Principal component analysis of driving forces of land use structure change in Wuhan city

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Abstract. With socio-economic development, the urbanization process within the region has also begun, and the land use structure has also undergone dynamic changes in the process. The purpose of this study is to analyze the driving factors influencing the dynamic change of land use in Wuhan using principal component analysis (PCA), and to provide suggestions for land use strategies in Wuhan.

1. Introduction
In recent years, with the rapid development of urbanization and industrialization, regional land use changes have become increasingly significant, and conflicts between people and land have become more prominent. Therefore, identifying the driving mechanism of regional land use change, rational coordination of urban and rural land use, saving and intensive use of land, and planning a rational land use structure are key to promoting new urbanization and rural revitalization. Shi-hua Li (2017) extracted 10 time-series remote sensing images as the main data source, based on socio-economic data of the Fuxian Lake watershed, and used principal component analysis and multiple regression analysis to analyze the driving forces of land use change in the watershed. Baude (2019) analyzed land use change in a typical agricultural landscape near Leipzig (Germany) to elucidate the impact of Prussian land reform, industrialization, technological and land management innovations, the Korholz system and the Common Agricultural Policy on ecosystem degradation.

At present, with the rapid socio-economic development, accelerated urbanization and expanding urban land use, regional land use change has attracted great attention, and many scholars have conducted extensive research on the driving forces of land use change. As a mega-city in Central China, Wuhan has experienced rapid economic development in recent years, and the pressure on resources and environment is increasing. Therefore, this paper attempts to use SPSS 23.0 software to analyze and reveal the driving mechanism of agricultural land and construction land use in Wuhan by investigating the socio-economic situation of Wuhan and selecting representative driving factors, so as to promote the coordinated development of economy, resources and environment.

2. Study area overview and research methods

2.1. Regional overviews
Wuhan is located in the eastern part of Hubei Province, at the confluence of the Yangtze River and Han River. As of the end of 2017, Wuhan has a land area of 8,569.15 square kilometers and a built-up area of 628 square kilometers. Wuhan has a low landform with hills and hillocks in the north and...
south, and low mountains in the north. In 2017, the total population of Wuhan is 8,536,500 with a GDP of 1,341,034 million Yuan, and the economic development is on a steady upward trend.

2.2. Data source
In order to maintain the continuity and consistency of the data, as well as the authenticity and reliability of the study, the land data of Wuhan City in this paper are from the 2008-2017 Land Change Survey of Wuhan Municipal Bureau of Natural Resources and Planning. The classification of land use data is based on the classification standard of the Ministry of Land and Resources (MLR) "Classification of Land Use Status" (GB/T21010-2017), which classifies land use types into 12 primary and 72 secondary categories. Socio-economic data are from the Wuhan Statistical Yearbook, 2008-2017, Wuhan Municipal Bureau of Statistics.

2.3. Research methods
The analysis of land use drivers is a multivariate problem, and too many variables increase the difficulty and complexity of the analysis process. The principal component analysis (PCA) is a statistical analysis method that reduces the original multiple variables to a few comprehensive indicators, which is a dimensionality reduction technique. Therefore, this paper adopts principal component analysis (PCA) and uses SPSS software to quantitatively analyze the factors influencing land use change in agricultural land and construction land in Wuhan, and to find out the driving factors of dynamic land use change in Wuhan.

3. Analysis of land use dynamics in Wuhan

3.1. Extent of change in land use structure
The changes in land use structure are mainly reflected in the changes in the total area of various types of land. Land use in Wuhan is mainly divided into eight types: arable land, garden land, forest land, grassland, urban village, industrial and mining land, transportation land, water conservancy facilities, and other land, etc. As can be seen from Figure 1, the proportion of agricultural land and construction land in Wuhan is comparable. The proportion of agricultural land and construction land in Wuhan is comparable, and the proportion of construction land has slightly increased in recent years. The larger agricultural land is mainly farmland and forest land, and the larger construction land is mainly urban villages, industrial and mining land, water bodies and water conservancy facilities. Water area accounts for one-fourth of the city's total water area, which constitutes the ecological environment along the rivers and lakes.

