Temporal-spatial variation atlas analysis of land use: A case study from Yiyang City, Hunan Province, China

Yun Xue¹,²,⁵, Fanghua Tang¹, Shishi Liu¹, Jianglong Liu³ and Yurong Sun⁴

¹ School of Municipal and Surveying Engineering, Hunan City University, Yiyang, Hunan, China;
² Key Laboratory of Metallogenic Prediction of Nonferrous Metals and Geological Environment Monitoring (Central South University), Ministry of Education, Changsha, Hunan, China;
³ School of Tourism, Central South University of Forestry & Technology, Changsha, China;
⁴ School of Science, Central South University of Forestry & Technology, Changsha, China

⁵ Email: 185963095@qq.com

Abstract. The paper finished the land use time series changes atlas analysis, spatial series changes atlas analysis and the fluctuation potential map analysis of Yiyang city by using the land use data in 2005, 2010 and 2014. The results show that: (1) during the period from 2005 to 2014, the land use situation in Yiyang changed greatly, the area of construction land and water continued to increase, the garden area was decreasing, the area of cultivated land increased first and then decreased, meanwhile the area of woodland first decreased and then increased, and the area of cultivated land and woodland decreased as a whole. In the newly added area, the cultivated area rose the strongest, followed by woodland and water. In the shrinking area, the woodland area decreased most significantly, followed by cultivated land and the construction land area transfer rate was relatively low. (2) On the land use change amplitude and velocity view, the most obvious growth type of land use in Yiyang is construction land, and the scale of construction land expansion in Anhua County is relatively large. Then followed by water area, in which the maximum growth rate is in Heshan District and the next is in Anhua County. The other types of land use were all reduced. (3) From the analysis of relative change rate of land use type, the regional difference of land use type change in Yiyang is remarkable. In the last ten years, the biggest increasing range of construction land and cultivated land is in Anhua County relative to the whole city, and the biggest garden land increasing rate appears in Nanxian County. There is relatively great difference in forest land increasing rate, the biggest rate appears in Ziyang District, The difference in relative rates of change in waters is small, except the Heshan District and Anhua County have relative large variations, the changes in other parts of water with the relatively consistent.

1. Introduction

Land is an essential natural resource in the world for the preservation of terrestrial ecosystems and the subsistence of humanity. Land use and land cover change (LURC) assessment helps to detect the extent of human influence on natural environment. Over the last few decades various techniques of LURC mapping and change detection have been developed and applied all over the globe [1–4]. The
importance of investigating LUCC and their impacts as a baseline requirement for planning and sustainable management of natural resources[5,6]. These researchers have argued that land use has significant impacts on the functioning of socio-economic and environmental systems with important tradeoffs for sustainability, food security, biodiversity and socio-economic vulnerability of people and ecosystems. Population growth, industrialization and urbanization have rapidly changed the LUCC [7].

With the deepening of the research on LUCC, people pay more attention to the changes in the characteristics of land use “geographic space and process unification” [8]. Geoscience information maps are developed with the support of remote sensing, geographic information systems, virtual reality and computer graphics. The geo-information map method can “exhibit the characteristics of spatial unit features” and “the starting point of the development of events and the spectrum of processes”. Combining the two into one, making up for the shortcomings of the data mining method based on non-spatial attribute database in terms of spatial location and image thinking [9]. At present, domestic and foreign scholars have carried out a series of studies on land use/land cover using geoscience information maps [10-12]. This paper uses geospatial information map theory to analyze the land use change in Yiyang City in the past ten years, in order to provide reference for land use management decision-making in Yiyang City.

2. Material and methods

2.1. Research area overview
Yiyang City (27°58′38″~29°31′42″N, 110°43′02″~112°55′48″E) (Figure 1) is located in the north of central Hunan Province and belongs to the subtropical continental monsoon humid climate. Sufficient, abundant rainfall and mild climate. The landform types are stepped, with mountains in the southwest, hills in the middle, and Pinghu in the northeast. The soil is fertile and is the main production base for grain and hemp. The middle and low mountainous areas in the west are the main forestry production bases; the central part is the economic forest production areas such as bamboo and tea; the northeastern Datong Lake is the largest inland aquaculture lake in Hunan. Yiyang City was included in the 3+5 urban agglomeration of Changsha, Zhuzhou and Xiangtan in 2008. In 2014, it became one of the core cities of the Dongting Lake eco-economic circle, and the overall planning and ecological sustainable development of the urban agglomeration of Hunan Province and the Dongting Lake area. Both are of great significance.

