatial overlaying function to research the changes in the spatial distribution of land use type. In order to reveal the spatio-temporal dynamic change in land use in Loess Plateau, we introduce the following spatio-temporal land use dynamic change model[20-30], which can be shown in Table 1.

Table 1 Spatio-temporal land use dynamic change model

Classification	Name	Expression	Meaning
Land use type change index	Dynamic degree of single land use type	$K=\frac{U_b-U_a}{U_a}\times\frac{1}{T}\times 100\%$ where K represents the dynamic degree of a certain land use type during the study period; U_a, U_b denote the area of one land type in the early and late study period; T is the length of the study period.	It signifies the number changes in a certain land type in the study area during a period of time.
	Dynamic degree of comprehensive land use	$L_c=\left[\frac{\sum_{i=1}^{n}\Delta Lu_{i-j}}{2\sum_{i=1}^{n}Lu_i}\right]\times\frac{1}{T}\times 100$ where Lu_i is the area of land type i at the beginning of the study; ΔLu_{i-j} is the absolute value of area of non – land type i transformed from land type i during the study period; T is the length of the study period.	It signifies the number changes in the land type in the study area during the study period.
Land use change regional differences index	Relative change rate of land use types	$R=(K_b/K_a)/(C_b/C_a)$ where K_a and K_b denote the area of a certain land type in a region in the early and late study period, respectively; C_a and C_b denote the area of a certain land type in the whole study region in the early and late study period, respectively.	It reflects regional differences in LUCC, and if the relative change rate of a certain land use type in a region $R>1$, it indicates that the change in this land type in this region is intenser than in the whole region.
Land use change regional direction index	Land use change type area ratio	$B=\frac{S_i}{S}\times 100\%$ where B is the change area ratio of a certain type of land use; S_i is the area of this land use change type; S is the total area of this region.	This ratio indicates the spatial distribution characteristics of land use change.
	Abundance of land use change type	$D=\frac{N_i}{N}\times 100\%$ where D is abundance of a certain land use change type; N_i is the number of pattern of this land use change type; N is the total number of pattern of all land use types in this region.	Abundance can quantitatively indicate the distribution of land use change type in the region.
	Importance value of land use change type	$IV=B+D$ where IV is the importance value of a certain land use change type; B is the area ratio of this land use change type; D is the abundance of this land use change type.	Importance value can quantitatively indicate the degree of importance of land use change type to the region, and is an important basis for determining the direction of land use change.

4 Results and analysis

4.1 Spatio-temporal dynamic change of land use In order to reveal the spatio-temporal dynamic change in land use between different provinces in southern Loess Plateau, we carry out the analysis of spatio-temporal dynamic change in land use according to different provincial units. Land use map is shown in Fig. 3, and land use change map is shown in Fig. 4. From Table 2, we know that the regions are sequenced in terms of the dynamic degree of construction land use from 1980 to 2005 in descending order as follows: Shaanxi, Ningxia, Henan, Gansu, Shanxi. It indicates

