Study on Spatial Model of Land Use Based on CA - Markov Model after Returning Cropland to Forest

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Abstract. At present, the frontier of global environmental change research is land use / cover change, and an important way to understand global land change is to analyze and study typical areas. In order to study the law and the driving mechanism of land use change in the loess hilly and gully region, this paper takes the county south ditch watershed as an example, takes the remote sensing image of the basin in 1995, 2005 and 2015 as the data source, combined with the topographic data, and the spatial and temporal dynamics of land use before and after returning farmland to forest in Nangou watershed was analyzed. Finally, based on the land use situation in 2015, a variety of CA criteria were used to carry out modeling analysis to predict the land use in 2025 Type of purpose. And thus hope for the region to implement the scientific implementation of the project of returning farmland to forest.

1. Introduction
For a case study of the typical region. County in the south of the Loess Plateau gully region as the object of study, the state from 1974 on the watershed to plant trees and grass as the focus of the comprehensive treatment, [1]-[4] and in the years of comprehensive management and reduce sediment benefits The monitoring study has accumulated a lot of data and rich experience. [5] In order to analyze the spatial and temporal patterns and evolution of land use, the remote sensing image data and ground data were processed by remote sensing and GIS software, [6] and then the results were analyzed and compared. The temporal and spatial pattern of land use change and the evolution of land use change in Nangou watershed, and the quantitative simulation of land use change in 2025 based on CA-Markov model.

2. Survey Area Overview and Data Processing

2.1. Overview of the Study Area
County South ditch watershed (E 109°19'30", N 36°51'30") is located in the second sub-region of the hilly and gully region of the Loess Plateau. [7] It is a tributary of the lower reaches of the Xingzi River, which belongs to the typical loess hilly gully Area, belonging to Ansai County, Shaanxi Province, the basin area of 8.27 km², most of the soil is yellow soil, accounting for 77.1% of the total area. In the basin, the density of the gully in the terrain is 8.06 km/km², and the elevation is 1100-1400 m. [8]

2.2. *The Specific Technical Process (it is shown in Figure 1)*

![Figure 1. Technical flow chart](image)

2.3. *Data Pre-Processing*

(1) ArcGIS data preparation;
(2) Data fusion;
(3) Overlay analysis;
(4) Calculate the area and export the attribute table;
(5) Export the data processing results;
(6) Data analysis.

① Time characteristics of land use structure.
② Land use type evolution analysis.
3. Temporal and Spatial Evolution of Land Use

3.1. Analysis of Land Use Time Process

3.1.1. Analysis of land use time before returning to cropland (1995-2005)

The relative rates of land use in the Nangou watershed in Ansai County from 1995 to 2005 are calculated, and as shown in Table 1.

| Land use type               | The total land area of all types in 1995 (m²) | The total land area of all types in 2005 (m²) | Added area (m²) | Relative change rate of land use (m²) |
|-----------------------------|-----------------------------------------------|-----------------------------------------------|-----------------|--------------------------------------|
| Rural settlements           | 43315.79904                                   | 64697.02214                                   | 26381.2231      | 1.23                                 |
| The river surface           | 88370.35988                                   | 66989.13678                                   | 19225.5163      | 0.90                                 |
| Reservoir water surface     | 10645.02185                                   | 25026.24495                                   | 32301.1152      | 2.25                                 |
| Dry land                    | 107744.0591                                   | 66362.83602                                   | 445620.9716     | 10.77                                |
| Orchard                     | 120184.9693                                   | 241566.1924                                   | 15320.6541      | 0.13                                 |
| woodland                    | 97319.63124                                   | 72938.40814                                   | 16589.5028      | 0.68                                 |
| Shrubbery                   | 449902.8673                                   | 261284.0904                                   | 17256.1265      | 0.09                                 |
| Natural grassland           | 1752439.4911                                  | 1762439.489                                   | 42056.2546      | 4.21                                 |
| Saline Land                 | 399141.8641                                   | 187760.641                                    | 20154.9861      | 0.10                                 |
| Cultivated land             | 1226174.781                                   | 1076827.288                                   | 12071.3695      | 0.08                                 |

3.1.2. Analysis on Land Use Time Process after Returning Farmland (2005 - 2015)

The relative rates of land use in the Nangou watershed in Ansai County from 2005 to 2015 are as shown in Table 2.

