A Cellular Automata Markov Model for Spatial Temporal Dynamic Analysis of Land Use Change in Guanzhong-Tianshui Region

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Abstract — In this paper we apply the technology of RS and GIS and use ERDAS, ArcGIS and IDRISI, to illustrate the land use distribution information and analyze the land use dynamic spatial-temporal change over 10 years in Guanzhong-Tianshui region. We use data from Landsat TM images of 2000 to 2010. Then we predict the land use situation in 2020 and 2030 by Cellular Automata CA-Markov model. The conclusions are: i) During the period of 2000 to 2010, at the municipality scale, land use of Xi’an has changed most apparently, especially in the increase of construction area and the decrease of farmland and grassland, while the land use of Shangluo has changed only slightly; ii) During the same time, at the landscape scale, the construction area increased most obviously with the change from 4872.58 km2 to 7311.59 km2, meanwhile, the water area increased less obviously with the change from 504.02 km2 to 608.44 km2; iii) For the future in 2020 and 2030, in the whole Guanzhong-Tianshui region, farmland and grassland will undergo a constant decrease, while forestland and construction will increase. The study results play an important role in scientific decision-making support for ecological environmental protection and rational resources utilization.

Keywords — LUCC; Guanzhong-Tianshui region; CA-Markov

I. INTRODUCTION

Nowadays, research on LUCC has become a global land change frontier issue and core theme. Existence and development of human being for land exploitation and the consequence of land cover change have been regarded as the crucial component of global environment change [1]. Study on LUCC, to explore how human activity dominates the change of land cover in different period and various districts, making a quantitative analysis on dynamic variables to predict land use changes and drawing a quantitative simulation, has become an important decision-making support for regional planning and development. Furthermore, the main reason of regional LUCC has become the primary new research tendency is that land use status is not only closely bound up with economic development level, but also interrelates the ecology and environment [2, 3, 4].

In foreign countries, the earliest research on LUCC was carried out by Webb. He found that land use type was decided by the degree of drought in corresponding areas [5]. Due to long-term research on LUCC and wide application of remote sensing technology, countries all over the world have started to have a preliminary cognition about LUCC, and its quantitative analysis [6]. Due to the acute problem of population, environment and resources, study on LUCC has become an important way of researching on human activity, environment and resource issues.

Currently, study on LUCC mainly focuses on 4 aspects: ①LUCC driving force that indicates the mechanism and process of land use change internal causes; ② LUCC remote sensing dynamic monitoring and classification, the extraction and analysis on regional information by multi-temporal and multi-scale images for supporting decision-making process; ③ Study on regional and global LUCC model, a crucial method of deeply understanding the complexity, to describe, interpret and predict the process of LUCC and make countermeasures to it; ④ Study on environmental influence since land cover tends to be changed by human production activity leading to global change[7].

However, some problems about LUCC still exist. Conclusion of those can be made as follows: i) The construction on theoretical system, because LUCC research involves many fields of society, and it is the closest interdisciplinary field between nature and humanity, rooted in theory of man-land relationship; ii) The construction of LUCC model is based on massive geographic spatial data and social-economic data [8], leading to difficulties in data collection and standardization for the variability of data format; iii) The distinct driving force factors of LUCC cause scale transformation problem; iv) Remote sensing classification and inter discipline issues.

Based on CA-Markov model, this paper focused on land use spatial-temporal dynamic change in Guanzhong-Tianshui region. It analyzed the change in time and space between 2000 and 2010 and predicted the tendency in 2020 and 2030, which played an important role in scientific decision-making support for ecological environmental protection and rational resources utilization.
II. MATERIALS AND METHOD

A. Study Area

Guanzhong-Tianshui region (104°35’-110°38’E, 33°35’-36°52’N) is the third important development economic area in the western China under permission of the state council, including Xi’an, Xianyang, Tongchuan, Weinan, Baoji, Shangluo(Shangzhou, Luonan, Danfeng, Zhashui districts) in Shaanxi province, and Tianshui in Gansu province. This region with total area of 80100 km², is located between the Loess plateau and Qinling Mountain belonging to the Wei River basin, across the Yangtze River basin and the Yellow River basin. The characteristics of this region are of rich soil in smooth terrain with lower precipitation. Besides, farmland is the primary land use type of this region, with good economic foundation. Hence, it is an area that does have vast potential to develop. However, currently, Tianshui city in Gansu province is affected by backwardness economic development and Xi’an in Shaanxi is less developed than national average level in economy, as a result, study on land use change in Guanzhong-Tianshui region is helpful not only for the exploration of economy growth direction but also the discovery on regional interactive development pattern, as well as direction of population growth. The development of this region will promote the economy in north-western district, simulating the industry transferring from central-eastern district, to achieve coordinated and stable statement.

