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Land use conflict identification and sustainable development scenario simulation on China's southeast coast

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A B S T R A C T

The southeast coastal region of China is a typical frontier region between urbanization and industrialization, where land use is facing the pressure and challenge of continuous expansion of construction land, decreasing agricultural land and accelerated degradation of ecological land. Solving the resulting land use conflicts (LUCs) has become an urgent issue in regional sustainable development. In order to explore LUC status and to guide LUC governance, an empirical model of land use conflict identification and intensity diagnosis was constructed, and a method for simulating sustainable land use scenarios based on conflict management was proposed. Nan'an City was selected as an empirical study area. The empirical model divides the conflict intensity into seven levels, and divides the LUC zones into 16 types according to their "dominant land + conflict intensity". We recommend formulating land use change rules according to the "distribution-land type-performance- intensity" of conflict zones when simulating future sustainable land use scenarios. The empirical results showed that the current land use pattern in Nan'an City has led to fierce competition and conflict. The spatial distribution, land type composition, conflict manifestation and intensity of different LUC zones varied widely; therefore, it is necessary to adopt different governance strategies to achieve a balance between the differential demands of land use and to guide the direction of sustainable development. The constructed empirical model and proposed simulation approach could better reflect the true situation of land use in the economically developed areas of China, and would provide theoretical and methodological support for the prevention and resolution of LUCs.

1. Introduction

Since the reform and opening up more than 40 years ago, China's land use has faced tremendous pressure and challenges in the context of the rapid advancement of urbanization and industrialization, the acceleration of rural transformation and development, and increasing ecological protection. These changes have led to increasingly fierce conflicts (Zhou et al., 2017). As the main driver of China's economic growth, the southeastern coastal region is not only a frontier for the rapid advancement of urbanization and industrialization, but also a typical region for rural transformation and development (Liu et al., 2013; Long et al., 2009; Qiu et al., 2016). The rapid socio-economic development has led to more prominent regional competition and contradictions of land use, manifested as the expansion of cities into high-quality arable land, the disorderly spread of rural settlements, the encroachment of arable land into ecological land, and the damage to biodiversity caused by land use (Long et al., 2009; Shan et al., 2017; Yu et al., 2014; Zhou et al., 2017). To some extent, these conflicts have threatened the sustainable use of regional land resources.

The term "conflict" originates from sociology, which means that two or more social units are incompatible or mutually exclusive in their goals, resulting in psychological or behavioral contradictions (Leong and Ward, 2000). With the intensifying contradiction between human activities and environmental resources, researchers have considered conflict in the field of resource utilization and have proposed the concept of land use conflicts (LUCs) (Reuveny et al.,

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2011). The LUCs refer to the contradictory states in the utilization process of land resource: for example, the inconsistency and disharmony of the way and quantity of land use by various stakeholders; the contradiction between various methods of land use and the environment; etc. (Campbell et al., 2000; Yu and Lv, 2006). As early as 1977, the British Rural Association selected “land management, land use relations and conflicts” as one of the five themes of the urban fringe academic forum, with “land use conflict” as the core content in the development of related research. The academic community conducted systematic research on the sources of LUCs(Wehrmann, 2008), the types of LUCs(von der Dunk et al., 2011), the identification of LUCs(Brown and Raymond, 2014; Groot, 2006), the evolution of LUCs(Delgado-Matas et al., 2015), the management of LUCs(Andrew, 2003; Petrescu-Mag et al., 2018) and so on.

In recent years, LUCs have become increasingly fierce due to specific social systems and policy environments, and are still receiving attention, such as those conflicts caused by traditional land tenure and ethnic composition (Kuusaana and Bukari, 2015), biodiversity conservation (Bircol et al., 2018), and integrated river basin management (Pacheco and Sanches-Fernandes, 2016). In addition, LUCs caused by globalization have become increasingly strong, becoming a new focus, such as the conflicts triggered by international population migration (McPeak and Little, 2018), the adjustment of international energy policies (Calvert and Mabee, 2015), and the change of international food planting structure (Petrescu-Mag et al., 2018). According to research trends, the manifestation, evolution process and reconciliation schemes of LUCs are still receiving continuous attention, but the research is focusing more on the “results” generated by conflicts and less on the “processes” of conflicts. There are relatively few simulation analyses of LUCs evolution scenarios. Conflict management also focuses on short-term economic benefits, neglecting the sustainable development of environmental resources. It is not appropriate here to expand on the theoretical system of LUCs and the promotion and application of relevant research results.

In the series of discussions on LUCs, the scientific identification of potential conflict zones is the basis and premise for preventing and resolving LUCs in accordance with local conditions. Multi-criteria analysis has become an important means of identifying potential conflict zones, and has included various identification criteria such as value criteria (Brown et al., 2014), functional criteria (Groot, 2006) and landscape criteria (Brown and Raymond, 2014). These criteria focus on the value and function of land use from an objective perspective, but ignore the rational demand for land resources from a subjective perspective. Since the development of most economies depends mainly on the natural supply of land resources at this stage, simply pursuing the objective effects of land use and ignoring the subjective needs of land use may lead to more complex conflict situations. Therefore, more reasonable evaluation criteria of land use need to be established to weigh the differential demands of development and protection. In fact, scholars have pointed out that successful conflict resolution should not only focus on the current impact of the economy, but also consider the sustainable needs of human society for the environment resources (Tudor et al., 2014).

As humans become more aware of environment resources, suitability criteria are widely used to analyze regional land use pattern change and to explore the impact of land use activities on nature, society and economy (Gong et al., 2012). In 1976, the United Nations Food and Agriculture Organization (FAO) formulated and promulgated the “Land Evaluation Outline”, which proposed that land use plans should be oriented to land suitability. Subsequently, countries around the world established their own evaluation systems with reference to this outline. After entering the 21st century, although the research objectives, methods and paradigms of land suitability evaluation have been continuously expanded and improved, no additional well-recognized evaluation indicators and methodologies have been formed (El Baroudy, 2016; Kalogirou, 2002). In general, land use is considered mainly to meet the needs of construction land, agricultural land and ecological land. When the multiple needs of land use overlap in space and cannot be coordinated and met, conflicts may occur (Wang et al., 2012). Therefore, how to construct an indicator system to evaluate the suitable pattern of construction land, agricultural land and ecological land, and then to identify the land use function (LUF) zones, is one of the problems to be solved in this paper.