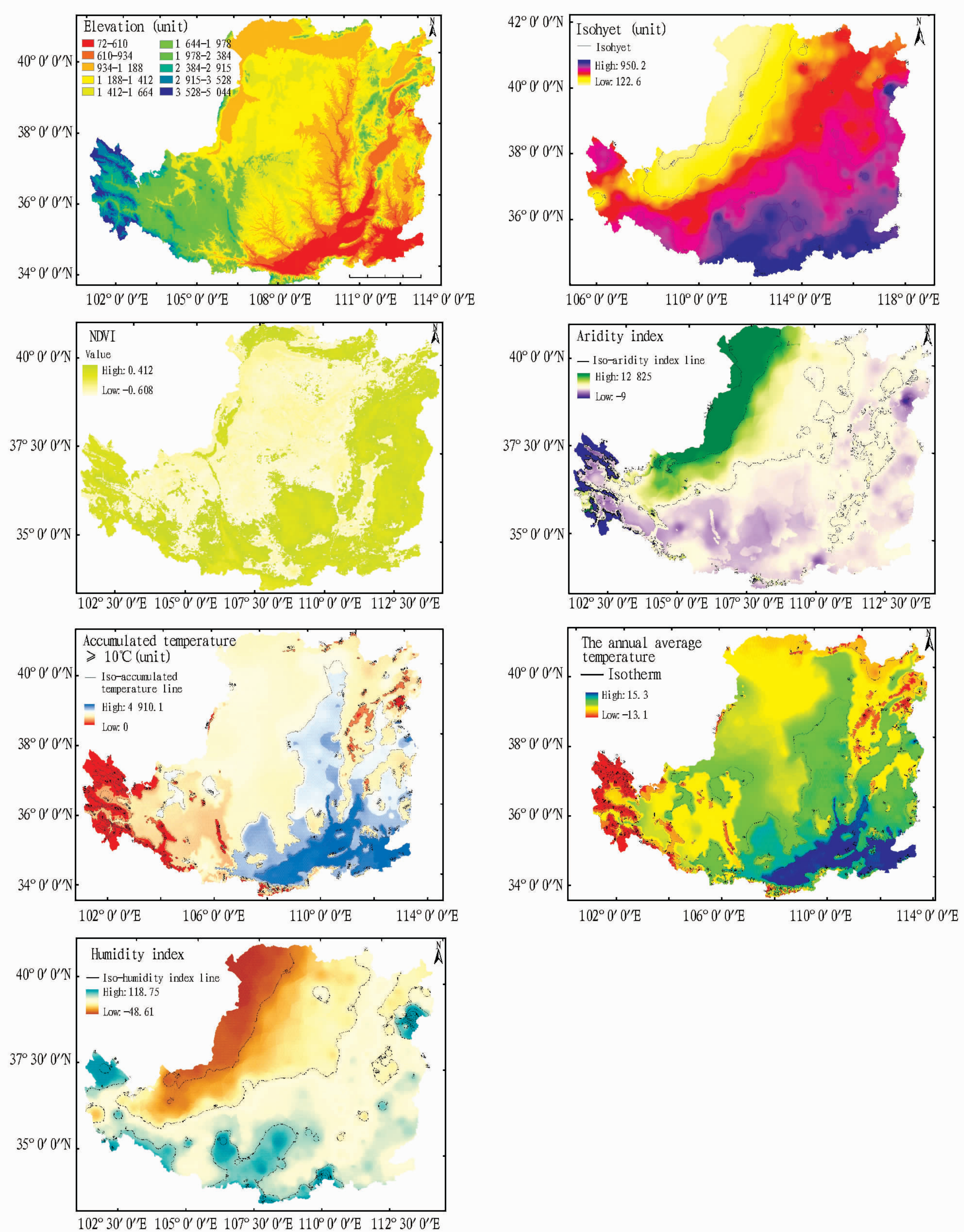

Fig. 1 Distribution map of natural factors in Loess Plateau

that the construction land area in Shaanxi Province was expanded rapidly, with the greatest growth rate in the study area, and the construction land area in Shanxi Province was also expanded, but the rate of expansion in the study area was the lowest; the unused

