Evolution of agricultural urban land-use and dynamic evaluation of benefits

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Abstract. This paper starts from the characteristics and driving factors of the land-use evolution in Jianli. The improved TOPSIS method is used to study the dynamic changes, including construction land, agricultural land, and waters and the facilities in Jianli from 2005-2020. Moreover, this paper uses the coupling harmonious degree model to evaluate the degree of coordination of each subsystem. Finally, this paper wants to promote sustainable, coordinated development land-use from domestic circulation in Jianli.

1. Introduction
With rapid urbanization and industrialization, the expansion of construction land has occupied a large area of agricultural land. Driving by the benefits, the land-use structure has corresponding changed, leading to the extensive use of construction land, polluting the ecological environment, and affecting food security. At present, there is much research on the benefits of land use.[1][2][3] However, the papers of agricultural cities are rarely found. From the characteristics and driving factors of land-use evolution in Jianli, this paper constructs the evaluation system of agricultural, urban land-use efficiency. Then, this paper uses the TOPSIS method and to study the dynamic change regularity of land-use efficiency. Afterward, this paper tries to reveal the coordinated development of urban agricultural subsystems by coupling harmonious degree model. This paper provides a reference for the rational layout and sustainable development for Jianli and the other agricultural cities.

2. Research methods

2.1. Build research system
This paper builds a land-use benefits evaluation system following scientific, systematic ways, and data availability. According to Land Management Law, the Classification of Land Utilization (GB/T21010-2017) is divided into three types: agricultural land, construction land, and unused land. Among unused land, and waters and the facilities are studied. The original data in the system comes from statistical yearbooks, The Third National Land Survey, etc. See Table 4.
2.2. TOPSIS based on entropy coefficient
TOPSIS method based on entropy coefficient takes the distance of objects to idealized targets as the basis for evaluating the relative advantages of objects. Thus, the method effectively eliminates the subjectivity to evaluate the weight of factors based on entropy coefficient and makes the results match the reality.

2.2.1. Calculate the weight of indicators
Due to different units and measurement scales of the indicators, the vector normalization is necessarily used to standardize the matrix.

\[
W_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \quad (j = 1, 2, ..., m) \tag{1}
\]

\(W_j\) represents the weight value of the item \(j\) indicator, \(d_j\) represents the information utility value of the item \(j\) indicator.

2.2.2. Calculate the distance between the object and the ideal solution

\[
D^+ = \sqrt{\sum_{j=1}^{m} W_j (V_j^+ - V_j^-)^2} \quad (j = 1, 2, ..., m; i = 1, 2, ..., n) \tag{2}
\]

\[
D^- = \sqrt{\sum_{j=1}^{m} W_j (V_j^- - V_j^+)^2} \quad (j = 1, 2, ..., m; i = 1, 2, ..., n)
\]

\(V_j^+\) represents the best indicators of the item \(j\), \(V_j^-\) represents the opposite. \(D^+\) represents the distance between the object and the positive ideal solution, the value of \(D^-\) represents the opposite.

2.2.3. Calculate the relative proximity

\[
C_i = \frac{D^-}{D^- + D^+} \quad (1 \leq i \leq n) \tag{3}
\]

\(C_i\) represents the relative proximity of the object to the optimal scheme.

The larger the value of \(C_i\), the closer the object to the optimal solution. As the value of \(C_i\) is 1, it reaches a high-quality state. As the value of \(C_i\) is 0, it is highly disordered. The relative proximity is divided into four grades to represent the benefits of land-use. See Table 1.

| Relative proximity | level       |
|--------------------|-------------|
| >0-0.3             | Low         |
| >0.3-0.6           | Intermediate|
| >0.6-0.8           | Good        |
| >0.8-1.0           | High-quality|

2.3. Coupling harmonious degree model
The degree of coordination between the subsystems of land-use is accessed. The value of the coupling coordination degree of the subsystem reflects the coordination status.

2.3.1. Calculate the coupling degree
Make the data normalized and calculate the coupling degree by the coupling harmonious degree model.

\[
C(U_1, U_2, \cdots, U_n) = n^* \left[ \frac{U_1 U_2 \cdots U_n}{(U_1 + U_2 + \cdots + U_n)^2} \right]^{\frac{1}{2}} \quad (n \geq 2) \tag{4}
\]

\(C\) represents the coupling coefficient, and \(U_n\) represents the value of the indicators.
2.3.2. Calculate the coordination index

\[ T = \beta_1 U_1 + \beta_2 U_2 + \beta_3 U_3 + \cdots + \beta_n U_n \quad (n \geq 2) \]  

(5)

T represents the coordination index, \( \beta \) represents the indicator weight.

2.3.3. Calculate the coupling degree

\[ D = \sqrt{C \cdot T} \]  

(6)

D represents the coupling degree.