The ultimate research goal of LUCs is to develop reasonable governance programs to promote coordinated regional development (Adam et al., 2015; Brown and Raymond, 2014). To this end, after identifying LUC zones, it is necessary to adopt a differentiated governance strategy in the future land use (Yu and Lv, 2006). Assessing whether these strategies can alleviate or eliminate conflicts needs to be tested through analyzing the land use scenarios (LUSs). Classic models offer many strategical options, such as the Logistic-CA model (Wu, 2002), the traditional ANN-CA model (Li and Yeh, 2002), the CLUE-S model (Verburg et al., 2002) and the FLUS model (Liu et al., 2017). The CA-Markov model is an effective method in simulating LUSs, because it can effectively predict the mutual conversion probability of land use types (LUTs) and simulate its spatial conversion pattern (Mondal et al., 2016; Yang et al., 2014).

When using the CA-Markov model to simulate LUSs, conversion rules of land use need to be formulated based on factors affecting land use change. In general, future land use changes are affected by both micro and macro factors. Micro factors include the current LUTs, the distance from the main road, the distance from the city center, the LUTs in the neighborhood, the landscape pattern and so on. Macro factors include land management policies (Milczarek-Andrzejewska et al., 2018), climatic conditions (Hunsberger et al., 2018), and socio-economic conditions (Hernik et al., 2013). Nevertheless, LUCs as a key factor guiding future land-use transitions have not received sufficient attentions. Studies have shown that LUCs are the result of the combined effects of various factors of land use, and different conflict states and governance objectives will lead to uncertainty in the evolution of LUSs (Brown et al., 2014; Brown and Weber, 2012). Therefore, establishing how to formulate land use change rules based on the differences between LUCs, to simulate future LUSs, and then guide the governance of LUCs is another problem that needs to be solved in this paper.

This paper is divided into six sections. Following this introduction, Section 2 introduces the materials and research framework. Section 3 describes the index systems of suitability evaluation, constructs the conflict identification and intensity diagnosis model and proposes the methodology of LUSs simulation. Section 4 empirically analyzes the LUCs and simulates LUSs. Section 5 discusses the empirical results and Section 6 concludes the research.

2. Research data and research framework

2.1. Study area

Nan'an City is located in the central part of Fujian Province in the hinterland of southeast China, across the sea from Taiwan. The city's geographical coordinates are 24°34′30″-25°19′25″north latitude and 118°08′30″-118°36′20″ east longitude. The terrain is low in the south and high in the north. The city has a southern subtropical monsoon climate; the annual average temperature is 18°C–21 °C, and the average annual rainfall is 1620 mm. The soil types mainly include red soil, latosolic red soil, moist soil and paddy soil. The forest coverage rate is 53.2%, and the vegetation is mainly Pinus massoniana forest, Chinese fir forest, coniferous and broad-leaved mixed forest and a small amount of bamboo forest. During the 12th Five-Year Plan period, the revenue of the general public budget of Nan'an City grew at an average annual rate of 10.6%, and financial resources grew at an average annual rate of 6.7%. In 2016, the city's GDP was 89.8 billion yuan, industrial added value was 49.5 billion yuan, industrial output value above designated size was 183.2 billion yuan, and investment in fixed assets of the whole society was 55.8 billion yuan (data from Nan'an Statistical Yearbook). Nan'an ranks 31st among the top 100 comprehensive strengths in small and medium-sized cities across the country.

2.2. Data sources and processing

Data sources mainly include data on land use in 2005, 2009 and 2015 in Nan'an, the General Land Use Planning of Nan'an City (2006–2020), Classification Results of Agricultural Land in Nan'an (2009), Plan of Centralized Drinking Water Protection Area in Nan'an, the 13th Five-Year Plan for Tourism Development and the Statistical Yearbook in Nan'an City (2016), water and soil loss interpretation map for Nan'an in 2011, distribution of geological disaster point map for Nan'an in 2015, and DEM data at 30 m resolution from the international service platform for scientific data. According to the research purpose, land is classified into three categories, namely, construction land, agricultural land, and ecological land. Subsequently, construction land was classified into urban land (LUT_1), rural residential land (LUT_2) and other construction land (LUT_3), agricultural land was classified into cultivated land (LUT_4) and orchard (LUT_5), and ecological land was classified into forest (LUT_6), water (LUT_7) and unused land (LUT_8), as shown in Fig. 1. The above vector layer was converted into a 100 m $\times$ 100 m raster layer as a minimum evaluation unit.

2.3. Research framework

To identify the LUCs and simulate the LUSs, we developed a research framework as Fig. 2. Firstly, this paper constructed the index systems of suitability evaluation of three land use categories. Secondly, the suitability of three land use categories were evaluated by the constructed index systems. Thirdly, the suitability was divided into three levels, and the LUC zones were identified according to the permutation and combination law. Lastly, the LUSs are simulated according to the land use change probabilities by the CA-Markov model.

3. Research process and methods

3.1. Construction of the land use suitability evaluation model

3.1.1. Constructing the index systems of land use suitability evaluation

Based on a literature analysis, this paper constructs the index systems for the suitability evaluation of construction land, agricultural land and ecological land according to natural factors, location factors, social factors and policy factors. Natural factors reflect the background conditions of land use and are the basic factors determining the land use suitability. The location factors reflect the spatial driving force of land use. Social factors represent the social and economic driving forces of land use. The policy factors indicate the planning direction of land use.