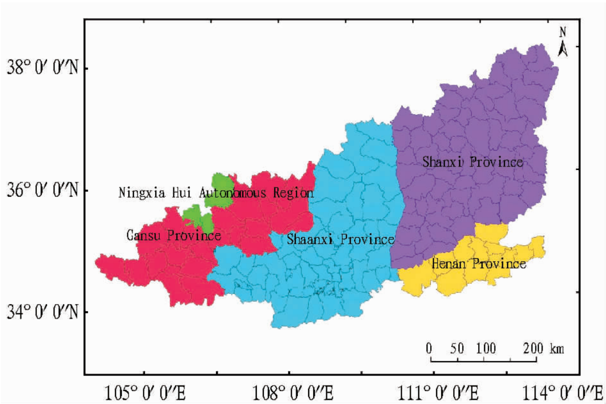

Fig. 2 Administrative division map of the southern Loess Plateau

land area in Shaanxi Province experienced the fastest decline rate in the whole region, and the unused land area in Gansu Province was increased in some local areas. The regions are sequenced in terms of the absolute value of dynamic degree of woodland use in descending order as follows: Ningxia, Shaanxi, Gansu, Shanxi, Henan. The woodland area in Ningxia and Shaanxi experienced a slight increase, but the woodland area in other provinces was decreased (Gansu with the highest decline rate). The regions are sequenced in terms of the absolute value of dynamic degree of water area use in descending order as follows: Henan, Gansu, Ningxia, Shanxi, Shaanxi. The waters area in Henan and Shaanxi was increased slightly, but the waters area in other provinces was decreased (Gansu with the highest decline rate). The regions are sequenced in terms of the absolute value of dynamic degree of arable land use in descending order as follows: Shaanxi, Gansu, Henan, Ningxia, Shanxi. There was a slight increase in the arable land area in Ningxia, but the arable land area in the remaining provinces was reduced (Shaanxi with the highest decline rate). The regions are sequenced in terms of the absolute value of dynamic degree of grassland use in descending order as follows: Henan, Gansu , Ningxia, Shaanxi, Shanxi. The grassland area was increased slightly in Gansu, but it was reduced in the remaining provinces (Henan with the highest decline rate).

4.1.1 Dynamic degree of single land use type. Based on the single land use dynamic change degree model, we derive the dynamic degree of single land use type during the period 1980 – 2005 under the support of ARCGIS9.2, and the dynamic degree of single land use type is shown in Table 2.

4.1.2 Dynamic degree of comprehensive land use. The dynamic degree of comprehensive land use during the period 1980 – 2005 is shown in Table 3. From Table 3, we know that the regions are sequenced in terms of the dynamic degree of comprehensive land use during the period 1980 – 2005 in descending order as follows: Henan, Shaanxi, Ningxia, Gansu, Shanxi. It indicates that there