B. Data Source and Processing

(1) Data Resource

Main data source used in this paper are Landsat TM images, 12 scenes respectively from the year of 2000 and 2010 covering study area with spatial resolution 30m, collected during July and September. Besides, vector administrative boundary of study area is derived from Guanzhong-tianshui administrative map.

(2) Data Processing

Data processing can be outlined as two parts: On the one hand, geometric calibration, mosaic and clipping are implemented in 24 scenes images from two periods under the platform of software ERDAS. Based on false color composite image chosen from band 5(R), 4(G), 3(B), supervised classification is applied to classify different land use types by nature and human features in the area. Land use types in this case mainly includes forestland, farmland, grassland, water, construction area and unused land. The classification standard is based on the classification system in 1996, which consist of 6 types of land use as mentioned before; The next step is using the two periods land use distribution map obtained from last step to predict the distribution of land use in 2020 and 2030, based on the land use transition area/probability matrix of Markov model, then run with CA-Markov model. Data conversion, converting from raster data to vector data, then to ASCII format in ArcGIS, ended up with raster data in software IDRISI is involved in this process. More specifically, the land use transition area matrix records area of each land cover type in the next period transferred from other land cover types.

C. Study Method

CA-Markov model was used in this study. Markov prediction model is a special stochastic movement process based on stochastic process theory from Russian mathematician [9], by calculating and analyzing initial probability of the various states and their transition probability relation, to determine the trend of land statement changing as time goes by, eventually, to be able to predict the land use change [10,11,12]. Moreover, this model has advantage on quantitative forecasting and its ability to spatial prediction is relatively weak so that it is hard to obtain the changing states of land use in space.

For CA (Cellular Automata) model, it implements dispersing processing to simulate the change according to a certain rule. CA model is a kind of iterative development model usually applied to objects involving in urban gradual change and development. In addition, CA model is concerned on spatial information concept and it has the temporal and spatial dynamic ability to simulate complicated spatial system. Although CA model has the powerful ability to spatial prediction, it is hard to explain in the aspect of temporal spatial change in urban sprawl.

A complete land use scenario consists of quantitative structure and spatial pattern. Specifically, the first phase is the setting of land use transition area in future scenario and spatializing in land use quantitative structure under the target year should be implemented in the second phase. The use of transition probability matrix and suitability map for predicating land use change in transition rules is beneficial to land use change scenario simulation. CA-Markov model incorporates CA model’s superiority in spatial dynamic simulation with the advantage of Markov model in temporal dynamic simulation to carry out the exploration and analysis about land use temporal-spatial dynamic change law.

In this paper, Markov model is to generate the land use type transition area and transition probability in 2000 and 2010. In CA model, cellular in this case is the raster data with the size of 30m×30m based on the spatial resolution of remote sensing images. The state variable is land use type, including farmland, forestland, grassland, water, construction and unused land. Spatial framework is a rectangle space consisted of 5×5 cellular. The number of iterations is 10 because the prediction in 2020 and 2030 is based on land use distribution maps in 2000 and 2010. In short, based on 2010 land use distribution map, using land use transition area matrix of 2000 and 2010, run the CA-Markov model to make prediction. For each iteration, each land use suitability map used as filter result and it will be run again and add weighted value to another map. In this study, the result of Markov model was applied for prediction.
III. RESULTS AND DISCUSSION

A. Analysis Based on Landscape Scale

From the pie chart of 2000 and 2010 (figure 1 and figure 2), it presented the total area of different land use type. And in Table 1, the quantitative change among different land use type during 10 years was shown clearly. In general, the area of farmland and grassland decreased, while the area of forestland, water increased slightly, meanwhile construction area increase notably and there was a decreasing trend in unused land area.

More specifically, farmland decreased to 2169.59 km² over 10 years transiting into grassland and forestland, accounted for 27% and 20% respectively indicating the policy of transforming farmland into forestland and transforming farmland into grassland were implemented well. The land not suitable for growing crops was covered by vegetation. Meanwhile, it showed the conflicts between agriculture and urban land. For farmland, it transited from forestland, grassland and unused land. To some degree, this phenomenon explains human occupied unused land to exploit farmland.