3.2. The dynamics of land use
The dynamics of regional land use can be analyzed in a quantitative way. On the one hand, the rate of change of a certain land use type within a certain time frame in a region can be described in a quantitative way for different parcel types, which is called a single dynamic attitude; on the other hand, the dynamics of each parcel type can be integrated to reflect the overall dynamics of regional land use in a quantitative way, which is called an integrated dynamic attitude.

The first step is to quantitatively describe the dynamic rate of change for different plot types, and explore the drivers and constraints of change by comparing the differences in change over a certain time horizon. In general, it is necessary to calculate the average annual dynamic attitude.

\[ k = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \]  

(1)

In equation (1), K is the dynamic attitude of a particular land use type in the area during the study period; \(U_a\) and \(U_b\) are the area of a particular land use type at the beginning and end of the study period, respectively; and \(T\) is the study duration. The calculation results are shown in Table 1. It can be seen from Table 1 that the overall land use of agricultural land in Wuhan shows a decreasing trend,
while construction land shows an increasing trend, reflecting the continuous development of urbanization and the expansion of urban areas in recent years.

![Variation range of land use area in Wuhan from 2008 to 2017.](image)

**Figure 1.** Variation range of land use area in Wuhan from 2008 to 2017.

In equation (1), $K$ is the dynamic attitude of a particular land use type in the area during the study period; $U_a$ and $U_b$ are the area of a particular land use type at the beginning and end of the study period, respectively; and $T$ is the study duration. The calculation results are shown in Table 1. It can be seen from Table 1 that the overall land use of agricultural land in Wuhan shows a decreasing trend, while construction land shows an increasing trend, reflecting the continuous development of urbanization and the expansion of urban areas in recent years.

The integrated land use dynamics is then calculated by describing the rate of land use change in Wuhan over a certain time period in terms of the integrated dynamics of each parcel type.

$$L_c = \left[ \frac{\sum_{i=1}^{n} U_{i-1}}{2 \sum_{i=1}^{n} U_i} \right] \times \frac{1}{T} \times 100\%$$

Equation (2) is the combined land use initiative of the study area; the area of land use type $i$ at the start of the study; the absolute value of the area of land converted from land use type $i$ to non-land use type $i$ during the study period; and $T$ is the study period. In order to better analyze the degree of change of land use types in Wuhan, the study period was divided into two periods from 2008-2012 and 2013-2017 to analyze the comprehensive land use attitudes in Wuhan.

**Table 1.** Dynamic degree of land use in Wuhan city.

| Land Use Type       | Amount of change ($U_b - U_a, hm^2$) | $K$ Single-motion attitude (%) | Dynamic Attitudes 2008-2012(%) | Dynamic Attitudes 2013-2017(%) |
|---------------------|--------------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Agricultural Land   |                                      |                                |                                |                                |
| Arable land         |                                      |                                |                                |                                |
| Garden land         |                                      |                                |                                |                                |
| Forest land         |                                      |                                |                                |                                |
| Grassland           |                                      |                                |                                |                                |
| Construction Land   |                                      |                                |                                |                                |
| Urban village       |                                      |                                |                                |                                |
| Transportation land |                                      |                                |                                |                                |
| Water and water conservancy facilities | |                                |                                |                                |
| Other land          |                                      |                                |                                |                                |

Figure 1. Variation range of land use area in Wuhan from 2008 to 2017.
Equation (2) is the combined land use initiative of the study area; the area of land use type i at the start of the study; the absolute value of the area of land converted from land use type i to non-land use type i during the study period; and T is the study period.

In order to better analyze the degree of change of land use types in Wuhan, the study period was divided into two periods from 2008-2012 and 2013-2017 to analyze the comprehensive land use attitudes in Wuhan.

