Land Use Structure Optimization Under Systematic Framework

LIU Yanfang  HUANG Liang

1 Introduction

The system of land use is a very complex system. We draw up the project of land use planning structure to implement the optimization of land resources. The optimization of land use structure is the kernel of land use planning.

Today, most of the urban land use plans only consider the optimization of the land use structure of certain levels, but that under the systematic framework. Therefore, this paper puts forward the concept of the land use structure optimization under the systematic framework. It includes the concept of space and time structure. In this paper, we list the models of the optimization of land use structure of different levels. At the same time, we analyze and research it in a case study to discuss how to achieve the optimization of land use structure.

2 Land use structure optimization of space level

So-called land use planning system is an interrelated system that is made up of the land use planning of different types, different levels and different periods. In order to draw up and carry out planning, we usually have five levels’ land use planning according to administrative divisions, i.e., levels of country, province, city, county and town. There is interrelated and complementary relation among different levels’ land use planning. The planning of the upper levels controls that of the lower which has a feedback function on the planning of the upper. From the viewpoint of systematology, land resources of the planned area make up of a big land use system. There is a complex relation among its child-systems and between the inside and the outside of the system.
From the structure of land use planning system, it can be seen that the five levels’ land use planning makes up of a spatial level structure of land use planning. Correspondingly, the land use structure optimization has the spatial structure of five levels’ optimization. That is to say, the upper level’s land use optimization structure controls the lower level’s and the lower has a feedback to the upper so as to optimize the lower land use structure on the basis of the optimization of the upper. Besides the structure should show the characteristic of the lower land use in order to exert its advantage. Only in this way can we reach the systematic optimization of land use structure.

3 Time characteristic of land use structure optimization

Land use structure has the characteristic of spatial layers and is a dynamic structure and changes with time and circumstance. In general, the land use structure has to change mostly due to the change of the country’s policies and the planning’s purpose and target, the controlled quantity of cultivated land and building land and unused land. At the same time, the change of the system’s influential factors, such as the social developing speed and level, population increase, land resource quality and land use technique level, etc. demand land use planning to keep modifying its contents and project. Therefore, the land use planning is a dynamic course of planning-actualization-modifying-planning-actualization. It surely brings forth the change of the land use structure. Certainly, the land use planning should keep stable in a certain period so that it can be actualized.

We should know the time characteristic of the land use structure in the optimization of the land use structure. Thus we can make the land use structure optimal together with the change of time.

4 Land use structure optimization under space-time coupling

This paper puts forward land use structure under space-time coupling just because of its characteristic in time and space. We should analyze the affecting factors in order to make the land use structure optimal under space-time coupling. We call it “switcher” for those factors that bring about the change of the land use structure. When the “switcher” acts on the land use structure of $T_1$ status (in Fig. 1), the areas of different types of land may increase or decrease so as to form a new land use structure of $T_2$ status. The “switcher” can be expressed by mathematical model of linear programming. It can optimize land use structure by figuring out the optimal solution. But, no matter how the structure changes, the sum of the land area of different type land at the lower level should be equal to the land area at the upper, which can be seen in Fig. 1.

There are many factors that influence the change of the land use structure, such as the country’s policy, population increase, construction of important projects. This paper only explains those factors that cause the increase and decrease of the cultivated land, which can be seen in Fig. 2.

5 Working system of the land use structure optimization under systematic framework

The optimization of the land use structure is a very complex job. The preparing jobs mainly include collecting the data of land resource, social and economic information and so on. On the basis of it, we can make some monographic study on those data such as the forecast of the quantity of demanded land and population. We can draw up the upper optimization structure of the land use on the basis of the forecasting value and different departments’ comments. Finally, the lower optimization structure land use can be determined. This paper mainly studies the system structure of county and town’s land use structure optimization. Its working system can be seen in Fig. 3.

There are many methods by which we draw up the projection of land use structure, such as complex equilibrium and linear programming. The result obtained by linear programming is more scientific through constructing mathematic model.
6 Construction of the optimization model at different levels

6.1 Brief introduction about linear programming model of land use structure

We usually optimize the land use structure by linear programming in planning. Constructing model in this way, we resolve it through transforming it to linearity when the limit-equation and objective function are nonlinear. We can construct different linear programming model for different zones and levels.

The mathematical models of land planning system have the same structure that is made up of objective function and constraints. Planning means seeking the approach by which we can reach the optimal goal under the given conditions. The land use struc-
ture optimization of planning system is a kind of theory and method that is about seeking the maximum or minimum of objective function under certain constraints. All system problems, which can be expressed by objective function and constraints, are the optimization problem of planning and can be expressed by mathematical model of linear programming. Detailed process can be seen in Fig. 4.

