

Multi-scenario Prediction of Carbon stock in the Loess Plateau Based on Coupled PLUS-InVEST-Geodetector Model

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Abstract. Since the Loess Plateau is a typical ecologically fragile area in China, it is crucial to investigate how land use/land cover and carbon stock change under various scenarios and the factors that influence these changes for the region's ecological protection and sustainable development. In this study, we coupled the PLUS-InVEST-Geodetector model to predict the land use and carbon stock of the Loess Plateau in 2040 based on four scenarios: natural development, ecological protection, water conservation, and economic development. We also examined the effects of various driving factors on the LUCC (land use/cover change) and carbon stock. The results show that the carbon stock in the Loess Plateau will increase under all four scenarios from 2020 to 2040, with the best sequestration effect under the natural development scenario, in which the carbon stock will increase by 1.9% compared with that in 2020; the spatial distribution pattern of carbon stock in the Loess Plateau will remain unchanged from 2000 to 2040, and the main influences of these factors are NDVI, precipitation and slope. According to the requirements of the “dual carbon” target, based on the prediction results, the best option for the Loess Plateau's future development is the natural development scenario.

Keywords: Carbon stock; LUCC; PLUS-InVEST-Geodetector model; Prediction; The Loess Plateau.

1. Introduction

Climate change is one of the most serious environmental problems facing all humankind. In order to cope with a series of problems caused by climate change, the Paris Agreement was adopted at the 21st United Nations Climate Change Conference held in Paris in 2015. The agreement urges all parties to actively respond to climate change, reduce carbon emissions, and mitigate the adverse effects of the greenhouse effect. In order to reduce carbon emissions, China has put forward the “dual carbon” goal of “achieving carbon peak by 2030 and carbon neutrality by 2060”. With the proposal of the “dual carbon” goal, China has carried out relevant research on ecological environment while adjusting its energy structure. Among them, ecosystem carbon stock has been emphasized. Carbon stock reflects the storage capacity of ecosystems for carbon; an increase in ecosystem carbon stock can reduce carbon emissions, thus weakening a series of climate impacts caused by excessive carbon emissions. Therefore, carbon stock plays an important role in the service function of ecosystems. However, land use change causes changes in carbon sinks and sources; land use change affects the original land cover, changes the land structure as well as the ecological structure, which in turn affects the carbon allocation of ecosystems, resulting in the loss of their carbon stocks. Therefore, quantitative assessment of carbon stocks based on land use change is essential to protect the ecological environment and promote social development.

The Loess Plateau is a typical ecologically fragile area in China with serious soil erosion. Currently, the loess plateau is rich in carbon stocks, but at a low level in China [1]. In most of the previous studies on carbon stock in the Loess Plateau, the carbon stocks of different environmental systems in the Loess Plateau were predicted. For example, Li, et al. [2] predicted the future carbon stock of regional forest, grass and agricultural ecosystems in the Loess Plateau. However, very few studies predicted the carbon stock of the whole Loess Plateau. In this study, we predicted the land use and



carbon stock of the Loess Plateau in 2040 by coupling the PLUS-InVEST-Geodetector modeling approach for the whole land class.

This study mainly made innovations in the parameterization of the model. Firstly, in the PLUS model, we set the domain weights and transfer matrix according to the land use pattern of the Loess Plateau from 2000 to 2020. Secondly, in the InVEST model, we set the carbon density data with direct reference to the results of previous studies in the Loess Plateau region [3]. Thirdly, in the Geodetector model, we set up sampling points based on the fishing nets, and extracted the value of carbon stock for each sampling point corresponding carbon stock value with the values of each factor. With these three sequentially related models, this study can realize the assessment of carbon stock in the Loess Plateau on a larger scale, and mine the effects of different driving factors on LUCC and carbon stock.

2. Literature review

Currently, the main methods for assessing carbon stocks based on land use are field sampling and modeling to obtain accurate carbon stock data. The accuracy of data obtained by field sampling method is often very high, but it cannot reflect the spatial characteristics. In recent years, more and more scholars have begun to use the modeling method to assess carbon stocks. However, with the depth of various studies, the functions of many models can no longer meet the needs of research [4]. The PLUS model, developed by China University of Geosciences, is a new model developed by integrating the random forest model on the basis of the traditional land use model [5-6], which is superior to the previous models in terms of simulation accuracy and mechanism analysis of land use change [7]. Compared with previous conventional models, such as Markov-CA, ANN-CA, Logistic-CA, CLUE-S, and FLUS, the advantage of the PLUS model lies in its ability to identify the spatial-temporal dynamics of land expansion and its associated drivers in order to predict the changes of different land use types under different scenarios [8]. In addition, among many ecosystem carbon stock models, the Carbon module in the InVEST model can assess the carbon stock in a region over a certain period of time with high precision using a small amount of data, and has been widely used in carbon stock assessment. Land use change is an important factor in ecosystem carbon stock change, therefore, more and more scholars have begun to use the method of coupling PLUS and InVEST models to predict regional carbon stock change and analyze its driving mechanism. Fu, et al. [9] used the coupled PLUS-InVEST-Geodetector model to predict the land use change in Xinjiang in 2035 and assess the carbon stock in the region; Wu, et al. [10] used the method based on the PLUS model and the InVEST model to assess the change of carbon stock in the Sichuan-Chongqing Economic Zone from 2000 to 2050; Zhang, Y., et al. [11] applied the coupled GMOP-PLUS-InVEST modeling approach to assess the carbon stock changes in the Hexi Corridor from 2000 to 2035.