| Land use type               | The total land area of all types in 1995 (m²) | The total land area of all types in 2005 (m²) | Added area (m²) | Relative change rate of land use (m²) |
|-----------------------------|-----------------------------------------------|-----------------------------------------------|-----------------|--------------------------------------|
| Rural settlements           | 64697.02214                                   | 103472.5069                                   | 55365.92072     | 1.43                                 |
| The river surface           | 66989.13678                                   | 71729.70324                                   | 59327.64578     | 12.51                                |
| Reservoir water surface     | 25026.24495                                   | 14953.5889                                    | 11107.01465     | 1.10                                 |
3.2. Analysis of Spatial Pattern of Land Use

3.2.1. Analysis on spatial pattern of land use before returning to cropland (1995-2005)

Transformation of Main Land Use Types in Nangou Watershed of Ansai County in 1995-2005. The results showed that the increase of rural settlements and orchards was mainly due to the transfer of forest land area, 0.2190 km² and 0.7854 km² respectively, and the probability of turning into the orchards was 24.31%, and the orchards were Part of the area out of grass and shrubs, the transfer probability was 19.93% and 14.86%. The increase in cultivated land area is mainly due to the transfer of dryland and sparse forest land area into 0.1153 km² and 0.0989 km², respectively. Overall, the transfer rate of rural settlements is 90%, the conversion rate of orchards is 88%, and the transfer rate of reservoirs and forest land is the lowest. The area of dryland, shrub and orchard was the most obvious. In the period from 1995 to 2005, 0.9896 km², 0.8631 km² and 0.7854 km² were transferred to dryland, shrub and orchard respectively. The transfer probabilities were 30.63%, 29.81% and 24.31%, respectively.

3.2.2. Analysis on Spatial Pattern of Land Use after Returning Farmland (2005 - 2015)

The transformation of the main land use types in the Nangou Watershed of Ansai County in 2005 and 2015 shows that the increase of the area of forest land is mainly due to the transfer of land area of other types of land and forest land to 0.8605 km² and 0.1415 km², the probability of turning grass into the shrubbery is 45.63%, and the probability of shrub forest turning into forest land is 35.78%. The increase of cultivated land area is mainly due to the conversion of grassland and other types of land area, Transferred to two separate 0.41 km² and 0.3102 km² respectively. Overall, shrubs, arable land and dry land transfer rate of the highest, are 94%, orchards and forest land transfer rate followed by 86% and 83%, river water transfer rate of the lowest, 17% The Grassland, shrubs and cultivated land conversion between the most obvious, during the 1.0082 km² and 0.4104 km² of grassland were converted to shrubs and arable land.

4. Simulation and Prediction of Dynamic Evolution of Land Use Change

4.1. Forecast of Land Use Distribution in 2025 Based on CA-Markov Model

Based on the CA-Markov model, that is, the probability of land use change in Nangou watershed of Ansai County based on Markov model, combined with the change of land use type in 2015, the time
interval is 10 years. Forest policy measures, the appropriate adjustment of its probability, through the CA model of space, that is, from the spatial prediction of land use change pattern.

4.1.1. The determination of the transfer probability

Year as a unit, the change of land use type is divided into a series of discrete processes, according to the average annual conversion rate of each type (after returning farmland to forest, that is, from 2005 to 2015, the land use type conversion area divided by the age Interval 13 to obtain an average annual conversion area of the original area of the percentage of the area) to determine the land use type unit transfer probability, the rural residential area into other types of transition probability as the first line, the river surface into other landscape types The probability of transition as the second row, and so on, the establishment of the transition probability matrix, the 2005-2015 time period to determine the initial transfer probability matrix, [9]-[11] and as shown in Table 3.