2.2. Data Source and Pretreatment
The land data is the land use change data and land use status map of Yiyang City in 2005, 2010 and 2014 provided by Hunan Provincial Land and Resources Planning Institute. The socio-economic
statistics are mainly from the Hunan Statistical Yearbook and the Yiyang Statistical Yearbook. According to the status quo of land use and the characteristics of land resources in the study area, combined with the national standard of the classification of land use status [13], the land use types in the study area are divided into five categories: cultivated land, garden land, forest land, construction land and water area.

2.3. Methods

2.3.1. Land use map generation. Each map unit in the land use map records the land use types in the initial and final stages of a certain area, with spatial and temporal composite characteristics; the land use area transfer matrix can be obtained by using the land use map unit to analyze the area transfer of each type. Using the geoscience information map theory, the land use transformation information map and transfer matrix of Yiyang City from 2005 to 2010 and 2010 to 2014 were obtained.

(a) Map data conversion and coding. In order to facilitate the generation of the map unit in the follow-up work, the re-sampling tool in ArcGIS is used to unify the cell size of the classified layers of three different periods in Yiyang City, and then encode the five land use types (Table 1).

Table 1. Yiyang city land use classification system and code.

| Type       | Cultivated land | Forest land | Garden land | Construction land | Water area |
|------------|-----------------|-------------|-------------|-------------------|------------|
| Code       | 1               | 2           | 3           | 4                 | 5          |

(b) Pattern generating means. Use the Raster Calculator in the ArcGIS Spatial Analysis Tool to perform map algebra calculations. Refer to Xu Wei's calculation formula: \( C = A \times 10 + B \) to generate a two-digit value [14]. Where C is the value of the map unit of a land use change during the study period, A is the value of the spatial unit at the beginning of the study period, and B is the value of the spatial unit at the end of the study period. After data processing and mapping, the information map of land use change in Yiyang City from 2005 to 2010 and 2010 to 2014 is obtained, as shown in Figure 2 and Figure 3.

![Figure 2. Information map of land use change in Yiyang City from 2005 to 2010.](image1)

![Figure 3. Information map of land use change in Yiyang City from 2010 to 2014.](image2)
2.3.2. Land use fluctuation map construction. A total of 25 types of map units were generated in Yiyang City, of which 20 types of land types changed. There are many types of map units, which is not convenient for data analysis. Therefore, in order to better understand the land use change situation, re-classify, synthesize, combine and extract the effective information of the land use map unit, use the set classification principle and the heavy mapping method to reconstruct the map and establish the reconstructed map unit. The uptrend map (Figure 4-A) is constructed by transferring out the map unit (Figure 4-B).

A. Arising atlas  
B. Declining atlas

Figure 4. Arising and declining atlas of land use pattern from 2005 to 2014.

2.3.3. Land use dynamics. Land use dynamics refers to the change in the quantity of a land use type in a study area within a certain time frame [14]. It can reflect the magnitude and speed of changes in land types, and can also be used to compare regional differences. The calculation formula is

\[ K = \left( \frac{U_b - U_a}{U_a} \right) \times \left( \frac{1}{T} \right) \times 100\% \],

where: \( U_a \) is the number of land use types at the beginning of the study; \( U_b \) is the number of land use types at the end of the study; \( T \) is the length of the study period.

2.3.4. Relative change rate of land use type. The relative change rate of land use type describes the change of a land use type in a certain area relative to the land use type of the whole study area, and is a reflection of the difference in land use area [15]. The calculation formula is:

\[ R = \left( \frac{K_a}{K_b} \right) \times \left( \frac{C_a}{C_b} \right) \],

where: \( K_a \), \( K_b \) are the area at the beginning and end of the study of a certain land use type in a certain area; \( C_a \), \( C_b \) are the area at the beginning and end of the study of a certain land use type in the w study area.