3. Materials and methodology

3.1. Overview of the study area

The Loess Plateau region is located between 33°41'~41°16'N, 100°52'~114°33'E, in the middle reaches of the Yellow River in China, spanning seven provinces and regions, namely Qinghai Province, Gansu Province, Ningxia Hui Autonomous Region, Shaanxi Province, Inner Mongolia Autonomous Region, Shanxi Province and Henan Province, and covering a total area of 640,000 km². It is the largest loess accumulation area in the world, with an average thickness of loess of 92.9 m. Influenced by various factors such as human activities and natural conditions, soil erosion is serious, and the average modulus of sand transport by erosion ranges from 1921 to 3355 t·(km²·a)⁻¹ over the years. The terrain is fragmented with gullies and ravines (Figure.1). The climate of the Loess Plateau is a continental monsoon climate, with an average annual temperature of 3.6-14.3 °C, annual precipitation of 150-750 mm, and uneven spatial and temporal distribution of precipitation. The Loess Plateau is one of the most serious regions in the world in terms of soil erosion, which has caused problems such as soil desertification, massive degradation of surface vegetation, and declining

productivity of the land, and therefore the ecological and environmental problems of the Loess Plateau region have been prominent for a long time [12].

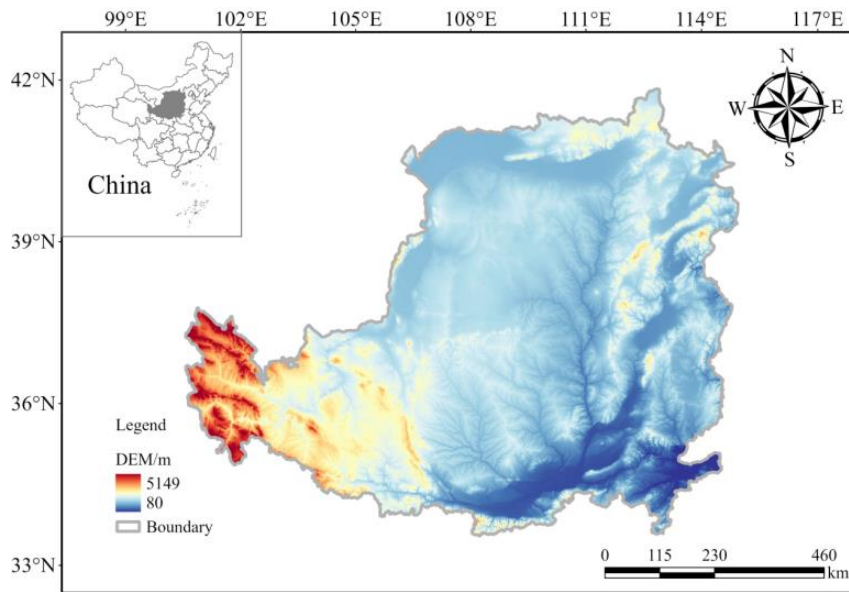


Figure 1. Geographic location of the Loess Plateau

3.2. Data sources

3.2.1. Land-use simulation data

In this study, a total of 15 driver data from natural and human aspects and LUCC data were utilized considering the characteristics of the study area. The LUCC data, soil type, mean annual temperature, mean annual precipitation, NDVI, GDP and population data for the two periods (2000 and 2020) of the study area were obtained from the Resource and Environmental Science Data Center of the Chinese Academy of Sciences (<http://www.resdc.cn>); the distance from roads (Class I, Class II, and Class III) and the distance from highways, railroads, county governments, water bodies in the study area Distance data of seven types were obtained from Open Street Map (<https://www.openstreetmap.org>); DEM data of the study area were obtained from Geospatial Data Cloud (<http://www.gscloud.cn>), and slope data were generated from DEM data calculations. Among them, the LUCC data were reclassified in ArcGIS pro to obtain six Level 1 land classes of cropland, forest land, grassland, water, construction land and unutilized land in the study area; Euclidean distance analyses were carried out in ArcGIS pro for the driving factor data; and all data were resampled in ArcGIS pro to harmonize the projected coordinate system (Krasovsky_1940_Albers), the number of rows and columns (9386×11598), and the resolution (100 m×100m).