Among the suitability evaluation indicators of construction land in Table 1, terrain index (*TI*) is a combination of elevation and slope expressed as a numerical indicator that reflects the overall spatial differences in geomorphic conditions (Wischmeier and Smith, 1978). The formula is expressed as follows:

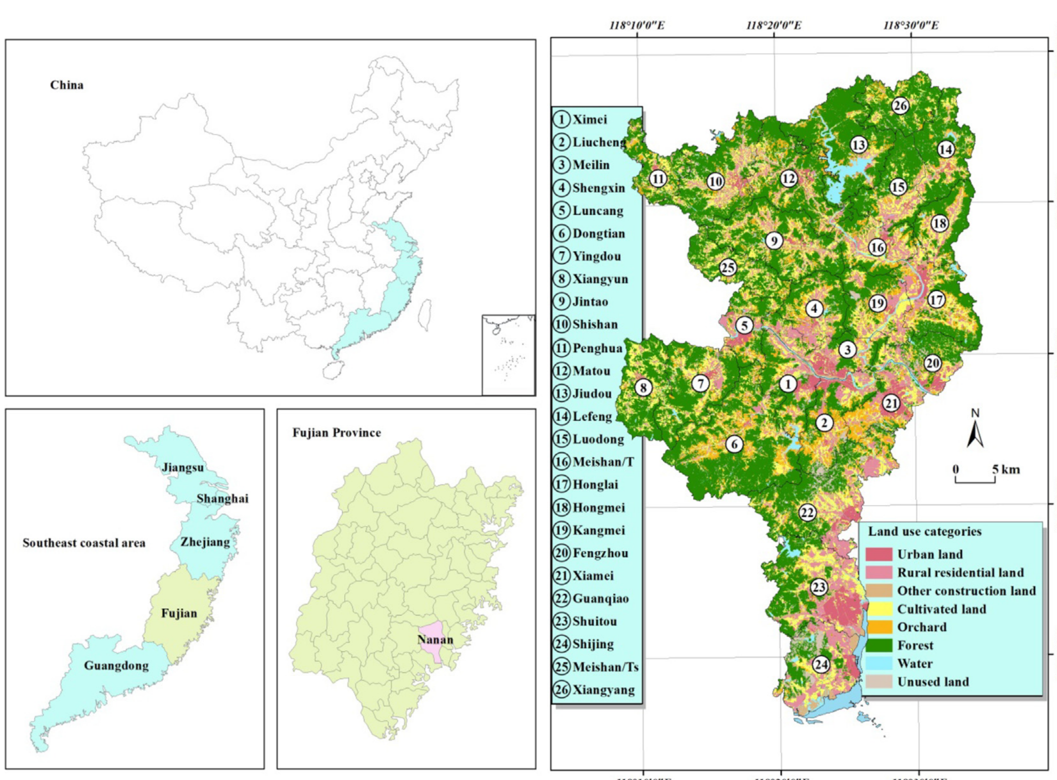

Fig. 1. Research location and land use status map in 2015.

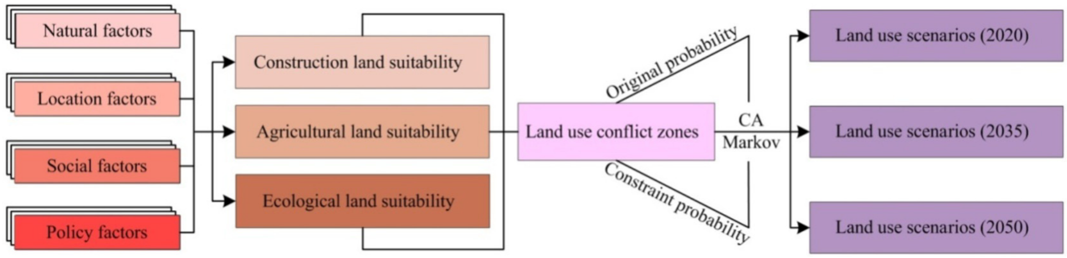

Fig. 2. The general framework of this study.

Table 1
Suitability evaluation indexes, graded values and weights of construction land.

Factors (weights)	Indexes			Index grading and score				
	Indexes	Value	Weights	100	80	60	40	20
Natural factors (0.182)	*FBC*	*kPa*	0.196	> 250	180–250	120–180	60–120	≤60
	TI	/	0.375	≤0.53	0.53–0.73	0.73–0.90	0.90–1.06	> 1.06
	GDP	*m*	0.252	> 1000	750–1000	500–750	250–500	≤250
	RIV	*m*	0.177	≤200	200–500	500–1000	1000–2000	> 2000
Location factors (0.329)	*TOW*	*m*	0.356	≤250	250–500	500–1000	1000–2000	> 2000
	VIL	*m*	0.176	≤200	200–500	500–1000	1000–1500	> 1500
	RAC	*m*	0.291	≤100	100–250	250–500	500–1000	> 1000
	RCT	*m*	0.177	≤50	50–100	100–200	200–500	> 500
Social factors (0.233)	*LUR*	*%*	0.402	Higher	High	General	Low	Lower
	AER	*%*	0.269	Larger	Large	General	Small	Smaller
	CAI	*%*	0.329	More obvious	Obvious	General	Not obvious	Less obvious
Policy factors (0.256)	*TDO*	/	0.212	Economic development leading area		Agricultural production leading area		Ecological conservation leading area
	LPZ	/	0.472	Construction zone	General agricultural zone	Forestry zone	Basic farmland zone	Ecological safety control zone
	RCC	/	0.316	Central town village	Priority development village	Conditional development village	Restricted development village	Demolition and merger village

$$T = \lg\left[\left(\frac{E}{\overline{E}}+1\right)\right]\left[\left(\frac{S}{\overline{S}}+1\right)\right] \tag{1}$$

where T is the terrain index, E is the elevation value, $\overline{E}$ is the average elevation value, S is the slope value and $\overline{S}$ is the average slope value. The bigger the index is, the worse the suitability is. Because construction land is the main place for human production and life, and the foundation bearing capacity (*FBC*) has been taken account in the indexes, the closer the river is, the more suitable of construction land is, thereby the weight is higher. The land urbanization rate (*LUR*) refers to the process of urban areas moving to rural areas, and the land conversion from non-urban land to urban land, which is measured by the proportion of urban land area to total land area (Long et al., 2009). The comparative advantage index (*CAI*) is the ratio of the average output value of construction land to agricultural land. A greater ratio indicates a stronger construction land suitability.