From the land use dynamics in Table 1, it can be seen that from 2008-2012, the area of cropland and other agricultural land decreased, especially forest land, while the area of construction land increased, mainly due to the active urban infrastructure construction in Wuhan. This is mainly due to the fact that the city of Wuhan has responded to the 2013 Central Rural Work Conference's call to "ensure food security and adhere to the red line of 1.8 billion mu of arable land", and has also joined the national trend of environmental protection, which has resulted in a decrease in the area of forest land, wetlands and lakes. The protection of the environment has also been effective. The growth rate of construction land has also decreased significantly, ensuring both the quantity and the quality of the environment and livability in the new urbanization construction. Therefore, overall, the overall utilization of land in Wuhan has been on the rise during this period, and the 2013-2017 land use is higher than the 2008-2012 period.

4. Analysis of the drivers of land use change

4.1. Selection of driving factors

According to the above analysis of the dynamic changes of land use in Wuhan, it can be seen that from 2009 to 2017, land use changes in Wuhan have shown a trend of decreasing agricultural land and increasing construction land. In this paper, we believe that the factors influencing land use change include: demographic factors, socio-economic environmental factors, residential area factors, and residents' economic factors. Therefore, this study mainly selects the driving factors of agricultural land and construction land for quantitative analysis. A total of 15 drivers were selected for principal component analysis. The driving factors in terms of demographic factors include: total population (10,000 people) at the end of the year X1, employed population in agriculture (10,000 people) X2, non-agricultural employed population (10,000 people) X3; the driving factors in terms of socio-
economic environmental factors include: social fixed asset investment (10,000 yuan) X4, GDP (100 million yuan) X5, output value of primary industries (100 million yuan) X6, output value of secondary and tertiary industries (100 million yuan) X7, value added of industrial output value (billion yuan) X8; driving factors in terms of living area factors include: per capita living area of rural residents (㎡/person) X9, per capita living area of urban residents (㎡/person) X10, and construction area of housing construction (10,000 ㎡) X11; driving factors in terms of resident economic factors include: per capita disposable income of urban residents (yuan/person) X12, per capita urban residents (yuan/person) X13, per capita urban residents (yuan/person) Consumption expenditure (Yuan/person) X13, disposable income per capita of rural residents (Yuan/person) X14, consumption expenditure per capita of rural residents (Yuan/person) X15.

|   | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 | X15 |
|---|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|
| 1 | 1.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | -  | 0.2 | 0.2  | 0.5  | 0.3  | 0.2  | 0.2  | 0.33 |
| 2 | 0.0 | 1.0 | -   | -   | -   | -   | -   | -  | -   | -    | -    | -    | -    | -    | -    |
| 3 | 0.1 | -   | 1.0 | 0.9 | 0.9 | 0.9 | 0.9 | 0.1 | 0.9  | 0.9   | 0.8   | 0.9   | 0.9   | 0.9   | 0.95 |
| 4 | 0.1 | -   | 0.9 | 1.0 | 0.9 | 0.9 | 0.9 | 0.0 | 0.9  | 0.9   | 0.8   | 0.9   | 0.9   | 0.9   | 0.95 |
| 5 | 0.2 | -   | 0.9 | 0.9 | 1.0 | 0.9 | 1.0 | 0.0 | 0.9  | 0.9   | 0.9   | 0.9   | 0.9   | 0.9   | 0.98 |
| 6 | 0.1 | -   | 0.9 | 0.9 | 0.9 | 1.0 | 0.9 | 0.1 | 0.9  | 0.9   | 0.8   | 0.9   | 0.9   | 0.9   | 0.94 |
| 7 | 0.2 | -   | 0.9 | 1.0 | 0.9 | 1.0 | 0.0 | 0.9 | 0.9  | 0.9   | 0.9   | 0.9   | 0.9   | 0.9   | 0.98 |
| 8 | -   | -   | 1.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | -    | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | -    |
| 9 | 0.1 | -   | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.0 | 1.0  | 0.9   | 0.9   | 0.9   | 0.9   | 0.9   | 0.99 |
| 10| 0.2 | -   | 0.9 | 1.0 | 0.9 | 1.0 | 0.0 | 0.9 | 0.9  | 0.9   | 0.9   | 0.9   | 0.9   | 0.9   | 0.98 |
| 11| 0.2 | 0.0 | 95  | 85  | 70  | 82  | 00  | 38  | 96   | 00    | 42    | 61    | 82    | 00    | 0.02 |
| 12| 0.2 | -   | 0.9 | 0.9 | 0.9 | 0.9 | 0.0 | 0.9 | 1.0  | 0.9   | 0.9   | 0.9   | 0.9   | 0.9   | 0.98 |
| 13| 0.5 | -   | 0.8 | 0.9 | 0.9 | 0.9 | 0.8 | 0.9 | -    | 0.9   | 0.9   | 1.0   | 0.9   | 0.9   | 0.96 |
| 14| 0.7 | -   | 75  | 74  | 50  | 77  | 52  | 0.0 | 59   | 15    | 00    | 62    | 60    | 45    | 7    |
| 15| 1.0 | -   | 54  | 54  | 54  | 54  | 54  | 54  | 54   | 54    | 54    | 54    | 54    | 54    | 54    |