3. Results and analysis

3.1. Land use time series change map analysis

According to the provided land use change data and land use status map analysis, the area change and structural change of land use types in Yiyang City in 2005, 2010 and 2014 were obtained, as shown in Table 2.

| Year | Construction land | Cultivated land | Garden land | Forest land | Water area |
|------|-------------------|-----------------|-------------|-------------|------------|
| 2005 | 484               | 4222            | 726         | 8912        | 1608       |
| 2010 | 748               | 4801            | 716         | 7768        | 1902       |
| 2014 | 861               | 3977            | 413         | 8527        | 2170       |

| Year | Proportion (%) |
|------|----------------|
| 2005 | 3.03           |
| 2010 | 26.47          |
| 2014 | 24.94          |

Table 2. Areas and structural changes of land use types in Yiyang City in 2005, 2010 and 2014.
It can be seen from Table 2 that the land use types in Yiyang City are mainly forest land and cultivated land, accounting for more than three-quarters of the area of the study area. From 2005 to 2014, the area of construction land and waters continued to increase, accounting for 5.40% and 13.61% of the total area of Yiyang City. However, by 2014, the area of cultivated land decreased to 24.94%. The area of woodland is decreasing first and then increasing. But on the whole, the area of forest land is still decreasing.

According to the land use dynamics formula and the relative change rate formula, the land use situation of each county is obtained (Table 3).

**Table 3.** Land use dynamics (a) (%) and relative change rate (b) of Yiyang City and its counties from 2005 to 2014.

| District | Construction land | Cultivated land | Garden land | Forest land | Water area |
|----------|------------------|-----------------|-------------|-------------|------------|
|          | a    | b   | a    | b    | a    | b    | a    | b    | a    | b   |
| Yiyang   | 8.65 | -0.64 | -4.79 | -0.48 | 3.88 |
| Heshan   | 10.67 | 1.10 | -2.98 | 0.78 | -8.54 | 0.41 | 1.69 | 1.20 | 12.66 | 1.59 |
| Ziyang   | 9.72 | 1.05 | -0.58 | 1.01 | -9.21 | 1.30 | 3.21 | 1.35 | 3.60 | 0.98 |
| Yuanjiang| 4.30 | 0.78 | -0.01 | 1.06 | -3.60 | 1.19 | -6.04 | 0.48 | 2.94 | 0.94 |
| Nan County| 1.75 | 0.65 | -0.94 | 0.97 | 2.18 | 2.10 | 1.05 | 1.14 | 3.40 | 0.97 |
| Taojiang | 7.81 | 0.96 | -2.45 | 0.83 | -5.56 | 0.88 | 0.39 | 1.08 | 4.72 | 1.06 |
| Anhua    | 16.34 | 1.39 | 7.12 | 1.74 | -2.46 | 1.37 | -0.75 | 0.97 | 10.82 | 1.46 |

It can be seen from Table 3 that from 2005 to 2014, the area of construction land in Yiyang City increased, the annual rate of change was 8.65%, and the area of construction land in all districts and counties showed an increasing trend, with Anhua County having the largest annual growth rate of 16.34%. Secondly, in Heshan District, the land use dynamics of construction land is 10.67%, and the smallest annual growth rate is Nanxian, only 1.75%. In the past ten years, the water area of Yiyang City has also increased, with an annual growth rate of 3.88%. The annual growth rate of Heshan District in the districts and counties is the largest, followed by Anhua County, which is 12.66% and 10.82% respectively. The area of cultivated land, garden land and forest land in Yiyang City decreased, and the annual change rates were -0.64%, -4.79%, -0.48%, respectively. Among them, the largest reduction rate of cultivated land is in Heshan District. The largest annual reduction rate of the cultivated land is Ziyang District, and the fastest reduction of forest land is Yuanjiang City.