In the suitability evaluation index of agricultural land in Table 2, as the high-quality farmland mainly distributes around towns, villages and roads, the closer it is to them, the more suitable it is for agriculture. The location entropy of per capita agricultural land area (*ALA*) refers to the ratio of the per capita arable area of the agricultural population in the region to the study area. A greater value indicates stronger comparative advantage in agricultural development. The land scale operation index (*LSI*) is the ratio of land transfer area to the total cultivated land area. A greater value indicates a higher land scale degree and a better agricultural land suitability. Agricultural subsidies are important economic policies for the protection of agricultural land, including funds of farmland protection, direct subsidies for grain production, improved seed subsidies, soil testing and fertilizer recommendation and other related subsidies.

In the suitability evaluation index of ecological land in Table 3, landscape fragmentation degree (*LFD*) reflects the degree of ecosystem disturbance by human activity, and is characterized by Area Weighted Mean Shape Index (AWMSI). As the East River and West River are the core areas of ecological protection and water source protection in Nan'an City, the closer to them, the stronger the ecological suitability. In addition, because the ecological land has agglomeration and radiation effects, as the evaluation unit becomes closer to the ecological patch, the ecological suitability increases. Those patches with internal homogeneity and the ability to expand around themselves or spread are referred to as "sources" (Knaapen et al., 1992). According to the land use status, they are identified as "ecological sources", and include main river trunks, reservoirs with an area larger than 20 hm^2 and forest areas with an area larger than 300 hm^2.

3.1.2. Index numerical quantification, grading assignment and weight determination

Due to the varying natures of the indicators, the methods of quantification and grading assignment are different. Indexes of town development orientation (*TDO*), rural comprehensive consolidation types (*RCC*), land use planning zones (*LPZ*), land consolidation types (*LCT*), soil erosion intensity (*SEI*), water source protection zones (*WPZ*), and land use types (*LUT*), use classification assignments. For the indexes of distance from the geological disaster points (*GDP*), slope (*SIO*), distance from the East River or West River (*E&W*) and location factors including the distance from towns (*TOW*), villages (*VIL*), roads (*ROA*), rivers (*RIV*) and the distance from the nearest ecological sources (*NES*), and the *ROA* is

Table 2
Suitability evaluation indexes, graded values and weights of agricultural land.

Factors (weights)	Indexes			Index grading and score				
	Indexes	Value	Weights	100	80	60	40	20
Natural factors (0.356)	*NQI*	/	0.371	> 3800	3500–3800	3200–3500	2900–3200	≤2900
	APA	/	0.151	Larger	Large	General	Small	Smaller
	SLO	°	0.203	≤2°	2°–6°	6°–15°	15°–25°	> 25°
	RIV	*m*	0.275	≤200	200–500	500–1000	1000–2000	> 2000
Location factors (0.153)	*TOW*	*m*	0.223	≤200	200–500	500–1000	1000–2000	> 2000
	VIL	*m*	0.316	≤100	100–250	250–500	500–1000	> 1000
	RAC	*m*	0.202	≤200	200–500	500–1000	1000–1500	> 1500
	RCT	*m*	0.259	≤100	100–250	250–500	500–1000	> 1000
Social factors (0.227)	*ALA*	%	0.212	Larger	Large	General	Small	Smaller
	AEC	/	0.472	> 0.33	0.29–0.33	0.25–0.29	0.20–0.25	≤0.20
	LSI	%	0.316	Larger	Large	General	Small	Smaller
Policy factors (0.264)	*LPZ*	/	0.425	Basic farmland zone	General agricultural zone	Forestry zone	Ecological safety control zone	Construction zone
	LCT	/	0.326	Basic farmland consolidation area	General farmland consolidation area	Land development zone	Land reclamation area	Other areas
	AS	/	0.249	≥4 kinds	3 kinds	2 kinds	1kind	None

Table 3
Suitability evaluation indexes, graded values and weights of ecological land.

Factors (weights)	Indexes			Index grading and score				
	Indexes	Value	Weights	100	80	60	40	20
Natural factors (0.356)	*LUT*	/	0.355	Water, forest	Cultivated land, orchard	Unused land	Other construction land	Urban land, rural residential land
	SEI	/	0.159	Mild	Moderate	Intense	More intense	Extreme
	LFD	/	0.195	Better	Good	General	Poor	Worse
	E&W	*m*	0.291	≤100	100–250	250–500	500–1000	> 1000
Location factors (0.192)	*TOW*	*m*	0.168	> 2000	1000–2000	500–1000	250–500	≤250
	VIL	*m*	0.206	> 1000	500–1000	250–500	100–250	≤100
	ROD	*m*	0.251	> 500	200–500	100–200	50–100	≤50
	NES	*m*	0.375	≤200	200–500	500–1000	1000–2000	> 2000
Social factors (0.160)	*FCR*	%	0.402	Higher	High	General	Low	Lower
	PCT	%	0.269	Higher	High	General	Low	Lower
	CAI	%	0.329	Less obvious	Not obvious	General	Obvious	More obvious
Policy factors (0.292)	*LPZ*	/	0.257	Ecological safety control zone	Forestry zone	General agricultural zone	Basic farmland zone	Construction zone
	WPZ	/	0.571	Primary water source		Secondary water source		
	ES	/	0.172	Yes				No