3.2.2. Carbon density data

In this study, the carbon density values of six land use types were determined with reference to previous studies in the Loess Plateau region [3], as shown in Table 1.

Table 1. Carbon density of land use types in the Loess Plateau(t/hm²)

Land use type	Above-ground carbon density	Under-ground carbon density	Soil carbon density	Dead organic matter carbon density
Cropland	4.70	0.00	33.46	0.00
Forest land	30.17	10.40	68.79	13.00
Grassland	3.37	7.48	44.36	4.47
Water	3.25	0.00	0.00	0.00
Construction land	2.50	0.08	78.00	0.00
Unutilized land	1.30	8.60	31.40	0.00

3.3. Methodology

3.3.1. PLUS Model

According to the current development and future development prospects of the study area, this study set up four scenarios of natural development, ecological protection, water conservation and economic development. The specific scenario setting is realized by transfer matrix, as shown in Table 2.

Table 2. Transfer matrix

	Natural Development Scenario						Ecological Protection Scenario						Water Conservation Scenario						Economic Development Scenario					
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
A	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	0	0	0	1	0
B	1	1	1	1	1	1	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0	0	1	0
C	1	1	1	1	1	1	0	1	1	0	0	0	0	1	1	1	0	0	1	1	1	0	1	0
D	1	1	1	1	0	1	0	1	1	1	0	0	0	0	0	1	0	0	1	1	1	1	1	0
E	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0
F	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1

Note: A, B, C, D, E, F represent cropland, forest land, grassland, water, construction land and unutilized land, respectively; where 0 indicates that conversion is not allowed, and 1 indicates that conversion is allowed; the rows in the matrix indicate transfers out, and the columns indicate transfers in.

Neighborhood weight is a numerical value used to reflect the expansion ability of various land use types, and its value ranges from 0 to 1. The closer its value is to 1, the stronger the expansion ability of a land use type is [13]. In this study, referring to the research method of Wang et al [14], the domain weights of each category were set by using the most value normalized assignment method (Table 3).

Table 3. Neighborhood weight settings

Land use type	Cropland	Forest land	Grassland	Water	Construction land	Unutilized land
Neighborhood weight	0.748	0.345	1	0	0.029	0.131

$$W_i = \frac{TA_i - TA_{\min}}{TA_{\max} - TA_{\min}} \quad (1)$$

Note: W_i is the weight of the area of land type in category 1, TA_i is the expansion area of land use in category 1, TA_{\min} is the minimum expansion area of land use in each category, and TA_{\max} is the maximum expansion area of land use in each category.

3.3.2. InVEST Model

The Carbon module in the InVEST model is mainly based on land use and the four basic carbon pools to estimate the carbon stock of the region in a certain time period, and its calculation formula is:

$$C_i = C_{i\text{-above}} + C_{i\text{-below}} + C_{i\text{-soil}} + C_{i\text{-dead}} \quad (2)$$

$$C_{\text{tot}} = \sum_{i=1}^n C_i \times A_i \quad (3)$$

Note: i is a land use type; C_i is the carbon density of land use type i ; $C_{i\text{-above}}$, $C_{i\text{-below}}$, $C_{i\text{-soil}}$ and $C_{i\text{-dead}}$ are the carbon density of above-ground vegetation ($t \cdot hm^{-2}$), below-ground vegetation ($t \cdot hm^{-2}$), soil ($t \cdot hm^{-2}$), and dead organic carbon ($t \cdot hm^{-2}$), respectively; C_{tot} is the total ecosystem carbon stock (t); A_i is the area of land use type i (hm^2); n is the number of land use types.

3.3.3. Geodetector Model

Geodetector model is a model developed by Wang et al [15] to explore the effects of single and interactive factors on phenomena, mainly analyzing the driving force of spatial differentiation. In this study, using the 2020 Loess Plateau carbon stock as an example, the model was applied to mine the driving force of the spatial differentiation of the carbon stock in the Loess Plateau. In this study, the 15 factors were reclassified in ArcGIS pro according to the mean value method, and a 10km×10km fishing network was established to generate sampling points, and the carbon stock value corresponding to each sampling point was extracted with the values of each factor.