Table 2. Driving factor correlation coefficient matrix.
Table 4. Principal component load matrix.

| Factor       | Numbering | Driving factors                                      | Principal Components |
|--------------|-----------|-----------------------------------------------------|----------------------|
| X1           | 10        | total population (10,000 people)                    | 0.262                |
| X2           | 90        | employed population in agriculture (10,000 people)   | -0.913               |
| X3           | 56        | non-agricultural employed population (10,000 people) | 0.984                |
| X4           | 39        | social fixed asset investment (10,000 yuan)          | 0.978                |

Table 3. Eigenvalues and contribution rates of each component.

| Explanation of total variance components | Initial Eigenvalue | Extract square and load |
|-----------------------------------------|--------------------|-------------------------|
| Total Variance                          | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Initial Eigenvalue | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
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|                                        | Total              | Variance (%)            | Cumulative (%)       |
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|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
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|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
|                                        | Total              | Variance (%)            | Cumulative (%)       |
### Economic Environment

| X5       | GDP (100 million yuan)          | 0.998 | 0.017 |
|----------|---------------------------------|-------|-------|
| X6       | output value of primary industries (100 million yuan) | 0.981 | -0.172 |
| X7       | output value of secondary and tertiary industries (100 million yuan) | 0.998 | 0.023 |
| X8       | Value added of industrial output value (100 million yuan) | 0.082 | -0.689 |

### Habitat Area

| X9       | per capita living area of rural residents (㎡/person) | 0.997 | 0.054 |
|----------|------------------------------------------------------|-------|-------|
| X10      | per capita living area of urban residents (㎡/person) | 0.995 | -0.051 |
| X11      | construction area of housing construction (10,000 ㎡) | 0.944 | 0.288 |

### Resident Economy

| X12      | Per capita disposable income of urban residents (yuan) | 0.997 | 0.064 |
|----------|-------------------------------------------------------|-------|-------|
| X13      | Per capita consumption expenditure of urban residents (yuan) | 0.994 | 0.046 |
| X14      | Per capita disposable income of rural residents (yuan) | 0.998 | 0.000 |
| X15      | Per capita consumption expenditure of rural residents (yuan) | 0.988 | 0.124 |

4.2. **Principal component analysis**

The driver correlation coefficient matrix (Table 2), eigenvalue and component contribution (Table 3), and principal component loadings matrix (Table 4) were automatically calculated using principal component analysis using SPSS software.

In Table 2, the correlation coefficient matrix reflects the significance level of each correlation coefficient test, the closer the value is to 1, the greater the degree of correlation. The correlation coefficients for income; social fixed asset investment and urban per capita living area; GDP and rural per capita living area, urban per capita living area, urban and rural per capita disposable income, and urban and rural per capita consumption expenditures. The correlation coefficients of these factors were 0.998 at the highest and 0.981 at the lowest, which indicates that they are interrelated.