Table 3. Transfer probability matrix for land use types in the initial state

|  | Residential Area | Forest | Grass | Orchard | Arable Land | Dry Land |
|---|------------------|--------|-------|---------|-------------|----------|
| Residential Area | 0.0657 | 0 | 0 | 0 | 0.0094 | 0.0015 |
| Forest land | 0.0044 | 0.3723 | 0.0297 | 0.0003 | 0.0252 | 0.0152 |
| 0.0273 | | | | | | 0 |
| Grass | 0.0004 | 0.0293 | 0.0151 | 0.0015 | 0.0111 | 0.0011 |
| 0.0013 | 0 | | | | | 0 |
| Orchard | 0.0007 | 0.0370 | 0.0051 | 0.0182 | 0 | 0.0159 |
| 0 | | | | | | 0 |
| Arable land | 0.0003 | 0.0131 | 0.0054 | 0.0407 | 0.0089 | 0.0085 |
| 0 | | | | | | 0 |
| Dry land | 0 | 0.0377 | 0.0114 | 0 | 0 | 0.0279 |
| 0 | | | | | | 0 |
| Saline Land | 0 | 0.0249 | 0.0016 | 0.001 | 0.0009 | 0.0485 |
| 0.0486 | 0 | | | | | 0 |
| Waters | 0 | 0.0089 | 0.0018 | 0 | 0 | 0.0074 |
| 0.0093 | | | | | | 0 |

4.1.2. Dynamic simulation prediction

Based on the survey of land resources and the data of soil and water conservation in Nangou watershed in recent years, the transfer probability of the initial state of Table 3 is adjusted appropriately. The probability of converting cultivated land into forest land is adjusted to 0.0051, the conversion between forest land is 0.0723, the probability of conversion of cultivated land to grassland is 0.0008, the probability of conversion of grassland to forest land is 0.0041, and the probability of
conversion between residential area and other land use type is adjusted to 0, and the remainder remains unchanged. The adjusted transition probability matrix is shown in Table 4.

| Waters          | Residential | Forest | Grass | Orchard | Arable | Dry | Saline |
|-----------------|-------------|--------|-------|---------|--------|-----|--------|
| Residential Area| 0.0657      | 0      | 0     | 0       | 0      | 0   | 0      |
| Forest land     | 0           | 0.0723 | 0.0297| 0.0003  | 0.0252 | 0.0152| 0      |
| Grass           | 0           | 0.0041 | 0.0151| 0.0015  | 0.0111 | 0.0011| 0      |
| Orchard         | 0           | 0.0370 | 0.0051| 0.0182  | 0      | 0.0159| 0      |
| Arable land     | 0           | 0.0051 | 0.0008| 0.0407  | 0.0089 | 0.0085| 0      |
| Dry land        | 0           | 0.0377 | 0.0114| 0       | 0      | 0.0279| 0      |
| Saline Land     | 0           | 0.0249 | 0.0016| 0.0010  | 0.0009 | 0.0485| 0      |
| Waters          | 0           | 0      | 0     | 0       | 0      | 0   | 0      |

**Table 4. Adjusted land use type transfer probability matrix**

4.1.3. Run the CA-Markov model
Specify the base land cover image for the land use map for 2015, enter the land use area transfer probability matrix from 2005 to 2015, and then input the adaptive image set, and specify the number of cycles of the geospatial automata to be 10, The cellular automaton filter creates a weight factor with significant spatial meaning, and uses the weighting factor to act on adjacent grid cells to change the state of adjacent grids. In the solution, a 5 x 5 filter was used to obtain the land use forecast for 2025 in the county.

4.1.4. The number of area changes in the forecast
The transfer matrix of the main land use types in the county south ditch basin from 2005 to 2015 is calculated by the formula 1. As shown in Table 5.

\[
S_{ij}^{t+1} = f(S_{ij}^t, \Omega_{ij}, T)
\] (1)

**Table 5. Main land use type transfer matrix for Nangou watershed**
| Waters Land(km²) | Residential Area(km²) | Forest land(km²) | Grassland (km²) | Orchard (km²) | Arable Land(km²) | Dry land (km²) | Saline Land (km²) |
|-----------------|-----------------------|------------------|----------------|--------------|-----------------|---------------|----------------|
| Residential Area | 142                   | 553              | 0              | 0            | 1               | 79            | 13             |
| Grass           | 162                   | 10812            | 5578           | 549          | 4101            | 397           | 483            |
| Orchard         | 23                    | 1162             | 159            | 571          | 0               | 499           | 0              |
| Arable land     | 19                    | 846              | 350            | 2629         | 577             | 546           | 0              |
| Dry land        | 0                     | 325              | 98             | 0            | 0               | 241           | 0              |
| Saline Land     | 0                     | 609              | 38             | 24           | 21              | 0             | 1185           |
| Waters          | 0                     | 106              | 22             | 0            | 0               | 88            | 0              |
| Total           | 947                   | 30037            | 8435           | 3788         | 5877            | 2466          | 1668           |