3.3.4. Global spatial autocorrelation

Global spatial autocorrelation is used to reflect the correlation of each spatial unit in an overall region [16]. This study explored the spatial aggregation of carbon stocks in the Loess Plateau by analyzing the global spatial autocorrelation of carbon stocks in 2000, 2020, and the predicted 2040, which is calculated by formula:

$$I = \frac{n \sum_{i=1}^n \sum_{j=1}^n w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{(\sum_{i=1}^n \sum_{j=1}^n w_{ij}) \sum_{i=1}^n (x_i - \bar{x})^2} \quad (4)$$

Note: I represents the Moran index, the value range is $[-1, 1]$, when the value is greater than 0, it means that there is a positive spatial correlation in the region; when the value is less than 0, it means that there is a negative spatial correlation in the region; the closer the value is to 1 or -1, it means the stronger the spatial correlation is, and the value is close to 0 which means that there is no spatial correlation in the region, n represents the number of spatial units in the region, and x_i and x_j represent the carbon stocks in the region i and j .

3.3.5. Analysis of hot and cold spots

Getis-Ord G_i^* can be used to reflect the spatial distribution characteristics of carbon stock in a region [17]. This study analyzed the spatial clustering characteristics of the loess plateau carbon stock in 2000, 2020 and the predicted 2040 by this method, which is calculated as:

$$G_i^*(d) = \frac{\sum_j^n W_{ij}(d) X_j}{\sum_j^n X_j} \quad (5)$$

Note: d is the distance, $W_{ij}(d)$ is the spatial weight defined in terms of the distance rule; X_j is the observed value of region j ; when $G_i^*(d)$ is positive it indicates high-value spatial agglomeration (hot spot area), and when $G_i^*(d)$ is negative it indicates low-value spatial agglomeration (cold spot area).

4. Results and analysis

4.1. Analysis of LUCC

Based on the historical land use data obtained in this study, the land use changes in the Loess Plateau from 2000 to 2020 were analyzed. From the results obtained from the statistics, the land use pattern of the Loess Plateau basically remained unchanged from 2000 to 2020 (Figure.2), with the area of land categories in the following order: grassland, cropland, forest land, unutilized land, construction land, water; according to the direction of land flow (Figure.3), the main mode of flow is the transfer of each category to grassland and cropland. The areas of grassland and cropland in the Loess Plateau in 2020 were respectively $26.83 \times 10^4 \text{ km}^2$, $20.28 \times 10^4 \text{ km}^2$, accounting for about 72.56% of the area

of the Loess Plateau; the area of its water is $94.93 \times 10^2 \text{ km}^2$, accounting for only about 1.46% of the area of the Loess Plateau. The Loess Plateau is mainly dominated by arid and semi-arid regions, which lack water for a long time, so the area of water bodies has been at a very low level during 2000 and 2020.

