

# Land Use Patterns under Ecological and Intensive Constraints--Scenario Simulation Based on SLEUTH

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**Abstract**—For urbanization in plateau lake basins, city planning needs to balance the tradeoff between urban growth and preservation of ecological environment by adopting intensive land use and maintaining sufficient open space. This research designs and evaluates four land use types in Dianchi Lake basin, Yunnan Province, China: development without constraints, ecologically constrained development, intensive land use development, and ecologically-constrained intensive land use development. The SLEUTH model is used to examine the four scenarios, and suggests that the ecologically constrained intensive land use development pattern outperform others. The scenario strikes a nice balance between the development across the whole urbanicity spectrum (i.e., City-Town-Village or CTV) and protecting the ecological environment in the Dianchi Lake basin. Related policy recommendations are also proposed.

**Keywords**-ecological constraints; City-Town-Village (CTV); intensive land use; SLEUTH; Dianchi Lake basin

## I. INTRODUCTION

Land use changes result in significant impacts on natural environment and alter ecological processes. Studying land use changes and corresponding impacts on ecological environment offers insight into regional sustainable development and protection of ecological systems [1]. Land use change in lake basins is a major factor affecting the regional ecological environment in plateau regions such as Yunnan Province, China [2]. For example, land use change across the whole urbanicity spectrum (i.e., City-Town-Village or CTV) and urban land expansion under the current pro-growth (or urban sprawl) policy are found to have major negative impacts on the water environment of lakes and the ecological environment of the basins [3-5]. Specifically, the urban land expansion resulted from decades of pro-growth policy has, to some extent, destroyed the regional ecological environment, and calls for a sustainable land use practice to protect the ecological environment [6]. Endless expansion of developed land under the current urban sprawl policy needs to be replaced by promoting intensive land use pattern, saving sufficient green space and making land development ecologically-friendly. This is critical for maintaining a healthy cycle for a regional ecological system. Only by doing so, we may undergo the urbanization and economic development while protecting the ecological environment in the plateau lake basin [7, 8]. This requires us to strike the right balance between *intensive land use development* (for economic development) and *ecological-constrained development* (for

protecting the regional eco-system)[9]. This research designs and evaluates four land use patterns in Dianchi Lake basin. SLEUTH model is used to implement and examine the four scenarios. The objective is to seek the best land use pattern in order to balance the lake ecological environment protection and regional urbanization and economic development.

## II. STUDY AREA AND DATA SOURCES

### A. Study Area

First, confirm that you have the correct template for your Dianchi Lake basin is located in the Yunnan-Guizhou Plateau, with longitude ranging 102°29'11.21"~103°0'51.16" & latitude ranging 24°28'19.11"~25°27'29.44". It is about 1900 meters above the sea level, surrounded by mountains and hills. The total area is 2920 km<sup>2</sup>, and the total population is 3.5 million.

### B. Data

Major datasets for the study include the RS satellite imagery associated with four time periods 1974, 1988, 1998, and 2008. Furthermore, Kunming and Dianchi Lake historical and contemporary data on urban development and design, land use, ecological environment, city planning, the 2nd national land use survey data, land use plan (2006-2020), Dianchi Lake wetland construction plan, 12th Five-year Plan of Dianchi Lake environment, Dianchi Lake landscape tourism plan, Kunming transportation maps, Kunming ecological barrier construction plan, new Kunming construction plan, and socio-economic development plan.

## III. DESIGN OF DEVELOPMENT SCENARIOS

Foremost, protection of lake ecological environment should be the prerequisite for intensive land use development in plateau lake basin. For example, urban development should not occupy the lake's ecological barrier land but protect the forest, garden, farm land and water area in the lake basin [10]. In addition, we should use the land more efficiently, strictly control the City-Town-Village construction scale, avoid the 'concentric' expansion model for the spatial layout, advocate a compact, intensive and collective expansion pattern, and increase the green space in the city.