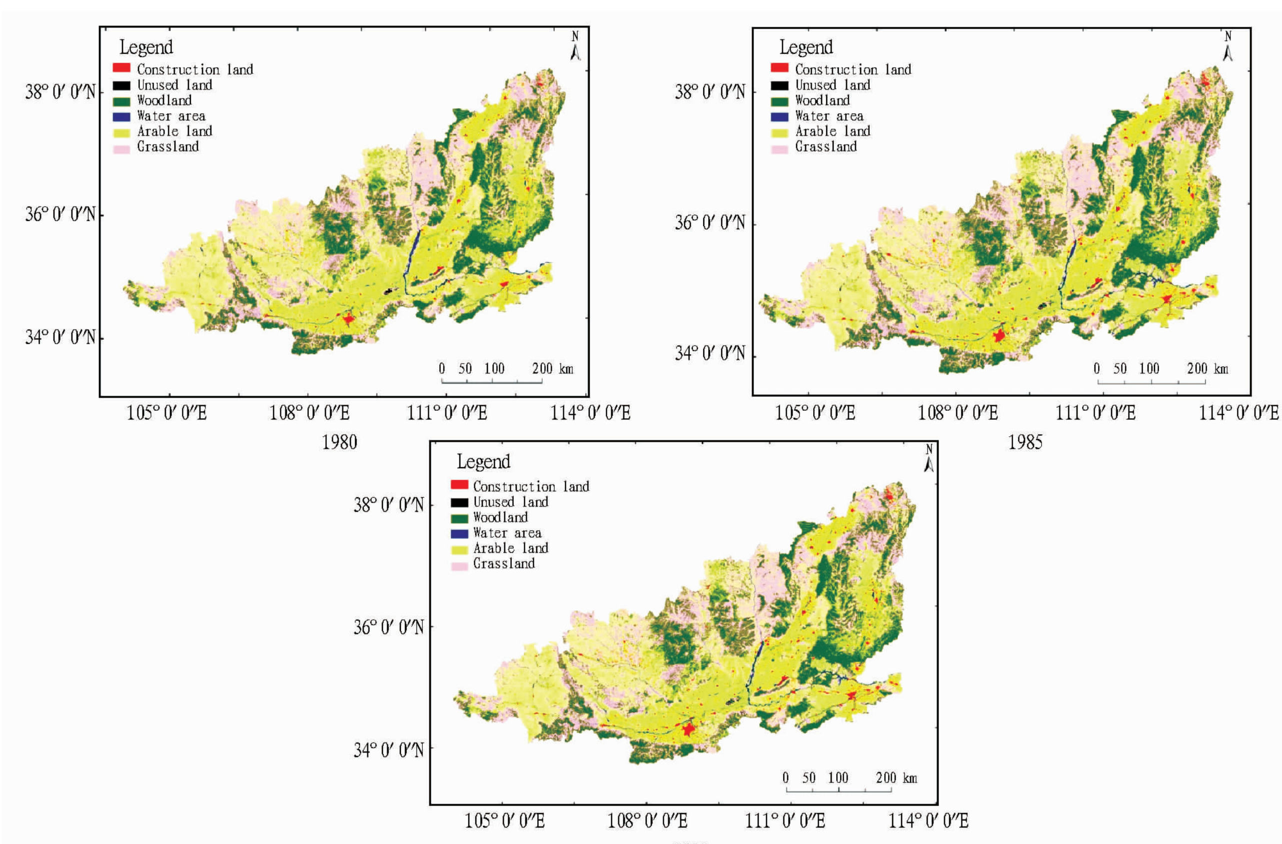

Fig. 3 Land use map of the southern Loess Plateau

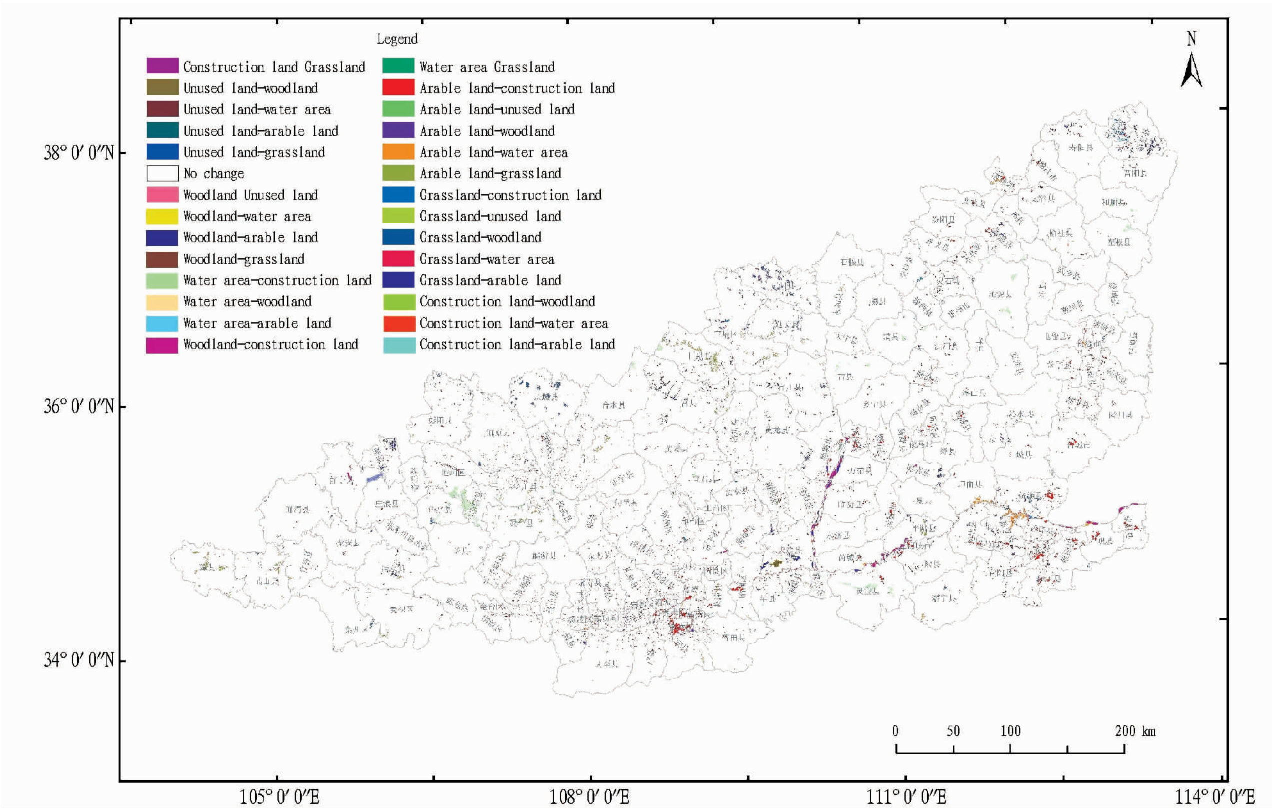

Fig. 4 Land use change map of the southern Loess Plateau

Table 2 The dynamic degree of single land use of provincial units during the period 1980 – 2005 Unit: %