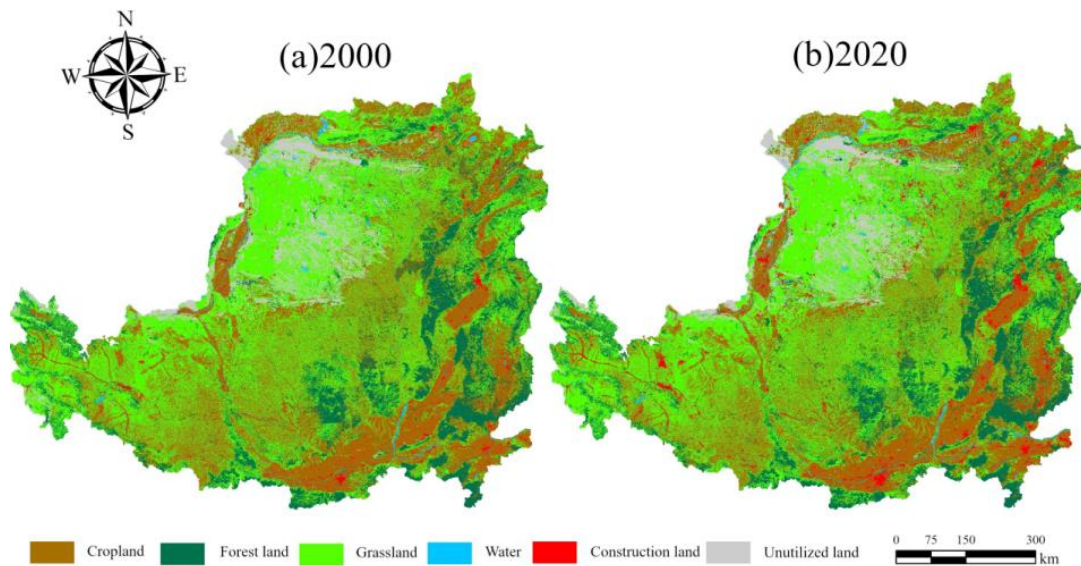


Figure 2. Land use of the Loess Plateau in 2000 and 2020

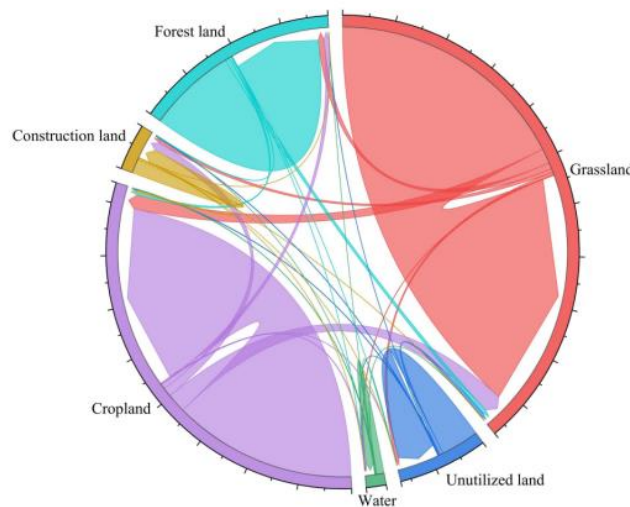


Figure 3. Land flow in the Loess Plateau from 2000 to 2020

Predicting land use with high accuracy is a prerequisite for studying future carbon stock. In this study, the PLUS model was run to simulate the land use in 2020, and the simulation results obtained were verified with the real land use in 2020, obtaining a Kappa coefficient of 0.823248, with an overall accuracy of 0.876902. Since the Kappa coefficient is greater than 0.8, it can be recognized that the simulation result is basically the same as the actual one. Therefore, this study has high simulation accuracy, and can be used to predict the future changes of land use and carbon stock.

In this study, the PLUS model was applied to predict the land use of the Loess Plateau in 2040 based on the land use data of the Loess Plateau in 2000 and 2020. The results show that compared with 2020, the land use pattern of the Loess Plateau in 2040 is basically unchanged; under the four different scenarios, except for the area of unutilized land, which decreases, the area of all the other categories increases or decreases or remains basically unchanged, which coincides with the increase in the land use demand of the region's human society and the continuous improvement of the natural environment. Under the four scenarios, changes in cropland are mainly concentrated in the areas surrounding the construction sites on the Loess Plateau; cropland expands only in the economic development scenario

because it can generate certain economic benefits. Forest land and grassland both increase in area under the ecological protection and water conservation scenarios, but both decrease in area under the economic development scenario. In addition, under the natural development scenario, the area of forest land expands but the area of grassland decreases slightly; the area covered by forest land is mainly in the eastern and central south of the Loess Plateau, while the majority of the area covered by grassland is on the western side of the forest land, which is relatively more drought-tolerant, and the area where it is situated has more precipitation and a more suitable climate for the expansion of the forest land. Water remains basically unchanged in the water conservation scenario, but in all other scenarios show a decrease in the area covered by them; the precipitation in the region increases, and the intensity of precipitation is enhanced, and soil erosion on the Loess Plateau will be further intensified, resulting in further soil and water loss, and relevant measures should be taken to protect the water appropriately. The area of construction land decreases under both ecological protection and water conservation scenarios, but expands under both natural development scenarios and economic development scenarios, and attention should be paid to harmonizing environmental protection and economic development in the future.

4.2. LUCC Driver Analysis

In this study, the contribution of each driver to land use change was automatically generated by the Land Expansion Analysis Strategy (LEAS) module in the PLUS model to perform LUCC driver analysis. Cropland is most affected by population; cropland is basically covered around construction land, and these areas are highly urbanized and densely populated, so people have a greater demand for cropland. Forest land and grassland are most affected by population; changes in population size and distribution will change the impact of human activity intensity on forest land and grassland ecosystems. In addition, the effects of temperature and NDVI on forest land are also significant; the more suitable the temperature and the higher the level of NDVI, the better the vegetation grows, which is conducive to the expansion of forest land. The most significant influence on water is DEM; the Loess Plateau is located in the Yellow River Basin, and the Yellow River continuously collects water from high to low elevations, and changes in elevation drop in the region will affect the formation of water bodies. Construction land is most significantly affected by population; the continuous development of built-up land is to adapt to the urbanization process and population growth, therefore, the population factor largely influences the change of construction land. Unutilized land is most affected by population; the rapid economic development of the Loess Plateau has resulted in more significant population growth and urbanization than ever before, and the demand for land has surged; therefore, the increasing population growth has enhanced the development and utilization of unutilized land by human beings.