3. Analysis of the land-use evolution

3.1. Characteristics of the land-use evolution

3.1.1. General features of the land-use evolution

In 2020, the area of agricultural land was the largest, followed by unused land, and the area of construction land is the least. Among them, the farmland and water area account for a large proportion. Among the general features of the land-use evolution between 2005-2020, agricultural land has decreased, and the construction land and unused land were opposite.

Table 2. Land-use types between 2005-2020

| types            | 2005 (ha.) | 2014 (ha.) | 2020 (ha.) | 2020 (%) |
|------------------|------------|------------|------------|----------|
| agricultural land| 22.62      | 18.73      | 19.64      | 61.36    |
| farmland         | 16.97      | 17.67      | 18.84      | 58.85    |
| Garden land      | 0.07       | 0.03       | 0.04       | 0.14     |
| woodland         | 0.48       | 0.44       | 0.76       | 2.37     |
| construction land| 2.99       | 3.69       | 3.54       | 11.05    |
| unused land      | 5.64       | 9.60       | 8.83       | 27.59    |
| water area       | 2.49       | 8.67       | 8.37       | 26.14    |
| total            | 31.25      | 32.01      | 32.01      | 100      |

3.1.2. Quantitative characteristics of the land-use evolution

Study the dynamic degree of a type land by using the value of \( K \). \[ K = \frac{U_b - U_a}{U_a} \cdot \frac{1}{T} \]  

(7)

\( U \) represents the area of a type land.

Table 3. Dynamic degree of a type land between 2005-2020

| types            | 2005-2014 | 2014-2020 | 2005-2020 |
|------------------|-----------|-----------|-----------|
| agricultural land| -1.91%    | 0.81%     | -0.88%    |
| farmland         | 0.46%     | 1.10%     | 0.73%     |
| Garden land      | -6.60%    | 10.17%    | -2.31%    |
| woodland         | -0.86%    | 11.78%    | 3.83%     |
| construction land| 2.58%     | -0.68%    | 1.21%     |
| unused land      | 7.80%     | -1.33%    | 3.77%     |
| water area       | 27.55%    | -0.58%    | 15.72%    |
In general, in the three first-level land types, the area of unused land changed the most, with the value of the dynamic degree is 3.77%, followed by construction land. And the change of agricultural land was small. Specific to the secondary land types, the area of water area changed the most, which the rising trend is apparent. The woodland, construction land, and farmland showed an upward trend. However, the garden land showed a downward trend.

3.1.3. Temporal features of the land-use evolution
Data show that agricultural land rose in the latter stage though it declined in the previous stage. Only the cultivated land area kept a rising trend in both stages, and the latter increasing rate is slightly higher than that of the previous stage. Garden land and woodland decreased in the previous stage, but all increased in the latter stage. The construction land and water area are just contrary to the situation of agricultural land. Unlike other cities' performance in the urbanization process,[5] the characteristics of agricultural cities are obvious.

3.2. Driving factors of the land-use evolution

3.2.1. Social driving factors
Between 2014-2020, the census register population generally grew slowly, the mechanical growth rates were negative in Jianli. The net outflow of population data increased year by year. The rural registered population (1,027,200) is about twice the urban population (538,500 people). Population factors may indirectly lead to the increase of agricultural land, reducing the construction land area. The decrease in construction land brings about fewer urban employment opportunities. Thus, it caused population outflow. They affect each other, interact with each other.

3.2.2. Economic driving factors
Its total GDP was relatively small, but the increase rate was significant, which exceeded the average growth level in Hubei province. The proportion of the secondary industry is relatively weak, mainly with light industry. And we can see that the area of construction land is maintained at a relatively stable level, and no significant change has occurred. However, the proportion of primary industry was high and in the leading position in Jianghan Plain. The phenomenon can also explain Jianli as an agricultural city.

3.2.3. Ecological driving factors
Jianli is located in the flood diversion and storage area. It has been affected by flood and the upstream flood diversion of the Yangtze River, which has affected local production and life. The water area has been transformed into paddy fields to promote the agricultural economy and deal with the threat of disasters.

4. land-use benefits and coordination degree

4.1. Dynamic analysis of the land-use benefits
Starting from the economic and social, and ecological environment driving factors of land-use evolution, the land-use benefits of three types land-use are studied. Build a land-use benefits evaluation system including 3 target layers, 6 criteria layers and 21 indicator layers.