Forestland area has increased slightly and the increment is 3351.29 km², increasing rate reaching at 10.33%. Forestland transformed into farmland and grassland and was generated from farmland and grassland, which indicates that original farmland district was covered by vegetation to balance the ecology balance, to achieve sustainable development.

Grassland experienced an obvious increase, and 40% of it has changed. The amount of decrease is 1003.42 km². Compared to 2000, it decreased by 5.48%. Grassland primarily was transformed from forestland and farmland. And the decrease of grassland mainly transform into forestland, farmland, and construction area.

Water area increased as well and the increment is 104.41 km². The reason for increase probably was the increase of precipitation, related to the project of south-of-Shaanxi-to-Guanzhong water diversion. However, study area still is an area short of water. Especially, the expansion of urban land, the increase of population, and the water requirement will cause the water shortage, as a result, water resource protection is essential.

TABLE I. LAND USE TYPE TRANSITION AREAS FROM 2000 TO 2010 IN GUANZHONG-TIANSHUI REGION (KM²)

<table>
<thead>
<tr>
<th>Time/Area</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
</tr>
<tr>
<td></td>
<td>Farmland</td>
</tr>
<tr>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>Farmland</td>
<td>11145.40</td>
</tr>
<tr>
<td>Forest</td>
<td>4075.53</td>
</tr>
<tr>
<td>Grassland</td>
<td>5629.35</td>
</tr>
<tr>
<td>Water</td>
<td>5.68</td>
</tr>
<tr>
<td>Construction</td>
<td>322.17</td>
</tr>
<tr>
<td>Unused land</td>
<td>76.12</td>
</tr>
</tbody>
</table>

Construction area increased from 4872.58 km² into 7331.59 km². Construction area was transformed from farmland, which showing most of urban land was transformed from high quality farmland. The decrease of unused land is 23.41 km². In detail, unused land mainly transited into construction, farmland, and water. At the same time, there were some new unused land, generated from farmland and forestland, caused by the crops unsuitability in the area.

The land use distribution map of 2000 and 2010 (figure 3 and figure 4) are shown as below.
Farmland area in each city decreased generally, especially in Xi’an, Xianyang, Weinan, Baoji and Tongchuan, at the rate of 17.22%, 23.54%, 26.36%, 30.87% and 47.97%, most of them transiting into construction area and forestland. The decrease area of farmland illustrated well that the policy, like returning farmland to forestland, was effectively implemented by government. Certainly, prime cropland needs preservation and protection.

For forestland area, it takes on a tendency of growth. In Xi’an, the area of forest presented a little decrease compared to other cities, the decrement rate of those are 11.21%, 5.42% respectively.

A great change of grassland area in Tianshui, Xianyang, and Weinan has taken on while grassland area in Baoji, Shangluo increased to some degree. From the data collected, part of grassland transformed into farmland and construction area, showing the reclaim and exploitation of grassland.

As for water area, in each city, it has increased very slowly in general, particularly in Xi’an and Tianshui. Even if, some rivers like the Yangtze River and the Yellow river along Guanzhong-Tianshui area, this region does have a problem of water shortage.

Unused land in Tianshui and Shangluo decreased most distinctly. Most unused land in Tianshui city transformed into construction area and farmland.

C. Land Use Simulation and Prediction

According to the prediction results of 2020(figure 5) and 2030(figure 6), the land use distribution can be seen in the map. In addition, the total area of different land use in 2000, 2010, 2020 and 2030 are shown respectively in Table 3. It clearly indicates that an obvious change of forestland, farmland and construction area has taken on, compared to all the land use types in Guanzhong-Tianshui area. In 2020 and 2030, under the implement of policy that return farmland to forestland and preserve the prime cropland, the farmland area will constantly and regularly decrease. And the grassland area will decrease slowly. The forestland area will increase as well in the future at relatively slower speed. Certainly, construction area will increase fast. The construction area will increase mainly along the Wei River, the Yellow river, the Han River, and the Jiangling river runoff area. As for water area, it will increase slowly, due to the climate and water diversion policy. Unused land will decrease at relatively slower speed in 2020 and 2030.
TABLE II. THE URBAN LAND USE AREAS OF GUANZHONG-TIANSHUI REGION IN 2000 AND 2010(KM²)