4.3. Analysis of spatial and temporal variations in carbon stock

In this study, the carbon stock changes in the Loess Plateau from 2000 to 2040 were evaluated by using the Carbon module of the InVEST model, based on the land use data in 2000 and 2020, the land use in 2040 generated by the PLUS model, and the carbon density of the Loess Plateau. The results showed that, in general, the carbon stock in the study area increased during the 40-year period. The carbon stock in the Loess Plateau in 2000 was $39.106 \times 10^8 \text{t}$; in 2020, it was $39.881 \times 10^8 \text{t}$, an increase of $7.75 \times 10^7 \text{t}$, or 2%, compared with that in 2000. According to the prediction results (Figure.4), the carbon stock of the Loess Plateau under the four scenarios of natural development, ecological protection, water conservation and economic development in 2040 will be $40.639 \times 10^8 \text{t}$, $40.226 \times 10^8 \text{t}$, $40.148 \times 10^8 \text{t}$ and $40.149 \times 10^8 \text{t}$, respectively, with varying degrees of increase from 2020. The carbon sink of the Loess Plateau ecosystem will increase in the future, and the carbon sequestration capacity will be enhanced, with the best sequestration effect under the natural development scenario, which is mainly due to the fact that the simultaneous increase in the carbon stock of forest and construction land under this scenario can more effectively replenish the carbon stock lost by the other land use types, and thus increase the total carbon stock.

