MULTI-AGENT BASED SIMULATION OF OPTIMAL URBAN LAND USE ALLOCATION IN THE MIDDLE REACHES OF THE YANGTZE RIVER, CHINA

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ABSTRACT:

The optimization of land-use allocation is one of important approaches to achieve regional sustainable development. This study selects Chang-Zhu-Tan agglomeration as study area and proposed a new land use optimization allocation model. Using multi-agent based simulation model, the future urban land use optimization allocation was simulated in 2020 and 2030 under three different scenarios. This kind of quantitative information about urban land use optimization allocation and urban expansions in future would be of great interest to urban planning, water and land resource management, and climate change research.

1. INTRODUCTION

As the economic development policies are continuously being implemented in China, urban agglomeration as the core area of socio-economic development will be given the priority for rapid development. However, fast urbanization and accelerated urban expansion will convert natural landscape to largely impervious land use patterns. Urban land use and related environmental changes would have impacts on regional sustainable development (Jiang et al., 2013; Lin et al., 2003; Seto et al., 2005; Liu et al., 2008). Therefore, it is important to optimize future urban land use allocation in urban agglomerations.

Optimization of land use allocation is a complex spatial optimization problem that involves allocating various land uses to specific units within a region. Therefore, a number of models have been widely used to simulate land use transformation. They include mathematical equation and empirical statistical model (Haque et al., 2014), intelligent evolutionary algorithm (Liu et al., 2012; 2013) and CLUE-S model (Verburg et al., 1999; 2002), CA model (Li et al., 2002; He et al., 2006), among which Cellular Automata (CA) model has been increasingly used to simulate urban growth and land use dynamics. However, the simulation of multiple land use changes using CA models is difficult because numerous spatial variables and parameters have to be utilized. They also have some limitations because they cannot explicitly consider the influences of social and human factors in urban expansion simulation.

Multi-agent systems (MAS) can be defined as a set of agents interacting in a common environment, able to modify themselves and their environment. It can explicitly formalize simple to complex representations of the behavior and cognitive processes of actors who make land use decisions within the system. Therefore, Multi-agent systems (MAS) based model is well adapted to the simulation the multiple land use changes in urban areas (An, 2012; Chen et al., 2010).

This study selected the Chang-Zhu-Tan agglomeration as study area, which is located in the middle reaches of the Yangtze River and is one of important urban agglomeration areas in China. Based on multi-agent system theory and land use decision-making process, a new land use optimization allocation model was developed. Using this multi-agent based simulation model, the future urban land use optimization allocations under three different scenarios were simulated in 2020, 2025 and 2030.

2. STUDY AREA AND DATA

The Chang-Zhu-Tan agglomeration in the middle reaches of the Yangtze River, China (Fig. 1) has been experiencing significant growth in both population size and urban area in the last decade. It is important to quantitatively reveal urban expansion in future.

Figure 1. Study area

Land use/cover data were excavated using Landsat TM/OLI images from 2010 to 2013. Land use types include construction land, arable land, forest land, water, and other land use. The overall accuracy of classification of land use/cover data reached 80%. We also collected DEM, topographical map, house price...
map, and socio-economic census data including population
density, GDP per capita, urbanization, and total fixed assets.

Using GIS spatial analysis model, we calculated and obtained
thematic layers such as, distance to the river, distance to village
road, distance to county road, distance to road, distance to
highway, distance to bridge, life service, facilitate of work, leisure and entertainment layers.

3. MULTI-AGENT BASED SPATIAL OPTIMIZATION
   MODEL

3.1 Model framework

The land use decision-making stakeholders are divided into three
categories, such as government, departments, and public, which
are macro-level decision maker, land administration decision
maker and land users, respectively.

Firstly, the spatial competition allocations of different land use
classes are determined through multi-agent based interactive
decision-making. Then, under different land use scenarios, the
optimized land use allocations are determined according to the
configuration order of land use class and the land use structure
constraints (Fig. 2).