The relative change rate of a certain land use type in a certain area is greater than 1, indicating that the change in land use type in this area is larger than that in the whole study area. It can be seen from Table 3 that the regional differences in land use change in various districts and counties of Yiyang City are significant. The relative changes of construction land in different districts and counties are obvious, among which the changes in Anhua County, Heshan District and Ziyang District are relatively large, and the relative change rates of land use types are greater than 1, respectively 1.39, 1.10, 1.05; Taojiang County and Northeast China The relative change rate of land for construction in the region is less than 1, Taojiang County and Yuanjiang City are 0.96 and 0.78 respectively, and Nanxian County is only 0.65. This shows that the construction land between the districts and counties is quite different. In the past ten years, the growth rate of construction land in Anhua County is the largest compared with the whole city, and the Nan County is the smallest.

In the relative change of cultivated land, the relative change rate of Anhua County is the largest, 1.74. The relative change rate of cultivated land in Yuanjiang City, Ziyang District and Nan County is basically the same as that in the whole city. The relative change rate of land use type is about 1.00.
The relative rates of change in both Heshan District and Taojiang County are less than 1, indicating that the change in cultivated land is less than the change in the city.

The relative change rate of gardens is very different. The relative change rate of Nanxian County is 2.10, while that of Heshan District is only 0.41. The changes of Anhua County and Ziyang District are also larger, which are 1.37 and 1.30 respectively. It shows that in the past ten years, the area of Nanxian Garden has changed greatly, while the area of Heshan District has changed little.

The relative change rate of forest land is quite different. Among them, Ziyang District has the largest change relative to the whole city, and the relative change rate is 1.35. The second is Heshan District and Nan County, which are 1.20 and 1.14 respectively. The relative change rate of forest land in Taojiang County and Anhua County is the same as that in the whole city. The changes are basically the same; while the relative change rate of Yuanjiang City is the smallest, at 0.48.

The relative change rate of waters is small. Except for the relative changes of Heshan District and Anhua County, the relative changes of waters in other areas are basically consistent with the changes in the whole city. The relative change rate of land use types is about 1.

3.2. Land use spatial sequence change map analysis

Using the land use transformation information map, calculate the area of each type of land change, and further calculate the degree of change of various land use types at the end of the study relative to the initial stage of the study, so as to obtain the transition probability matrix of two periods (Table 4). From 2005 to 2010, the retention rate of waters was the highest, reaching 81.6%; followed by forest land, the retention rate was 80.4%; the retention rate of cultivated land was 76.2% lower than the former two. Among them, the cultivated land was mainly converted to forest land and construction land, and the transfer rates were 9.1% and 6.2% respectively. This shows that the policy of returning farmland to forests was effective at the beginning, and the scope of land acquisition was too large and too large, resulting in a part of cultivated land being occupied by construction land. The reduction of forest land is mainly reflected in the transfer to cultivated land. This may be mainly because the southwestern region has expanded the scale of urbanization, and the population growth has led to the attempt to open up sloping farmland, thus increasing the area of cultivated land. Among the reductions in construction land, cultivated land accounts for nearly 30% of the total, which means that although a certain degree of cultivated land is occupied by construction land, the government has taken measures to curb this phenomenon, such as the 1988 Land Reclamation. The Regulations require that the idle and abandoned land in the construction land be reconverted into available cultivated land, and land consolidation should be carried out to improve the quality of cultivated land and increase the effective cultivated land area.

Table 4. Probability matrix of land use pattern transition in Yiyang City from 2005 to 2014

|       | 2005 | 2010 (%) | 2014 | 2010 (%) | 2014 (%) |
|-------|------|----------|------|----------|----------|
| A     | 76.2 | 9.1      | 4.7  | 6.2      | 3.8      |
| B     | 10.0 | 80.4     | 3.8  | 1.5      | 4.3      |
| C     | 49.2 | 13.3     | 17.0 | 13.9     | 6.5      |
| D     | 29.3 | 14.8     | 5.9  | 47.6     | 2.3      |
| E     | 11.3 | 4.0      | 1.8  | 1.3      | 81.6     |

Note: A- Cultivated land  B-Forest land  C-Garden land  D-Construction land  E-Water area