divided into distance from roads above county level (*RAC*) and distance from roads at county and township level (*RCT*) in construction and agricultural suitability assessment, a spatial analysis function in a GIS is firstly used to obtain the actual value of each evaluation unit, and then a value is assigned according to expert experiences and reference literature. The indicator values of social factors including *CAI, ALE*, *LSI,* non-agricultural employment ratio (*AER*), forest cover rate (*FCR*), pollutants concentrated treatment rate (*PCT*) are obtained by querying the statistical yearbook, and the graded assignments are based on cluster analysis. The natural quality index (*AQI*) and utilization and economic coefficients (*AEC*) of agricultural land come from the Results of Grading Agricultural Land in Nan'an in 2009. The former is graded by the equal difference series method, and the latter is graded by the natural break point method, which is a statistical method of grade and classification according to the law of numerical statistical distribution. To obtain the terrain index, we first calculate the actual value of each evaluation unit by using the corresponding formula, and then use the natural break point method to grade the value. To get the average patch area (*APA*) of farmland and *LFD*, we firstly use Fragstats software to calculate the actual value, and then classify the assignment based on cluster analysis. Agricultural subsidies (*AS*) and ecological subsidies (*ES*) are classified and evaluated according to the number of types of actual subsidies. Weights are determined by Analytic Hierarchy Process (AHP). AHP provides a rational framework for constructing decision-making problems, quantifying representation elements and overall goals, and evaluating alternative solutions; it is often used to deal with complex issues involving human perception and judgment (Aburas et al., 2017; Cay and Uyan, 2013).

3.1.3. Calculating the land use suitability score of grid cells

The suitability scores of the evaluation units of different LUTs are calculated by the weight-adding model. The specific formula is:

$$F_{i,j} = \sum \left(w_{i,factor} \cdot w_{i,index} \cdot f_{i,score} \right) \quad (2)$$

Here, $F_{i,j}$ is the suitability score of the *i* evaluation unit, and the symbol *j* represents construction land, agricultural land or ecological land. The larger the value of $F_{i,j}$, the stronger the suitability. $w_{i,factor}$ is the factor weight of the *i*-the valuation unit, $w_{i,index}$ is the index weight of the *i* evaluation unit, and $f_{i,score}$ is the index score of the *i* evaluation unit.

3.2. Conflict identification and intensity diagnosis of land use

Conflict identification and intensity diagnosis of land use are mainly determined by the empirical model in Fig. 3. The specific steps are as follows. Firstly, according to the evaluation unit score, we use the natural break point method to classify the suitability of construction land, agricultural land and ecological land into three levels: strong, medium and weak. Secondly, according to the suitability levels, the 27 combinations are obtained. Thirdly, by comparing the suitability level and combination mode in different combination relations, the land use category with the strongest level is selected as the dominant land, and the conflict intensity is divided into seven levels (no conflict, milder conflict, mild conflict, moderate conflict, intense conflict, more intense conflict, extreme conflict). Finally, the conflict zones are named by the method of “dominant land + conflict intensity”, and 16 types of LUCs are obtained, comprising the three land use categories with no conflict zones(I), three land use categories milder conflict zones (II), construction land dominating mild conflict zones (III_1), agricultural land dominating mild conflict zones (III_2), ecological land dominating mild conflict zones (III_3), construction land and agricultural land dominating moderate conflict zones (IV_1), construction land and ecological land dominating moderate conflict zones (IV_2), agricultural land and ecological land dominating moderate conflict zones (IV_3), three land use categories with moderate conflict zones (IV_4), construction land dominating intense conflict zones (V_1), agricultural land dominating intense conflict zones (V_2), ecological land dominating intense conflict zones (V_3), construction land and agricultural land dominating more intense conflict zones (VI_1), construction land and ecological land dominating more intense conflict zones (VI_2), agricultural land and ecological land dominating more intense conflict zones (VI_3), and three land use categories extreme conflict zones (VII).

3.3. Land use scenario simulation

In this paper, the CA-Markov model is used to simulate future LUSs following the steps in Fig. 4. Firstly, the original probability matrix is obtained by the Markov model, and the relative probability matrix is determined relying on the expert experience. Secondly, the original probability and the relative probability are merged to form the constraint probability matrix and the suitability atlas. Finally, the prepared data are input into the test model, and the results are exported. It should be noted that, in order to implement land macro-control and land-use control, China has compiled comprehensive land-use planning since 1986, in which 15 years is taken as one planning period. The base period of current plan is 2005, and the planning period is from 2006 to 2020. In 2009, China released the second land use survey data. To link with the data, the base period of current round planning was updated from 2005 to 2009. Therefore, this paper chooses to simulate the LUSs at the end of three future planning periods: 2020, 2035 and 2050, based on data for 2009 and 2015. In addition, to assess the feasibility of predicted land use pattern evolution under conflict constraints, two scenarios using the original probability and constraint probability are compared; these are defined as unsustainable land use scenarios (ULUS) and sustainable land use scenarios (SLUS), respectively.

3.3.1. Using the Markov model to calculate the original probability matrix of land use change

The Markov model is a method to predict the probability of occurrence, and is generally used to predict the evolution of geographic events that have no after-effects. Specifically, the probability distribution of next state depends only on the current state and not on the previous state (Mondal et al., 2016). The selected case area meets the basic requirements of the Markov model: 1) LUTs in the case area can be transformed from one type to another; 2) the mutual transformation of LUTs is difficult to accurately describe because of random events; and 3) the conversion state of LUTs was relatively stable during the study period. The original probability matrix of land use change in the three periods, obtained by the Markov model calculation, is shown in Table 4 (only the conversion probability of 2020 is listed in the paper).