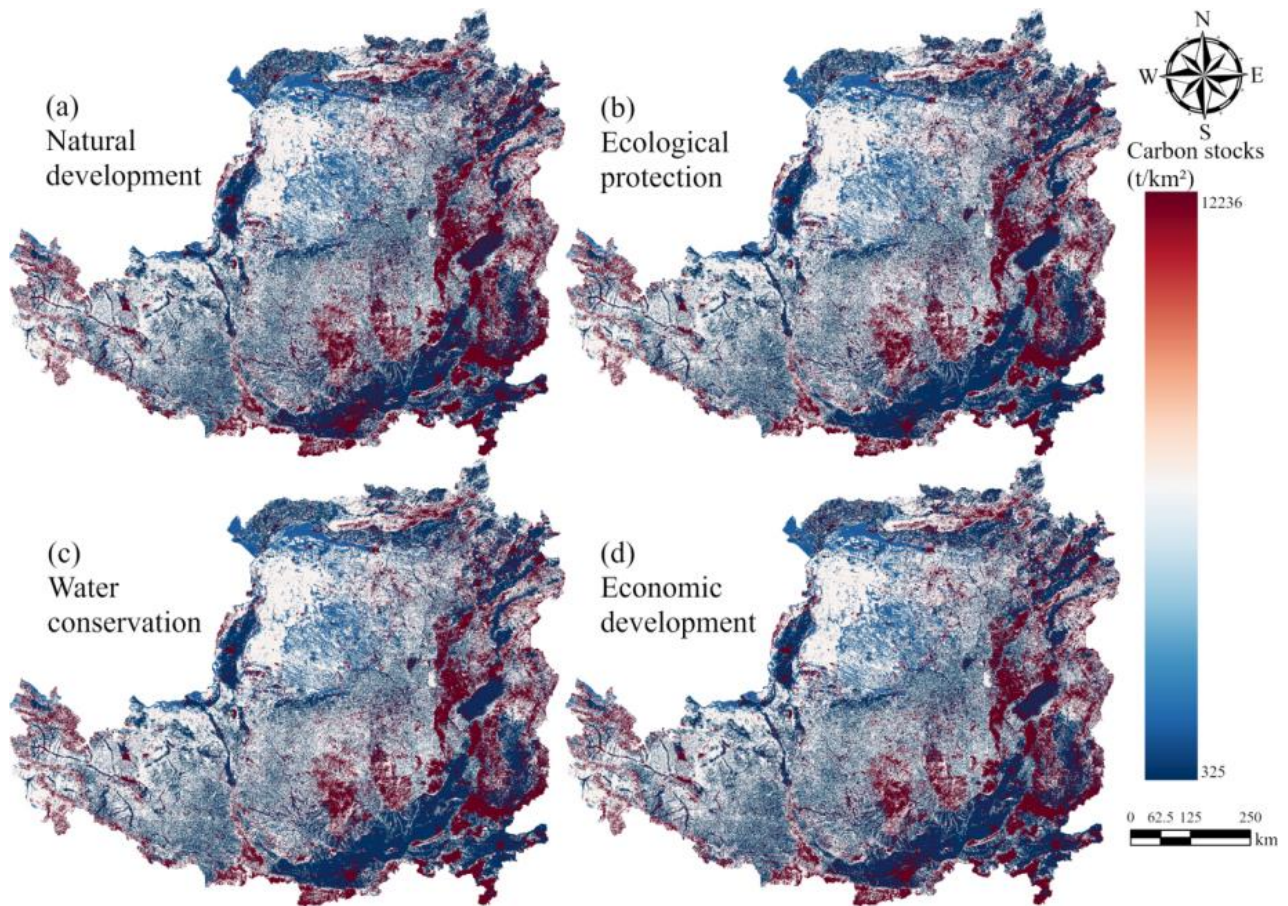


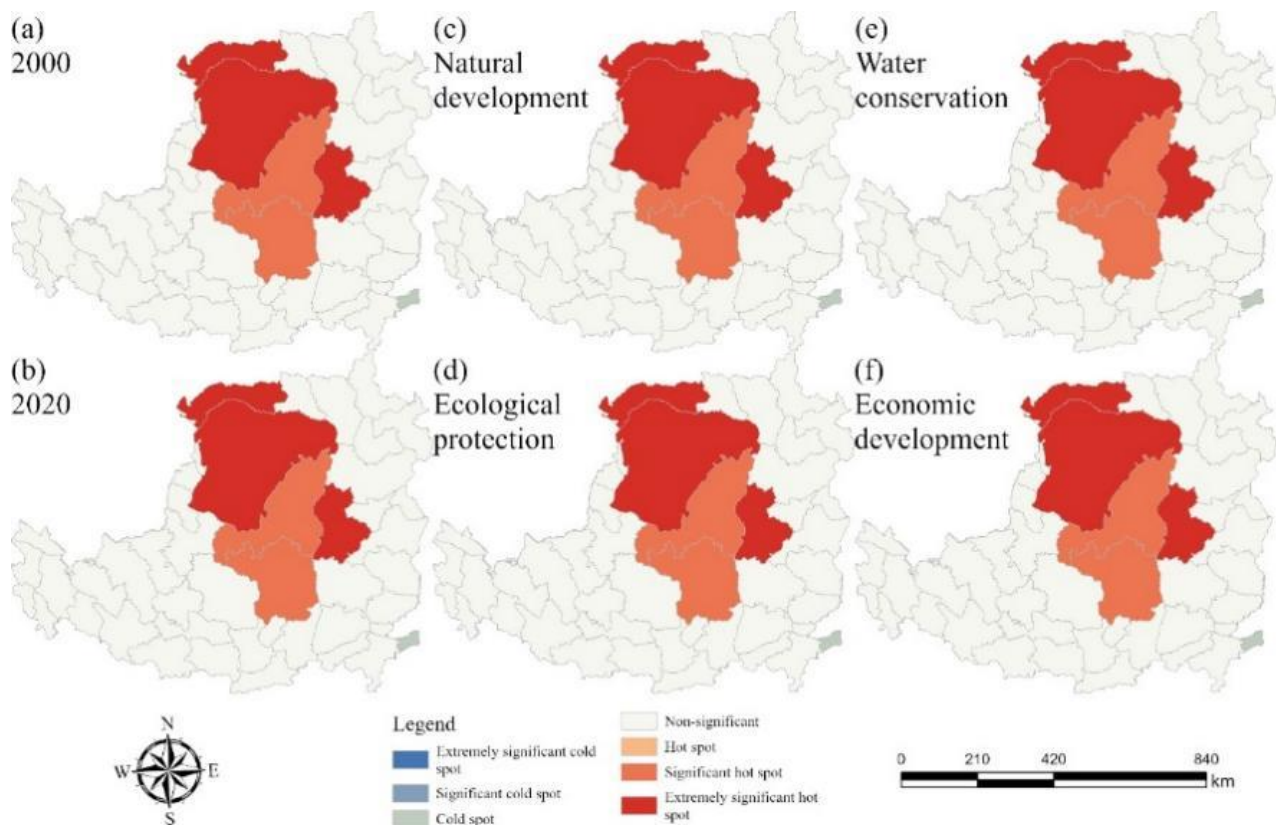
Figure 4. Spatial distribution of carbon stocks in the Loess Plateau in 2000, 2020 and 2040