<table>
<thead>
<tr>
<th>Landuse type</th>
<th>Farmland /km²</th>
<th>Forest /km²</th>
<th>Grassland /km²</th>
<th>Water /km²</th>
<th>Construction /km²</th>
<th>Unused land /km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tianshui</td>
<td>5891.5</td>
<td>6425.43</td>
<td>5063.88</td>
<td>2292.8</td>
<td>173.13</td>
<td>134.89</td>
</tr>
<tr>
<td>Baoji</td>
<td>2861.07</td>
<td>1977.74</td>
<td>10877.0</td>
<td>2292.8</td>
<td>770.85</td>
<td>75.16</td>
</tr>
<tr>
<td>Shangluo</td>
<td>995.64</td>
<td>881.43</td>
<td>7071.02</td>
<td>96.41</td>
<td>275.69</td>
<td>193.52</td>
</tr>
<tr>
<td>Tongchuan</td>
<td>1147.11</td>
<td>569.84</td>
<td>2057.55</td>
<td>4.21</td>
<td>149.89</td>
<td>64.64</td>
</tr>
<tr>
<td>Weinan</td>
<td>7637.56</td>
<td>5624.17</td>
<td>3146.95</td>
<td>196.99</td>
<td>1383.5</td>
<td>30.53</td>
</tr>
<tr>
<td>Xi’an</td>
<td>2517.93</td>
<td>1512.01</td>
<td>4943.8</td>
<td>164.67</td>
<td>770.85</td>
<td>46.87</td>
</tr>
<tr>
<td>Xianyang</td>
<td>4647.26</td>
<td>3553.14</td>
<td>4287.27</td>
<td>450.8</td>
<td>196.99</td>
<td>46.87</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Time</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmland</td>
<td>24144.15</td>
<td>21974.55</td>
<td>19174.89</td>
<td>17375.24</td>
</tr>
<tr>
<td>Forest</td>
<td>32446.43</td>
<td>35797.73</td>
<td>36113.82</td>
<td>37529.91</td>
</tr>
<tr>
<td>Grassland</td>
<td>18316.76</td>
<td>17313.34</td>
<td>16377.79</td>
<td>15190.59</td>
</tr>
<tr>
<td>Water</td>
<td>504.02</td>
<td>608.44</td>
<td>697.39</td>
<td>795.06</td>
</tr>
<tr>
<td>Construction</td>
<td>4872.58</td>
<td>7331.59</td>
<td>8598.43</td>
<td>9843.37</td>
</tr>
<tr>
<td>Unused land</td>
<td>231.4</td>
<td>208.26</td>
<td>157.32</td>
<td>136.38</td>
</tr>
</tbody>
</table>

IV. SUMMARY

A. Conclusion

In this research, we apply the technology of RS and GIS to extract regional information and analyze the land use change over the past 10 years at the municipality and landscape scale, and then use CA-Markov model to predict and simulate the land use change in 2020 and 2030. The main conclusion are made as follows: ① At the municipality scale, in Xi’an, the construction area has increased obviously. For farmland area in Xi’an, Xianyang, Weinan, it has decreased. In Xianyang, forestland has increased apparently while the forestland area in Xi’an and Shangluo decreased a little. At the same time, grassland in Tianshui, Weinan and Xianyang decreased. The water has increased apparently in Tianshui and Xi’an. In Tianshui and Shangluo, unused land area has decreased ②. At the landscape scale, main land use types in Guanzhong-Tianshui region are forestland, farmland and grassland. Farmland area decreased over 10 years, mainly transiting into grassland and forestland, and forestland area increased slightly. For grassland area, 40% of it has changed into forestland, farmland and construction area. Water area in study area has increased a very little as well and the area of construction presents an obvious increase while unused land area decreased.③ At the temporal scale, in 2020 and 2030, the forestland and farmland still accounts for a large proportion overall. The overall tendency is that forestland area will increase slightly and the area of farmland will start to decrease while the water area will increase appreciably. And the construction area will continue to increase in the future, while unused land area will decrease. Compare to the situation in 2000 and 2010, the forestland and water area will increase at relatively slower speed and the expansion of urban land will be rather rapid.
B. Discussion

In this paper, the characteristics of land use structure dynamic temporal spatial change analysis are based both on coverage city scale and landscape scale. Meanwhile, multi-data fusion is the feature of this study as well, including remote sending data, land use data and its data format conversion. This paper applied several kinds of software platform, including ERDAS, ArcGIS and IDRISI, combining all the edges of all the used software, to extract geographic information and process geo-data. In data processing, data conversions among different formats are used, including the conversion between vector data to ASCII format in ArcGIS and the conversion between ASCII format and raster data in IDRISI.

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