Preparing phase

| Collect, sort and analyze data |
|-------------------------------|
| Land use data                 |
| Social circumstance          |
| Natural circumstance         |
| Economic circumstance        |
| Other relative data          |

Analytical study phase

| Province’s control quantity |
|----------------------------|
| Government, department’s comment |
| Monographic study          |
| Set planning goal and policy |
| Analysis of current situation of land use |
| Evaluation of land quality  |
| Study of land yielding potential |
| Forecasting of demanded land quantity |
| Study of land’s population carrying capacity |

Linear optimization and harmony phase

| Construction of county optimal structure |
| Model |
| Transform |
| Transformer |
| Analyze village circumstance and set constraints |
| Construction of village optimal structure |
| Whether the sum of village optimal result cooperates with that of county optimal result |
| If not |
| Analyze results and harmonize each other |

Fig. 3 Working system of land use structure optimization

6.2 Construction of land use structure optimization model at different levels

Today, county land use planning is a key level in the planning system because it is a link between the preceding and the following. Therefore, we mainly studies land use structure optimization system of county-town levels.

As mentioned above, the construction of the model mainly involves the setting of objective functions and constraints. Objective functions of different levels can be set as the maximization of economic benefit, and the social and ecological benefit can be set as constraints because our country’s economy is in the developing period. In Fig. 4, the constraints usually include limitation of land and other resources, social and economic condition, ecological balance and so on.

The steps by which the linear programming is applied to the town land use structure optimization are the same to those at county level except the setting of variables and constraints. Now we introduce how to construct the linear programming model of land use structure. Before the optimization of the town land use structure, we should have different directive comments for different towns’ land use planning according to the differences of their geographic location, serving function and property, then we can set the magistral land use type, land use scope and layout of different types of land so as to construct different land use structures. The details are given as follows:
1) City-diffusive type The town of city-diffusive type means the town adjoining with city zone. Its planning's task is mainly to carry out city planning contents and show the characteristic of city planning to supply construction use land for the enlargement of the city.

2) Serving-city type The town of serving-city type is located at suburb or future developing zone. Its planning task is mainly to supply "vegetable Skep" and industry material for city, supplying developing zone and industry zone for the development of city economy to create conditions for the future development of the city.

3) Agriculture type The town of agriculture type is far from city. Its planning mainly includes designating basic-farmland protection zone, planning of village's residential area and reasonable modification to the inner agricultural structure so as to self-support the city with food.

In sum, we should ensure key area of land use type according to different towns' characteristics so that we can exert their resource advantages fully and develop characteristic industries. We can make the optimization structure more scientific and reasonable through setting the constraints according to the goal of town planning.

7 A case study

7.1 Construction of county land use structure optimization model

Qionghai city is located in the east of Hainan province, its west part is higher than its east part in hypsography. Mesa and plain are the main types of land. There are few mountains and ungraded fields in its area. The current situation of land use can be seen in Table 1. In the process of constructing the model, we reflect the requirement of economic balance and ecological balance, the limit of manpower, material resources and financial resources in the target year of land use planning (2010) by setting a set of linear equations as the constraints.

Now we make a detailed description for the construction of land use structure optimization model of Qionghai city, Hainan province.

7.1.1 Setting variables

We select 14 variables according to the charac-
teristic of Qionghai city’s land resource and the requirement of land use planning on the basis of the classification of land use.

7.1.2 Setting relative weight coefficient of different types of land

We can set the benefit coefficient by AHP, expert judge, integrative balance and other methods to make up a benefit coefficient collection: \( W_i (i = 1, 2, 3, \cdots, 14) \). The land use coefficient of \( X_{13} \) (unused land) can be considered as zero and do not join the judge.

\[ W_i = (0.0753, 0.0816, 0.0389, 0.0921, 0.0812, 0.0676, 0.1337, 0.0863, 0.0794, 0.1079, 0.0164, 0.0562, 0.0834) \]

7.1.3 Constructing objective function

\[ S(X) = \sum (K \times W_i \times X_i) + X_{13} \]

where \( K \) (except \( X_{13} \)) is a constant denoting benefit coefficient of different types of land; \( W_i \) denotes relative weight of \( X_1 \) to \( X_{14} \) different types of land; \( X_i \) denotes area of different types of land \((hm^2)\).