	Dynamic degree of construction land use	Dynamic degree of unused land use	Dynamic degree of woodland use	Dynamic degree of water area use	Dynamic degree of arable land use	Dynamic degree of grassland use
Gansu	1.4147	0.2555	–0.0243	–0.2958	–0.0801	0.0877
Ningxia	1.9679		0.1662	–0.2206	0.0610	–0.0841
Shaanxi	2.0468	–1.3055	0.0530	0.0592	–0.0835	–0.0049
Shanxi	0.8966	0.0000	–0.0231	–0.1960	–0.0190	–0.0029
Henan	1.5733	0.0000	–0.0103	0.5622	–0.0792	–0.1449

were the most dramatic changes in land use in Henan in the study period, and the smallest changes in land use in Shanxi.

Table 3 The dynamic degree of comprehensive land use during the period 1980 – 2005 (Proportion//%; area//km^2)

	The dynamic degree of comprehensive land use
Gansu	0.0412
Ningxia	0.0438
Shaanxi	0.0449
Shanxi	0.0293
Henan	0.0679

4.1.3 Relative change rate of land use types. The relative change rate of land use types during the period 1980 – 2005 is shown in Table 4. From Table 4, we can find that the regions are sequenced in terms of the relative change rate of construction land in descending order as follows: Shaanxi, Ningxia, Gansu, Henan, Shanxi. Except Shanxi, the relative change rate in other regions is higher than in the whole region, indicating that the construction land changes are more violent than in the entire region. The regions are sequenced in terms of the relative change rate of unused land in descending order as follows: Gansu, Shanxi, Henan, Shaanxi. Except Shaanxi, the relative change rate in the remaining areas is higher than in the whole region. The regions are sequenced in terms of the relative change rate of woodland in descending order as follows: Ningxia, Shaanxi, Henan, Shanxi, Gansu. Except Ningxia and Shaanxi with relative change rate higher than in the whole region, the relative change rate in the remaining regions is lower than in the whole region.

4.1.4 Importance values of land use change type. Based on the land use change type area ratio model and abundance model, we get the land use change type area ratio and abundance during the period 1980 – 2005 using ARCGIS9.2, and further calculate the importance values of land use change types. During the period 1980 – 2005, the changes in four land types in Loess Plateau were sharp. In terms of the degree of changes in descending order, they are as follows: the change of arable land into other land, the change of other land into construction land, the change of other land into grassland, the change of other land into woodland. The importance value results are shown in Table 5. Hereinafter "→" represents "turns into", for example, "woodland→construction land" means the land type changes from woodland into construction land.

Table 4 The relative change rate of land use types during the period 1980 – 2005

	Gansu	Ningxia	Shaanxi	Shanxi	Henan
Construction land	1.0040	1.1066	1.1212	0.9080	1.0335
Unused land	1.3614		0.8620	1.2798	1.2797
Woodland	0.9928	1.0404	1.0121	0.9932	0.9963
Water area	0.9196	0.9383	1.0077	0.9444	1.1326
Arable land	0.9943	1.0301	0.9935	1.0098	0.9946
Grassland	1.0193	0.9765	0.9962	0.9967	0.9613

Table 5 The importance values of land use change types of provincial units during the period 1980 – 2005

Importance values	Gansu	Ningxia	Shaanxi	Shanxi	Henan
Woodland→construction land	0.067 6	0.000 0	0.262 9	0.078 2	0.127 7
Water area→construction land	0.020 9	0.000 0	0.049 2	0.020 4	0.165 7
Grassland→construction land	0.354 9	0.171 0	0.270 2	0.319 9	0.284 4
Arable land→construction land	2.700 9	0.623 6	7.402 3	2.650 8	7.365 2
Arable land→unused land	0.019 0	0.000 0	0.000 0	0.000 0	0.000 0
Arable land→woodland	1.027 0	1.137 4	1.743 7	0.439 7	0.301 9
Arable land→water area	0.112 2	0.000 0	0.682 3	0.658 3	2.287 0
Arable land→grassland	6.137 4	3.549 8	2.884 4	1.022 7	0.560 8
Construction land→grassland	0.035 8	0.000 0	0.008 2	0.004 0	0.000 0
Unused land→grassland	0.000 0	0.000 0	0.015 8	0.000 0	0.000 0
Woodland→grassland	1.900 1	1.111 3	0.672 7	1.055 6	0.997 4
Water area→grassland	0.102 1	0.258 3	0.243 7	0.188 7	0.114 9
Construction land→woodland	0.034 9	0.000 0	0.004 0	0.000 0	0.000 0
Unused land→woodland	0.000 0	0.000 0	0.096 3	0.000 0	0.000 0
Water area→woodland	0.010 3	0.000 0	0.044 8	0.012 0	0.020 3
Grassland→woodland	1.146 9	1.146 3	1.058 9	0.423 3	1.708 2