Therefore, a reasonable CTV development pattern for Dianchi Lake basin under the ecological constraints should be

planned by taking into account the landscape ecology, intensive land use, and compact grouping [11-13]. Specifically, the following aspects should be considered: landscape ecological constraints; intensive land use; develop the center town; optimize rural residential places; compactly grouping development. Based on the above ‘rules’, we designed four scenarios for the Dianchi Lake basin (see “Figure 1”):

#### A. Scenario 1 — Development without Constraints

This scenario is to develop CTV in the Dianchi Lake basin as it is, without considering the ecological impact and the capacity of land. Specifically, it only considers the transportation, infrastructure, socio-economic condition, slope of land (a basic factor considered by Cellular Automata simulation) and so on.

#### B. Scenario 2 — Ecologically-Constrained Development

Ecologically-constrained development is defined as an extension to the first scenario by adding the constraint of ecological land use. Specifically, it controls the need for land by the CTV development, especially around the wetland and lake ecological protection area, and encourages to the land use with minimum impacts on the eco-system. In addition, it also imposes a minimum green space in a city. In short, this scenario considers ecological constraints but not the land capacity and structure of the CTV.

#### C. Scenario 3 — Intensive Land Use Development

This scenario also represents an extension to the first scenario that considers, however, land capacity rather than ecological constraints in the CTV development. For instance, it increases urban population and decreases rural population, increases the urban land and decreases rural land according to the recommendation of Kunming’s ‘metropolitan-wide urbanization’. Furthermore, it adjusts the structure, function and spatial layout of the CTV for land use efficiency. Note that this scenario does not consider the ecological constraints of Dianchi Lake basin.

#### D. Scenario 4 — Ecologically-Constrained Intensive Land Use Development

This scenario works as an integration of scenario 2 (ecologically-constrained development) and scenario 3 (intensive land use development), and is thus a comprehensive development pattern. It coordinates the development of CTV with the protection of ecological environment in the Dianchi Lake basin to achieve a ‘win-win’ outcome in terms of regional economic development and eco-system management and protection.

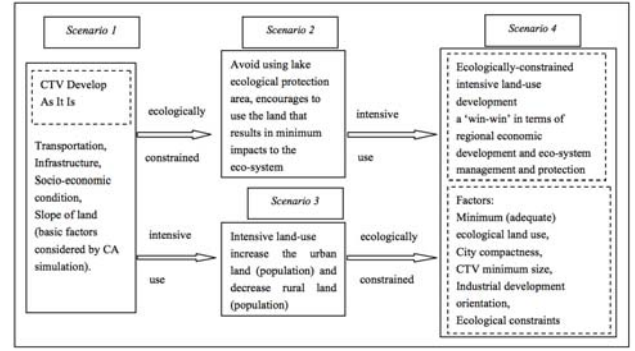


FIGURE 1. CITY-TOWN-VILLAGE INTENSIVE LAND USE SCENARIO.

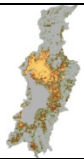
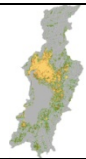



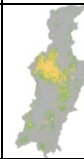






## IV. IMPLEMENTATION OF DEVELOPMENT SCENARIOS

Cellular Automata (CA) is often used to model the land use change from the existing development pattern and has shown promising results [15]. The research considers indicators such as ecological environment limit and intensive land use limit in the CA model to adjust the development rates in different regions [16]. This can help predict the urban development under ecological constraints. The SLEUTH model has demonstrated its advantages in terms of model transferability [17], prediction accuracy of urban growth, landscape change, as well as environmental impacts assessment [18]. This research adopts the auto-adjust city dynamic stimulation system from the SLEUTH to simulate and model the dynamic process of urban sprawl in Dianchi Lake basin [19-21]. Specifically, we use it to simulate the growth of the city, its spatial boundary and roads, among others based on a series of control indices such as spread coefficient, reproduction coefficient, expansion coefficient, slope coefficient, road weights, as well as the customized coefficients which accounts for ecological limit and intensive land use [22].