4.2. Dynamic Prediction of Land Use Change

According to the forecast, the area of settlements, woodlands, grasslands, orchards, arable land, dry land, saline land and waters will reach 131954.7 m², 4571225.3 m², 690310.7 m², 497044.2 m², 508629.6 m², 275068.8 m², 108511.1 m² and 75275.2 m². Because of the absence of 2025 years of remote sensing image data, the results cannot be tested. However, this prediction result is consistent with the overall trend of land use after returning farmland to forest (2005-2015), indicating that the model is reasonable and good forecast of future land use change. The results show that land use change will continue to maintain the trend of 2005-2015 during the 2015-2025 period, and the area of forest land, orchard, rural settlements and dry land will increase as a whole. In 2015, the net increase in woodland was 1567525.3 m², an increase of 52.2%, mainly from the transfer of cultivated land and grassland, while the area of cultivated land, saline land, grassland and waters continued to decrease, The net area decreased by 79070.4 m², a decrease of 13.5%, mainly due to the transfer of woodland and orchard area. However, with the deepening of the project of returning farmland to forest, this increase and decrease will be reduced, because the area of returning farmland to forest is limited, the forest area changes over time will become saturated, and cultivated land can not be reduced. So the final forest land, grassland, arable land and other areas will remain basically stable, in a dynamic balance.
5. Conclusions
Based on ArcGIS software and CA-Markov model, this paper analyzes the relationship between the land use efficiency, the land use dynamic degree, the land use type relative change rate, the land use transfer matrix data and the relevant indicators, and analyzes the implementation of the policy of returning farmland to forest before and after the implementation the time course and spatial pattern of land use change in Nangou watershed of Ansai County, and the CA-Markov model was used to simulate the change of land use structure in Nangou watershed in 2025. And thus hope for the region to implement the scientific implementation of the project of returning farmland to forest.

6. References
[1] Yu Xing-xiu, Yang Gui-shan. Status Quo and Problems of Land Use / Cover Change in China [J]. Advances in Geography, 2002, 21 (1): 51-57.
[2] Wang Cheng, Han Xin-hai. Extraction of Hydrological Features Based on DEM in ArcGIS Environment - A Case Study of Nangou Watershed in County [J],. 2007 (4): 178-180.
[3] Dong Qian-kun. Study on Spatial and Temporal Pattern of Land Use in Zhifanggou Watershed Based on GIS [J]. Mining Survey, 2015 (4): 59-64.
[4] LU Kai. Study on cellular automata and its establishment [D]. Harbin University of Science and Technology, 2007.
[5] YANG Ding-ting, LEO Cheng-de, GONG Yuan-bo, et al. Soil nutrient dynamics of forest and grass complex model in returning farmland to forestland [J]. FORESTRY SCIENCE, 2007, 43 (s1): 101-105.
[6] TOBLERWR, A computer movie simulating urban growth in the Detroit region[J]. Economic Geography,1970,46:234—240.
[7] BATTY,M, XIEYC. From cells to cities[J]. Environment and Planning B,1994,21:531—548.
[8] WHITER, ENGELENG. Cellular automation and fractal form: a cellular Modeling approach to the evolution of urban land-use patterns[J]. Environment and Planning A,1993,25:1175—1199.
[9] Wang Wanzhong (1983). Study on the Relationship between Rainfall Characteristics and Soil Loss in Loess Area. Soil and Water Conservation Bulletin (4), 7-13.
[10] Liu Changping, Li Xia, Chen Yimin, Qin Yan, Li Shaoying, and Chen Minghui (2009). Landscape expansion index and its application in urban expansion analysis. Acta Geographica Sinica, 64 (12), 1430-1438.
[11] Wischmeier W H,Smith D D. Predicting Rainfall Erosion losses. A Guide to Conservation Planning with the Universal Soil Loss Equation (A) Agriculture Handbook No. 537, United States Department of Agriculture, Spring field,USA,1978.