From 2010 to 2014, the forest reserve rate was the highest, followed by the waters, and again the cultivated land, which was 90.0%, 76.9%, and 61.6%, respectively. The forest land not only has a high retention rate, but also the probability of other land use types being converted to it. The probability of the transfer of cultivated land to the waters is 8.7%, which indicates that the policy of returning farmland to forests and returning to the lake has been well implemented. The large conversion of construction land to cultivated land and forest land indicates that the land reclamation policy has been
intensified, and most of the production and construction excavation wasteland, rural construction wasteland and other abandoned land have been redeveloped and utilized in order to be converted into high-quality cultivated land. The reduction of construction land also shows that the government is aware of the importance of enhancing land use planning and management, and begins to limit the scale of urbanization, effectively strengthen the management of idle land, strengthen the intensive use of land, and guarantee the area of cultivated land.

3.3. Analysis of land use rise and fall Map

It can be seen from Figure 4 and Table 5 that in 2005-2014, the area of cultivated land increased the most in the newly added area, the newly added area was $1212.5km^2$, accounting for 28.7% of the total new area, and the cultivated land growth area was mostly distributed in the northeast. The Pinghu area indicates that the topography has a certain impact on the growth of cultivated land area; the increase of forest land and water area is relatively high, accounting for 27.6% and 20.6% of the total area respectively. The forest land increases more in Taojiang County, Ziyang District and Heshan District. It increased significantly in the northeast; the newly added area of construction land reached $663.8km^2$, which was expanded from the old city to the surrounding area and developed along Yincheng Avenue and 319 Provincial Road. In the shrinkage area, the reduction of forest land area is the most significant, accounting for 36.4% of the total shrinkage area, followed by cultivated land area, accounting for 34.8% of the total shrinkage area. Cultivated land and forest land are the main sources of new land use types. The southwestern region is dominated by forest land, and its development and utilization have not reached a certain level, so the forest land remains relatively stable. The transfer rate of construction land was relatively low between 2005 and 2014.

| Land use types | Newly increased part | Transfer part |
|----------------|----------------------|---------------|
|                | km² | %  | km² | %  |
| Cultivated land | 1212.5 | 28.7 | 1469.1 | 34.8 |
| Forest land     | 1165.8 | 27.6 | 1537.2 | 36.4 |
| Garden land     | 308.9  | 7.4  | 617.1  | 14.6 |
| Construction land | 663.8 | 15.7 | 290.5  | 7.0  |
| Water area      | 868.8  | 20.6 | 305.9  | 7.2  |
| Total           | 4219.8 | 100.0 | 4219.8 | 100.0 |

4. Conclusions and discussions

Based on the current situation of land use in Yiyang City in 2005, 2010 and 2014, the time series analysis of land use changes, the analysis of spatial sequence changes, and the analysis of the fluctuation potential spectrum were carried out. Research indicates:

1) During the period from 2005 to 2014, the land use situation in Yiyang City has undergone major changes. The construction land and water area have continued to increase, the area of the garden has been decreasing, the area of cultivated land has increased first and then decreased, and the area of forest land has decreased first and then increased. Overall, the area of cultivated land and forest land is still decreasing. In the newly added area, the cultivated land area has the strongest increase, followed by the forest land and water area; In the shrinking area, the forest land area decreased most significantly, followed by the cultivated land, and the construction land area transfer rate is relatively the lowest.

2) In terms of the magnitude and speed of land use change, the most obvious land use type in Yiyang City is construction land, in which the scale of construction land in Anhua County has been greatly expanded; secondly, the increase in water area, among which Heshan District has the largest growth rate, followed by Anhua County; other land use types have decreased.
(3) According to the analysis of the relative change rate of land use types, the regional differences in land use change in Yiyang City are significant. In the past ten years, the largest increase in construction land and cultivated land relative to the whole city is Anhua County; the largest relative change rate of the garden is Nanxian County; the relative change rate of forest land is quite different, of which Ziyang District has the largest change relative to the whole city; The relative change rate of the difference is small. Except for the relative changes of Heshan District and Anhua County, the relative changes of waters in other areas are basically consistent with the changes in the city.

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