## V. ANALYSIS RESULTS AND DISCUSSION

We implemented the four scenarios in the SLEUTH CA model, and simulated the city growth in 1988, 1998 and 2008. In comparison to the practice data, we calculated the Kappa coefficient is 0.4, 0.43, 0.55. respectively. We also simulated the city growth in 2015, 2020, and 2028. See Table I for results. Based on the 2020 Kunming city planning for Dianchi Lake basin, the CTV developed land should not exceed 620 km<sup>2</sup>. Therefore, we adopted the model with a cumulative percentage > 80%.

TABLE I. SIMULATION RESULTS FOR 2015, 2020, AND 2028

Cum. Per.	Scenario 1			Scenario 2		
	2028	2020	2015	2028	2020	2015
100	662.62	457.04	418.35	632.37	453.85	418.42
>90	823.97	589.66	453.47	781.20	569.97	450.71
>80	875.78	<b>641.01</b>	499.12	834.58	<b>616.98</b>	490.86
>70	912.25	679.75	535.65	872.52	654.71	523.09
>60	942.72	711.78	566.69	904.27	687.30	551.57
>50	970.96	741.62	593.37	934.04	718.15	577.92
>40	998.11	772.10	621.69	962.91	749.11	606.90
>30	1027.04	802.64	653.73	993.26	780.19	640.34
>20	1059.95	838.31	689.24	1028.68	817.43	677.39
>10	1104.13	887.51	737.12	1076.25	868.26	725.37
>0	1229.88	1012.58	856.27	1209.18	997.69	847.77
Fig.						
	Scenario 3			Scenario 4		
	2028	2020	2015	2028	2020	2015
	657.74	455.45	418.47	620.12	450.62	418.25
	826.50	586.50	452.09	768.30	561.67	448.16
	882.07	<b>639.74</b>	496.87	822.50	<b>608.07</b>	485.89
Fig.						

## VI. CONCLUSIONS

Based on the comparison among the above four land use development scenarios, summarized as follows.

First, the cumulative percentage declines over time in all four scenarios, and the developed land increases significantly, which corresponds to the development of CTV.

Secondly, scenarios 1 and 3 without ecological constraints do not save land for development as much as scenarios 2 and 4 under ecological constraints.

Thirdly, scenario 4 yields less developed land use for CTV than scenario 2 or 3 at all time periods. This indicates that the intensive land use can benefit from imposing the ecological constraints, and thus the CTV development under the ecological constraints is the best intensive land use pattern for Dianchi Lake basin.

Fourthly, the built-up area in scenario 3 becomes larger than that in scenario 1 as the cumulative percentage declines. This indicates that the land use optimization and adjustment policy (e.g., village relocation and consolidation, and increasing urban land and decreasing rural land) results in more intensive land use. However, as the growth rate increases, especially in large cities, the CTV development (without ecological constraints) has a probability of 70% to lose control because of the encroaching on ecological land, i.e., the CTV development exceeds the ecosystem carrying capacity in the study area.

Fifthly, the existing CTV development (i.e., scenario 1) in Dianchi Lake basin is unsustainable. According to the results from scenario 4, the internal structure and the external morphology of CTV would be more compact under the promise of maintaining most of the ecological land, especially the wetland and lake protection barrier. Moreover, increasing the ratio of CTV and improving the land utilization rate may help protect the ecological environment, maintain CTV development, and achieve the intensive land use to the highest degree in the study area.

Finally, we need to properly control the population growth and expansion of development area to make development of the Dianchi Lake basin sustainable. Population and construction area can be regarded as two indicators of CTV development. The simulation results show that by 2020, there would be a healthy cycle of CTV development and ecosystem in Dianchi Lake basin if the population is capped to 5 million (vs. 6.2 million under the current plan by the Kunming Municipality Government), and the built-up area under 608 km<sup>2</sup>. As for the central area of Kunming, which already has high population density and intensive land use, the population and built-up area should be controlled to 4 million and 380 km<sup>2</sup>, respectively (vs. 5 million and 430 km<sup>2</sup> under the current plan) by 2020.

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