7.1.4 Setting benefit coefficient \( K \)

We can figure out the constant \( K \) according to the forecast value of output benefit per square hectare forest land. Then we can obtain the output benefit of unit area for different types of land by multiplying the result by corresponding relative weight \( K \). The final result can be called benefit vector \( V_i (i = 1, 2, 3, \cdots, 14) \). According to the forecast, the average output benefit will be 6 000 yuan per square hectare of cultivated land in 2010, viz,

\[ V_1 = 0.0389 \times K = 6000, \text{ so } K = 154241 \]

And then figure out:

\[ V_i = (11614, 12586, 6000, 14205, 12524, 10426, 20622, 13311, 12247, 16642, 2530, 8668, 13936) \]

According to this, the objective function is:

7.1.5 Constraints

We can take the sum area of the city land and the upper control value as constraints. In this example, the number of the constraints in six aspects is 14.

1. Total land

The summation of the area of all types of land should be equal to the amount of land area, viz.

\[ X_1 + X_2 + \cdots + X_{14} = 171037.29 \]

2. Total population

The population beared by agricultural and urban land should be controlled in the planned population of 2010,

\[ P_1 \sum X_j + P_2 \sum X_k \leq P \]

where \( P_1 \) denotes the forecast average population density of agricultural land; \( P_2 \) denotes the forecast average population density of urban land; \( P \) denotes the planned population in the city; \( X_j \) denotes the type of agricultural land; \( X_k \) denotes the type of urban land.

\[ 1.7(X_1 + X_2 + X_3 + X_6) + 60(X_4 + X_5) \leq 530000 \]

3. Quantity of retained cultivated land

\( X_7 \geq 37913.3 \)

4. Ecological Balance

- forest cover rate

Forest cover rate should be larger than 54%, viz.
\( X_2 + X_3 \geq 171 \, 037.29 \times 0.54 \)

- Basic farmland protecting: \( (\sum X_k - \sum X'_k) \leq (1 - t_2)(X_1 + X_2) \)

where \( q \) denotes the conversion coefficient; \( \sum X_k \) denotes the planned area of all types of construction land; \( \sum X'_k \) denotes the actual area of all types of construction land; \( t_2 \) denotes the farmland protection rate.

Most of building land should be controlled in the upper limit value of macroscopic plan, viz.

\( X_4 \leq 160, X_5 \leq 1500, X_6 \leq 5000, X_7 \leq 1219, X_8 + X_9 \leq 2911, X_10 \leq 1936, X_11 \leq 1045, X_{14} \leq 500 \)

\[ X_{13} = (1 - r) \times X'_1 \]

where \( r \) denotes the exploiting rate of unused land; \( X'_{13} \) denotes the actual area of unused land.

Requirement of mathematic model

\( X_i \geq 0, i = 1, 2, \ldots, 14 \)

7.1.6 Solve this problem and obtain the optimal project

We can obtain the optimal project of land use through listing a set of equations-inequalities of the \( S(x) \) maximization and all constraints by the simplex method. The optimal project of land use can be seen in Table 2.

| Variable | Land type                        | Optimal area/hrm² | Variable | Land type                        | Optimal area/hrm² |
|----------|----------------------------------|-------------------|----------|----------------------------------|-------------------|
| \( X_1 \) | Cultivated land                  | 37 928.633       | \( X_8 \) | Special land                     | 112.4             |
| \( X_2 \) | Garden land                      | 52 264.74        | \( X_9 \) | Travelling land                  | 556.62            |
| \( X_3 \) | Forest land                      | 50 990.62        | \( X_{10} \) | Transportation land              | 634.05            |
| \( X_4 \) | City land                        | 2 159.83         | \( X_{11} \) | Land for water conservancy       | 735.1             |
| \( X_5 \) | Town land                        | 1 508.74         | \( X_{12} \) | Other water areas                | 10 309.32         |
| \( X_6 \) | Residential district in village  | 4 915.65         | \( X_{13} \) | Unused land                      | 4 204.79          |
| \( X_7 \) | Land for independent industry and mine | 891.67   | \( X_{14} \) | Development zone                 | 498.67            |

7.2 Construction of structure optimization model of village land use

The trail of thoughts about how to construct the structure optimization model of village land use is mentioned above. We should catch hold of the primary resource advantages and do our best to optimize current level structure. Of course, the job should be as simple as it can be. The setting of detailed constraints needs further perfection.

8 Conclusion

1. This paper has expounded the conception of the land use structure optimization under the system framework and puts forward that we should look on it from the view of the system.
2. This paper constructs the land use structure optimization under coupling, and expounds the function of "transformator" in the structure optimization.
3. This paper expounds the working system of the land use structure optimization under the system framework, and presents respective feature to the construction of land use optimal model at different levels.
4. This paper explains the feasibility of land use structure optimization through the example.

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