The carbon stocks in the Loess Plateau in 2000, 2020, and 2040 projected under the four scenarios were partitioned into six Class 1 land use categories, and the carbon stocks in each land use category were obtained for the corresponding years (Table 4). The results show that compared with 2020, in 2040, except for the carbon stock of unutilized land, which decreases under all four scenarios, the carbon stocks of the other land classes increase, decrease or remain basically unchanged under each scenario, which is mainly related to the intensification of human land use. The carbon stock of cropland increases only under the economic development scenario; cropland has a variety of cash crops, and the expansion of cropland area will inevitably result in an increase in its carbon stock to a certain extent under the economic priority scenario. The carbon stock of forest land decreases only under the economic development scenario, indicating that economic and social development will affect the ecological quality of forest land to a certain extent. Although forest land has a smaller area than cropland, it has a higher carbon stock, indicating that forest land has a stronger role in reducing carbon emissions than cropland, which is related to the higher level of vegetation cover and carbon density in the region where forest land is located. The carbon stock of grassland increases in the ecological protection and water conservation scenarios, and decreases in the nature scenario and the economic development scenario; grassland is an important part of the ecosystem, and environmental protection can encourage it to utilize its carbon sequestration capacity. Carbon stocks in water remain largely unchanged in the water conservation scenario, but decrease in the remaining scenarios, indicating that ecosystems dominated by water are fragile, and soil erosion will be further aggravated in the absence of special protection. Construction land increases under both the natural and economic development scenarios, but decreases under both the ecological protection and water conservation scenarios; construction land has a profound effect on economic development, and its carbon stock will inevitably increase under the economic development scenario, but also under the natural development scenario, which is related to the stable economic and social development of the region.

Table 4. Carbon stocks in the Loess Plateau for each category in 2000, 2020 and 2040 ($1 \times 10^8 t$)

	2000	2020	Natural development in 2040	Ecological protection in 2040	Water conservation in 2040	Economic Development in 2040
Cropland	8.249	7.738	7.506	7.496	7.482	7.747
Forest land	11.683	12.143	12.534	12.534	12.534	11.804
Grassland	16.057	16.013	15.920	16.677	16.608	15.920
Water	0.030	0.031	0.019	0.026	0.031	0.018
Construction land	1.297	2.234	2.998	1.830	1.830	2.998
Unutilized land	1.790	1.722	1.663	1.663	1.663	1.663

From the global spatial autocorrelation analysis, the global Moran's index of carbon stock in the Loess Plateau in 2000, 2020, and the projected 2040 are all around 0.11, which indicates that the spatial distribution of carbon stock in the region has a certain aggregation phenomenon. This study further analyzed the cold-hot spot analysis of carbon stocks in the region (Figure.5), and the results showed that the spatial distribution pattern of carbon stocks in the Loess Plateau is basically unchanged during these 40 years. The concentration of carbon stocks in the northwestern and central parts of the Loess Plateau suggests that these areas have a favorable land environment and rich vegetation cover, which should be protected in the future.

**Figure 5.** Cold-hot spot distribution of carbon stocks in the Loess Plateau from 2000 to 2040

4.4. Analysis of the drivers of spatial heterogeneity of carbon stocks

According to the results of single-factor detection, the q-value of X5 (NDVI) is 0.156, the q-value of X7 (precipitation) is 0.133, the q-value of X11 (slope) is 0.104, and the q-values of the rest of the influencing factors are less than 0.1, so that the NDVI, precipitation, and slope are the main factors

of carbon stock in the region. All three factors also play an important role in plant growth, so the spatial differentiation of carbon stock in the region is mainly related to various plant ecosystems.

According to the results of the interaction detection, any factor interacting with X5 (NDVI), X7 (precipitation) and X11 (slope) has high explanatory power, which is mainly due to the high single-factor explanatory power of these three factors. Among them, the highest explanatory power under interaction is X5 (NDVI) interacting with X11 (slope) with a q value of 0.23465. All the factor interactions are two-factor enhancement or nonlinear enhancement, which indicates that the explanatory power of the regional carbon stock is higher under the interaction of different factors, and thus the spatial differentiation of the carbon stock in the region is influenced by the interaction of various geographic factors.

5. Conclusion and suggestion

In this study, the coupled PLUS-InVEST-Geodetector model was applied to predict the land use and carbon stock of the Loess Plateau in 2040. The results showed that: Between 2020 and 2040, the carbon stock of the Loess Plateau will increase under all four scenarios, with the best sequestration effect under the natural development scenario, whose carbon stock increased by about 1.9%; comparing the regional land use projections under the four scenarios, the only scenario that takes into account both ecological protection and economic development is the natural development scenario.

Because of a series of ecological conservation measures, the habitat quality of the Loess Plateau has been significantly improved. The predicted results of the natural development scenarios in this study are generally consistent with the effects that these ecological conservation measures are intended to achieve. In this study, the future Loess Plateau has the highest carbon stock under the natural development scenario, suggesting that in terms of the role of carbon sequestration in the region, the best option for development of the Loess Plateau in the next at least 20 years is to continue to adhere to the current land management measures. In addition, forest and construction land under natural development scenario contribute the most to the replenishment of carbon stocks, and therefore the protection of forest and construction land should be emphasized in the future, with a focus on integrating and planning the relationship between the development of these two types of land.

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