3.3.2. Reliance on expert experience to determine the relative probability matrix of land use change

Because the spatial distribution, land composition, conflict manifestation and intensity of individual LUC zones are different, the theoretical trend of land use change should be variable. In order to express this difference quantitatively, the AHP method is used to determine the relative probability of various LUTs in different conflict zones: that is, the probability that other LUTs will be converted into designated LUTs. The results are shown in Table 5, and the specific steps are as follows. Firstly, the transfer probability of LUTs is set to 1, 2, 3, 4, 5, where 1 → 5 indicates that the relative probability of another LUTs converting to the specified type is

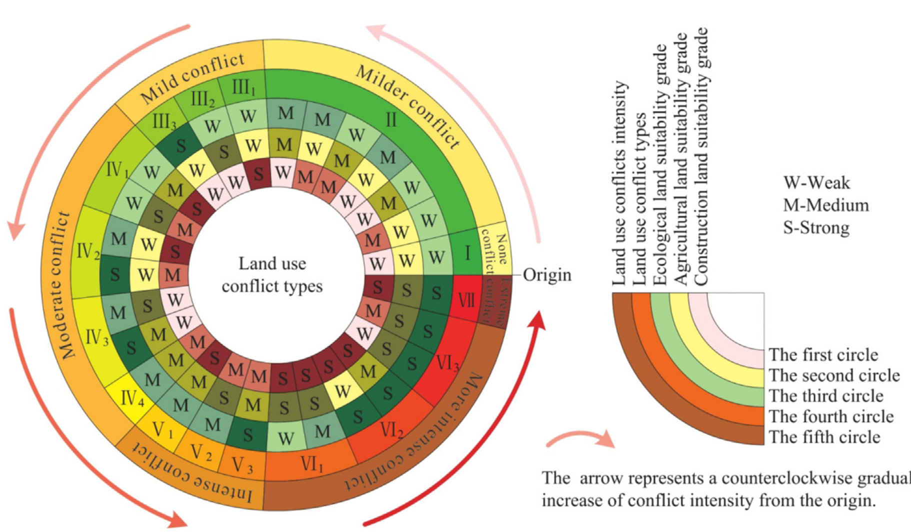

Fig. 3. Empirical model for conflict identification and intensity diagnosis of land use. The color deepens gradually, it represents the suitability grade or conflict intensity is gradually increasing.

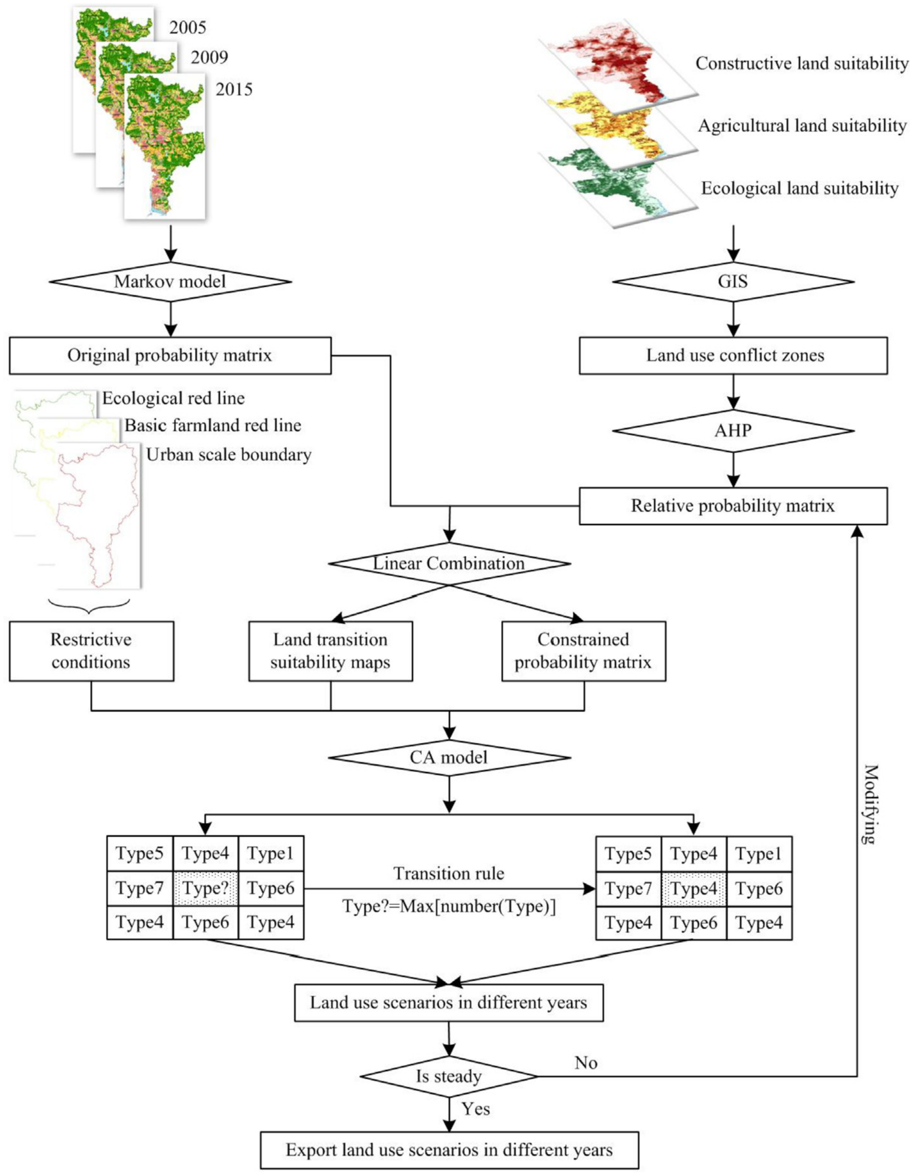

Fig. 4. Flow chart for the CA-Markov model.

Table 4
Original probability matrix of land use change from 2015 to 2020 in Nan'an.