From Table 5, we know that during the period 1980 – 2005, for Gansu, the greatest importance value of land use change type is arable land→grassland (6.1374), and the smallest importance value of land use change type is unused land→woodland, unused land →grassland (0); for Ningxia, the greatest importance value of land use change type is arable land →grassland (3.5498), and the smallest importance value of land use change type is woodland →construction land, water area→construction land, arable land→unused land, construction land→grassland, unused land→grassland, construction land→woodland, unused land→woodland, water area→woodland, arable land→water area (0); for Shaanxi, the greatest importance value of land use change type is arable land→construction land (7.4023), and the smallest importance value of land use change type is arable land →unused land (0); for Shanxi, the greatest importance value of land use change type is arable land→construction land (2.6508), and the smallest importance value of land use change type is unused land →grassland, construction land→woodland, unused land→woodland, arable land→unused land (0); for Henan, the greatest importance value of land use change type is arable land→construction land (7.3652), and the smallest importance value of land use change type is arable land→unused land, construction land→grassland, unused land→grassland, construction land→woodland, unused land→woodland (0).

5 Conclusions and discussions

(i) The change in the amount of land shows that during the period 1980 – 2005, the construction land area increased from 3 555.99 km^2 to 4 794.28 km^2 in the southern Loess Plateau; the unused land area was slightly reduced; the woodland area was slightly increased, from 51 011.31 km^2 in 1980 to 51 066.79 km^2 in 2005; the area of waters was slightly increased, only increasing by 0.01 percentage points; there were dramatic changes in arable land area, decreasing from 100 004.79 km^2 to 98 561.57 km^2; the grassland area was increased. During the 25 years, the land use structure in the southern Loess Plateau remained basically stable. The land use types in 1980 are sequenced as follows in terms of the area proportion in descending order: arable land (44.69 %), grassland (29.76%), woodland (22.80%), construction land (1.59%), water area (1.08%), unused land (0.08%). The sequencing of the land use types in 2005 in terms of the area proportion does not change, indicating that the land use structure remains stable, and arable land, grassland and woodland are the main land landscape types in the southern Loess Plateau.

(ii) Land spatial variation shows that the change of arable land into construction land is mainly concentrated in Guanzhong Plain, Fen River Valley and Northwest Henan. The regions with increased construction land area are basically consistent with the regions with decreased arable land area. The area of waters is increased slightly, mainly in Weihe River banks and Huanghe River banks.

(iii) There are significant regional differences in the degree of single land use dynamic change, the degree of comprehensive land use dynamic change, the relative change rate of land use types, and importance values of land use change types in provincial units.

(iv) There are many reasons for significant regional differences in the degree of single land use dynamic change, the degree of comprehensive land use dynamic change, the relative change rate of land use types, and importance values of land use change types in the provincial units. They are not only affected by natural factors, such as climate, topography, precipitation, vegetation, soil and hydrology, but also affected by social and human factors, such as national policies, regional customs, the people's way of life, and level of economic development. The reason for land use changes is the combined action of the above natural and human factors.

(v) Land use change is closely related to climate change and ecological security. On the one hand, land use change has a profound impact on the natural environment by influencing climate, soil, hydrology and other factors; on the other hand, it causes ecosystem nutrient cycling and energy flow as well as the dramatic changes in biodiversity and landscape structure. In different levels, it causes changes in the structure, processes and functions of the ecosystem, having a direct impact on the water and heat balance, carbon adjustment process of the ecosystem, energy balance, service function, and climate change.

Therefore, the study of land use change is the basic work for assessing the ecosystem service value, dynamic change in the landscape pattern and ecological processes. The results of this study will lay the foundation for future studies, and it is necessary to further carry out assessment and research of dynamic change in landscape pattern and the value of ecosystem services in the southern Loess Plateau.

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