| target layer | criteria layer | indicator layer                  | weight |
|--------------|----------------|----------------------------------|--------|
| construction land | Social-economic | Urbanization Level               | 0.03   |
|              |                 | Urban Disposable Income per       | 0.03   |
| Ecological | Proportion of Secondary and Tertiary Industries | 0.04 |
| Ecological | Industrial Output | 0.03 |
| Ecological | Built-up Area Greenbelt Coverage | 0.06 |
| Ecological | Sewage Treatment Rate | 0.03 |
| Agricultural land | Rural Disposable Income per | 0.03 |
| Agricultural land | Proportion of Primary Industry | 0.03 |
| Agricultural land | Agricultural Output | 0.03 |
| Agricultural land | Rural Employment | 0.02 |
| Agricultural land | Area of Regularly Cultivated Land | 0.15 |
| Agricultural land | Grain Output | 0.03 |
| Agricultural land | Dry Land Area | 0.06 |
| Ecological | Barren Afforestation Area | 0.08 |
| Ecological | Mature Timber Tending Area | 0.02 |
| Social-economic | Freshwater Aquaculture Area | 0.02 |
| Social-economic | Paddy Field | 0.08 |
| Social-economic | Fishery | 0.02 |
| Social-economic | Effective Irrigation Area | 0.10 |
| Social-economic | Cargo Throughput Situation | 0.05 |
| Ecological | Area with Stable Yields Despite Drought or Flood | 0.07 |

The comprehensive benefits of land-use generally presented an upward trend in Jianli. In 2019, the value of comprehensive benefits of land-use was 0.825, and ranked first. It can be seen from the figure that the value of land benefits was at a high-quality level, and the development of urban land-use structure has a good trend in 2019. The benefits of construction land, agricultural land, and waters and the facilities showed an upward trend respectively, among which the comprehensive benefits curve is highly compatible with the curve of agricultural land, water area. The characteristics of agricultural cities are evident.

As an agricultural city, due to the rapid development of the primary industry and the government's support for agricultural industrialization, the benefits of agricultural land continue to rise. The increasing benefits for water area and facilities are related to its vigorous aquaculture development in Jianli, as "the national aquatic county."

Although the area of construction land has declined, the four critical industrial parks develop rapidly and promote the efficiency of construction land an upward trend, among which the two industrial parks focus on the development of major grain and side-line food processing. Construction and agricultural land have a certain connection.
Fig. 1. Change of land-use benefits

Fig. 2. Distribution of land-use benefits in 2012
From the figure 4, the ecological benefits of agricultural land-use changed greatly from 2014 to 2016, which affected its socioeconomic benefits to some extent. However, it showed a continuous upward trend after 2016, and the ecological environment of agricultural land was optimized. In 2018-2019, the ecological benefits of the three types of land-use all increased, among which the ecological benefits of water area and facilities, and construction land increased sharply. The ecological environment in the region was gradually improving. Thus, it is imperative to protect the ecological environment of the water area, so as to improve the urban anti-flood capacity and anti-risk ability.
4.2. Analysis of the land-use coupling harmonious degree

The value of land-use coupling coordination degree changed from 0.216 to 0.867 from 2012 to 2019. The coupling harmonious degree inverted into a good coordination state in Jianli. Moreover, the coupling coordination degree of land use shows a convergence phenomenon with the coupling degree of social economy and ecological environment. It indicates that the coordinated development of socioeconomic and ecological environments strongly correlates with urban land-use benefits.

From the changing trend of land-use benefits and coupling coordination, the socioeconomic land-use benefits were the highest. The social, the combined coupling coordination degree also reached the highest in 2018. In 2019, due to the decline of benefits of the agricultural land, and waters and the facilities, various kinds of indicators declined slightly. As a result, types of land development were unbalanced and mismatched with urban economic development. During 2013-2014 and 2015-2016, the coupling coordination degree both decreased. The sharp decline in the ecological benefits of water and its facilities led to the unbalanced land subsystem development while the rise of construction and agricultural land-use benefits. Also, the story of the ecological environment and the social and economic subsystems is unbalanced.

5. Conclusions

Unlike the sacrificial cultivated land for the development in ordinary cities, the area of cultivated land continued to rise between 2005-2020 in Jianli. The driving factors of its unique land-use evolution are not only related to solid agricultural foundation and slow industrialization development, but also related to the geographical location. While the economy is developing, they protect the ecological environment and actively respond to floods and other natural disasters.

Jianli has formed an initial scale of agricultural industrialization. The benefits of agricultural land and, and waters and the facilities have extensively promoted the comprehensive benefits. The city can determine its aquaculture and agricultural and side-line foods deep processing as the leading industries of development orientation. Making the rational distribution of agriculture and aquaculture and promoting industrial parks surrounding the agricultural land is necessary. At length, the city should strengthen the integration of primary, secondary, and tertiary industries and accelerate the construction of a spatial pattern of green agricultural development.

On the basis of studying the driving factors of land-use evolution in Jianli, this paper constructs an agricultural city land-use benefits evaluation system. Further, this paper studies the coupling harmonious degree of its subsystem, providing some reference for exploring the land utilization model.
of agricultural city. However, due to data accessibility and other reasons, the evaluation system still needs to be optimized and strengthened in the future.

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