LUTs	LUT_1	LUT_2	LUT_3	LUT_4	LUT_5	LUT_6	LUT_7	LUT_8
LUT_1	**0.9412**	0.0114	0.0116	0.0245	0.0040	0.0049	0.0021	0.0003
LUT_2	0.0046	**0.8784**	0.0114	0.0736	0.0131	0.0134	0.0033	0.0022
LUT_3	0.0212	0.0514	**0.7943**	0.0438	0.0208	0.0433	0.0153	0.0099
LUT_4	0.0156	0.0584	0.0210	**0.8235**	0.0248	0.0467	0.0050	0.0050
LUT_5	0.0061	0.0360	0.0171	0.0626	**0.7881**	0.0780	0.0036	0.0084
LUT_6	0.0018	0.0067	0.0060	0.0183	0.0143	**0.9438**	0.0015	0.0075
LUT_7	0.0091	0.0199	0.0199	0.0284	0.0144	0.0353	**0.8554**	0.0175
LUT_8	0.0138	0.0310	0.0149	0.0816	0.0161	0.1120	0.0233	**0.7073**

Note: numbers represent the proportion of LUTs in rows converted to LUTs in columns.

gradually increasing. Secondly, 21 experts in the fields of land management, land planning and ecological science research were invited to score the change probability of LUTs in each conflict area, by following the principle of "distribution-land type-performance-intensity" of LUCs and the theoretical trends of land use change shown in Table 7, and each invited expert provided a relative probability matrix. Then, following the reliability dependence method of group decisions proposed by Xiong et al. (2004), the consensus matrix of all experts was calculated (to test for consistency, the calculated $CR = 0.0102 < 0.1$, which is significant), and adopted as the relative probability matrix of land use change under conflict constraints. Finally, linear combination was used to combine the original probability and the relative probability into the constraint probability matrix, thus creating the suitability atlas of land use change.

3.3.3. *The combination of Markov model and CA model*

The CA model is a dynamic grid model with spatial interaction and temporal causality (Li et al., 2013). The model can effectively reveal the changing interaction between LUTs and is widely used to simulate urban development and spatial pattern evolution of regional land use. This paper uses a filter of 3×3 size, that is, each cell unit is affected by 8 units of the surrounding neighborhood. Accordingly, the LUT of the cell unit shifts to the type of the highest

Table 5
Relative probability matrix of land use change based on expert experience.

Number	Land use suitability			LUF types	Relative probability of land use conversion							
	Constructive	Agricultural	Ecological		LUT_1	LUT_2	LUT_3	LUT_4	LUT_5	LUT_6	LUT_7	LUT_8
1	W	W	W	I	1.007	1.086	1.043	1.233	1.203	1.544	1.121	1.027
2	M	W	W	II	1.109	1.124	1.258	1.123	1.085	1.003	1.567	1.045
3	W	M	W		1.086	1.422	1.336	1.884	1.886	1.542	1.276	1.059
4	W	W	M		1.007	1.074	1.250	1.247	1.336	2.389	2.057	2.006
5	M	M	W		1.105	1.212	1.258	1.357	2.887	2.408	2.027	2.006
6	M	W	M		1.552	1.875	1.258	1.045	1.174	2.578	2.643	1.058
7	W	M	M		1.027	1.143	1.175	1.965	2.350	2.041	2.687	1.324
8	S	W	W	III_1	3.249	3.600	2.475	1.121	1.050	1.351	1.249	1.107
9	W	S	W	III_2	1.059	1.123	1.256	3.688	3.945	2.420	2.275	2.063
11	W	W	S	III_3	1.004	1.007	1.203	1.258	1.365	4.684	4.652	2.270
11	S	M	W	IV_1	3.214	3.325	2.276	2.185	2.027	1.965	1.682	1.175
12	M	S	W		2.356	2.449	2.215	3.070	3.116	2.204	1.766	1.352
13	S	W	M	IV_2	2.125	2.320	1.745	1.006	1.203	2.236	2.254	1.351
14	M	W	S		1.544	1.690	1.673	1.233	1.233	3.255	3.286	2.450
15	W	S	M	IV_3	1.045	1.203	1.447	3.850	3.291	2.047	2.586	2.554
16	W	M	S		1.007	1.112	1.175	1.038	1.255	3.627	3.025	2.384
17	M	M	M	IV_4	1.027	1.154	1.154	1.229	1.202	1.357	1.186	1.163
18	S	M	M	V_1	2.420	2.556	2.605	1.434	2.021	2.569	2.408	1.333
19	M	S	M	V_2	1.784	1.452	1.170	3.558	2.479	2.278	2.692	1.645
21	M	M	S	V_3	1.175	1.175	1.682	1.694	1.853	3.649	3.020	2.686
21	S	S	W	VII_1	3.677	3.546	2.793	3.247	3.188	1.052	1.043	1.059
22	S	S	M		2.438	2.362	1.524	2.887	2.140	2.523	1.264	1.422
23	S	W	S	VII_2	2.385	2.327	1.357	1.336	1.203	3.286	3.325	2.784
24	S	M	S		2.027	2.387	2.215	1.965	1.105	3.214	3.025	2.320
25	W	S	S	VII_3	1.121	1.243	1.552	2.047	2.356	3.546	3.546	2.340
26	M	S	S		1.074	1.175	1.337	2.356	2.218	3.214	3.207	2.356
27	S	S	S	VIII	1.542	1.058	1.247	1.059	1.045	4.248	4.086	3.850

Note: W, M, S refer to the abbreviation of weak, medium and strong, respectively. Numbers represent the probability of another LUTs converting to the specified LUTs.

number of surrounding cells. If several neighboring cells have the same number, the change direction is determined according to the number of the 16 neighboring cells around the 8 cells, and so on. In addition, China emphasizes spatial zoning control through the overall land use planning. For example, the scope of urban land, basic farmland and ecological land cannot cross the boundaries of urban areas, the red line of basic farmland protection and the red line of ecological protection. Accordingly, this paper regards these three types of boundaries as restrictions on land use change.