In Table 3, the larger the contribution rate, the stronger the information that the component contains about the original variable. The cumulative contribution of the principal component is generally required to be at least 85% in order to ensure that the composite variable includes most of the information of the original variable. The cumulative contribution of the first and second components has reached 93.41%, and the eigenvalues of the first two components are greater than 1. Therefore, the first and second components are the principal components.

In Table 4, the larger the factor loadings indicate the stronger the correlation with the principal components. The first principal component is more strongly correlated with factors such as habitat area and resident economy. These factors reflect the standard of living of the inhabitants. Therefore, the first principal component can be considered a proxy for the living conditions of the residents. The second principal component is more strongly correlated with the socio-economic environment, which reflects the economic development of the society as a whole. Therefore, the second principal component can be considered as a representative of the economic development of the whole society. Therefore, the driving factors of land use change in Wuhan can be summarized as the living standards of the residents and the level of socio-economic development.

5. **Conclusions and recommendations**

5.1. **Conclusions**

The following conclusions can be drawn from the analysis of the dynamics changes in land use and their driving factors in Wuhan from 2008-2017.
(1) The area of urban villages, industrial and mining land, transportation land and other land areas are all on the rise, and the trend is faster then slower. The proportion of urban village, industrial and mining land, and transportation land has increased by more than 10%, indicating that Wuhan has achieved good results in urbanization construction in recent years. Waters and water conservancy facilities have decreased slightly, but have turned back slightly in recent years, indicating that Wuhan, as a "river city", is gradually paying attention to the protection of wetlands and lakes.

(2) The area of agricultural land shows a decreasing trend, faster then getting slower. Among them, the area of cropland has decreased the most, but stabilizing in recent years, which shows that the implementation of Wuhan's policies for cropland protection has been effective. The area of forest land in Wuhan has also been increasing in recent years, although the overall trend is still decreasing, which shows that Wuhan is gradually shifting from urbanization to environmental and ecological protection.

(3) Principal component analysis shows that the two main drivers of land dynamics in Wuhan are the living standards of residents and socio-economic development. The living standard of residents is often related to the level of economic development of the whole society, which cannot be improved without government policies and state support. Wuhan has used collective construction land to build rental housing, which to a certain extent also solves the housing problem of Wuhan residents. Secondly, in recent years, the central government's "Rise of Central China" policy has also brought a lot of policy support for Wuhan's socio-economic development. In this context, it can be found Wuhan's construction land has been increased, agricultural land has been decreased, arable land has tended to stabilize, and the overall structure of land use has undergone dynamic changes.

5.2. Recommendations

This paper makes the following recommendations for land use in Wuhan in light of Wuhan's socio-economic development and land use dynamics.

(1) Wuhan enjoys the reputation of being a "river city" and should take advantage of its regional geographic advantages to protect and maintain the ecological regulatory functions of its waters, lakes, and wetlands. Although Wuhan has made some achievements in this regard in recent years, it is still far from reaching the goal of a world-class quality ecological zone and needs to further respond to the central government's call for environmental and ecological protection.

(2) For example, the successful construction of the Wuhan East Lake Greenway, which has become a world-class greenway, has played an important role in enhancing the human and ecological functions of the city. At the same time, the arable land protection policy has led to a stabilization of the arable land area in Wuhan in recent years. The city should continue to pay attention to the ecological environment in the future, not lose sight of the general direction of the central government's red line farmland protection policy.

(3) In recent years, Wuhan's development speed has been accelerating, and the land use structure has been changing constantly. It is important to maintain a dynamic balance and steady optimization of the land structure. It is important to keep up with the "fast train" of central government policies, to improve the socio-economic development of Wuhan, to improve the living standards of the city's residents, and to optimize the dynamic changes in the land structure.

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