![Figure 2. Model framework of multi-agent spatial optimization](image)

3.2 Multi-agents and their interactive decision making

(1) Department and public agents and their land use decisions

Department and public agents are pursuing to maximize their
own interests. Therefore, based on comprehensive trade-offs of
land use effectiveness, department and public agents apply to
government for land use. The utility functions of department and
public agents for land use are as follows:

\[ U_i = \sum_{j=1}^{k} \alpha_{ij} X_j + \mu_{ij} \]  (1)

\( U_i \) is the utility of the land use i; \( X_j \) is the decision factor of
department and public agents (j=1, 2, 3... k); \( \alpha \) is the decision
weight; \( \mu \) is the random disturbance term.

(2) Government agent and its land use decisions

The government agents use competition function to resolve land
use conflicts. The competition function is as follows:

\[ C_{t(i,j)} = U_{g(i,j,t)} + \alpha \cdot U_{p(i,j,t)} + P_t \]  (2)

\( C_{t(i,j)} \) is the competition of land use class t in unit \( (i, j) \); \( U_{g(i,j,t)} \)
and \( U_{p(i,j,t)} \) are utility functions of land use class t in unit \( (i, j) \) for
department and public agents, respectively; \( \alpha \) is the public agent
participation \( (0 \leq \alpha \leq 1) \); \( P_t \) is priority of department agent to
land use class t \( (p \geq 0) \).

In order to consider the land requirements of department agent
and public agent, the government needs to coordinate land use
through competition adjustment as follows:

\[ C'_{t(i,j)} = C_{t(i,j)} + n_d \cdot \delta P_d + n_p \cdot \delta P_p \]  (3)

\( C'_{t(i,j)} \) is the adjusted competition for land use class t in unit \( (i, j) \);
\( n_d \) and \( n_p \) are number of application of department and public
agents to the government for the unit \( (i, j) \); \( \delta P_d \) and \( \delta P_p \) is the
competition increase of departments and the public agent for
each time.

(3) Land use optimal allocation based on the degree of land use
competition

In multi-agent based interactive decision-making process, the
optimal allocation of land use was implemented dynamically
based on the degree of competition of all land use types, as well
as the sequence of configurations of land use and the constraint
condition of land use structure.

4. THE RESULTS AND ANALYSIS

4.1 Model test

![Figure 3. Comparison of modelled land use with actual land use](image)

(a) 2010 actual land use, (b) 2013 actual land use, and (c) 2013 modelling result

Based on the land use classification data in 2010, which is the
base year data, the spatial pattern of land use in 2013 was
simulated by using the multi-agent land use spatial optimization
model (see Fig. 3c). Using a cell-by-cell method, we compare the
simulated results with the actual land use pattern in 2013 (see
The Kappa coefficient is 0.7716. This indicated that the modelling accuracy using the multi-agent land use spatial optimization model is sufficient to model the land use allocation.

Using the multi-agent land use spatial optimization model, we simulated the land use spatial optimization allocations in 2020 and 2030 under these three different scenarios. The modelling results are shown in Fig. 4.

The simulation results indicate that land use patterns and changes are different under different scenarios, which provide the basis for land use management and scientific decision-making of regional sustainable development.

5. CONCLUSIONS

A multi-agent land use spatial optimization model was proposed to support the optimized land use allocation practices. The model was first applied to the past land use data to test if it is capable of modelling land use allocations. It was further applied to simulate the future urban land use optimization allocation under three different scenarios for 2020 and 2030. The results show that land use patterns and changes are different in different scenarios. This kind of quantitative information about urban land use optimization allocation and urban expansions in future would be of great interest to urban planning, water and land resource management, and climate change research.

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REFERENCES


4.2 Scenarios of land use spatial optimization modelling

Three different scenarios of urban land use were designed, which were urban integration development scenario, farmland and ecological protection scenario. The urban integration development scenario assumes that the future construction land area will be increased than that of natural increment. The farmland protection scenario assumes future permanent basic farmland protection zone will be increased. The ecological protection scenario assumes that areas along with the Xiangjiang River and its major branches, mountains and hills, and ecological landscape corridor between cities will be strictly restricted to use for construction.