3.3.4. *Validity test of simulation results*

In order to test the validity of results, LUSs in 2015 were simulated using data for 2005 and 2009, and then it was compared with the real land use in 2015. Fig. 5 showed that the average relative error of area proportion of simulated land use and actual one was less than 5%; the relative error for urban land (LUT_1) was the smallest, and rural residential land (LUT_2) and other construction land (LUT_3) was the largest. These characteristics resemble the simulation results of mountain land by Sang et al. (2011), thus verifying that the CA-Markov model is effective in predicting future land use change. However, the change in area does not reflect the spatial structure of land use. Since landscape indicators can describe the spatial pattern of land use and reflect the key aspects of spatial form, the landscape indexes were used to test the validity

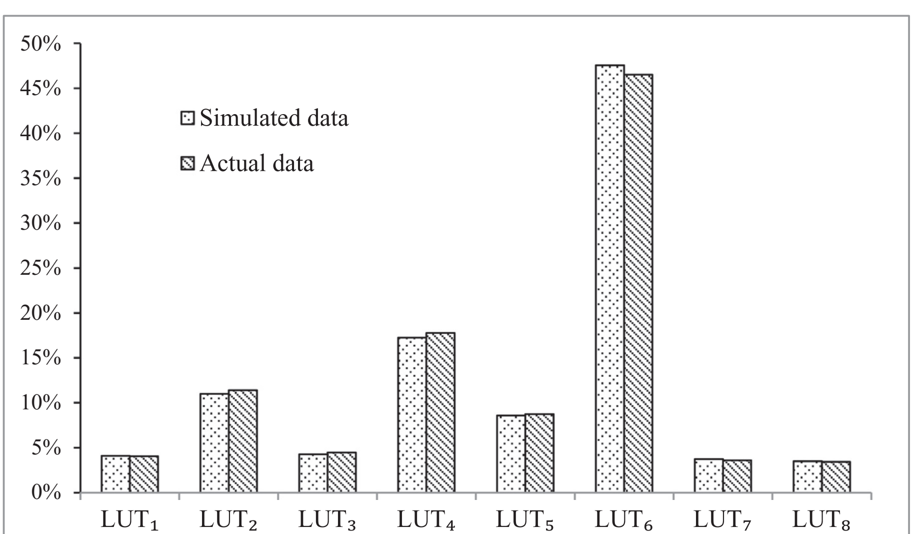

Fig. 5. Simulated change versus actual change of LUTs in 2015.

of the CA model. The fractal dimension (FD) and mean shape index (MSI) were selected to compare between the actual situation and simulation results. Fig. 6 showed that the difference of FD and MSI between the actual situation and the simulation results is evidently small, which indicated that the landscape patterns in the simulation and in reality show good consistency, thereby demonstrating that the CA model is highly capable of simulating the land-use pattern. Therefore, the CA-Markov model can be used to predict future spatial patterns of land use.

4. Results

4.1. Land use suitability distribution characteristics

Through the land use suitability evaluation model, the spatial distribution characteristics and areal proportions of construction land, agricultural land and ecological land use in Nan'an in 2015 were obtained. Fig. 7 shows that the spatial gradient characteristics and agglomeration characteristics of different suitability levels of construction land are more significant and spatial connectivity is better than others. The strong grade land is mainly distributed in the central West River Basin, the southern coastal zone and the northern East River and Luoxi River watersheds. The weak grade land is mainly distributed in Dongtian Town, Xiangyun Town and Meishan Township in the west and Jiudu Town, Fengzhen Town and Xiangyang Township in the north. From Table 6, the proportions of strong, medium and weak grades of construction land suitability are 20.22%, 35.48% and 44.30% respectively. The proportion of strong grade land is much lower than the land urbanization rate (48.24%), indicating that large areas of medium and weak grade land were converted to construction land. From the perspective of LUTs, the strongest area of rural residential land is 7.85%, followed by urban land 3.94%, cultivated land 3.08%, and forest land 1.71%, indicating that urban and rural residential land is still the main area having high suitability for construction land in Nan'an; at the same time, the change probability of cultivated land and forest to construction land is still high, suggesting that there may be fierce competition and conflict regarding land use in Nan'an.

Fig. 7 shows that the spatial distribution of different suitability grades of agricultural land is relatively more dispersed, the fragmentation degree is higher and the spatial connectivity is poor, compared to those of construction. Overall, the different grades are evenly distributed throughout the area, and mixed together locally. This is mainly because Nan'an is located in the hilly area of the southeast coast, and the agricultural land suitability is obviously restricted by the topography. From Table 6, the proportions of strong, medium and weak grades of agricultural land suitability are 14.40%, 34.05% and 51.55% respectively. The proportion of strong land use area is smaller than the proportion of agricultural land (26.27%). This shows clearly that a large area of agricultural land in Nan'an is not suitable for agricultural cultivation, or that agriculture is in an over-developed state. From the perspective of LUTs, the proportion of cultivated land in high-grade agricultural land is 12.94%, which indicates that China's current farmland protection policy has achieved good results. The quantitative structural characteristics of agricultural land suitability on the one hand reflect that the agricultural economy still occupies an important position in the current Chinese social economy; on the other hand, they reveal that the rapid urbanization promotion since the reform and opening up has begun to endanger the development and protection of cultivated land.

Fig. 7 shows that the spatial agglomeration characteristics and spatial connectivity of different suitability grades of ecological land lie intermediate between those of construction suitability and agricultural suitability, and are complementary with the spatial distribution of construction land suitability. Specifically, the strong grade land is mainly distributed in Dongtian Town, Xiangyun Town and Yingdu Town in the west and Jiudu Town, Lefeng Town and Xiangyang Township in the north. These areas are at high altitude or in important water source areas, and the land has difficult or restricted development and utilization. The weak grade land is mainly distributed in the central West River Basin, the southern coastal zone and the northern East River and Luoxi River Basins. These areas are economically active and have a high degree of land development and utilization. From Table 6, the proportions of strong, medium and weak grades of ecological land suitability are 44.00%, 30.85% and 25.15% respectively, indicating that the ecological environment in Nan'an is generally good, but since the proportion of strong ecological land is lower than the actual ecological land (53.95%), indicating that the ecological environment is challenged to some extent. From the perspective of LUTs, the proportion of forest in strong ecological land is 39.20%, indicating

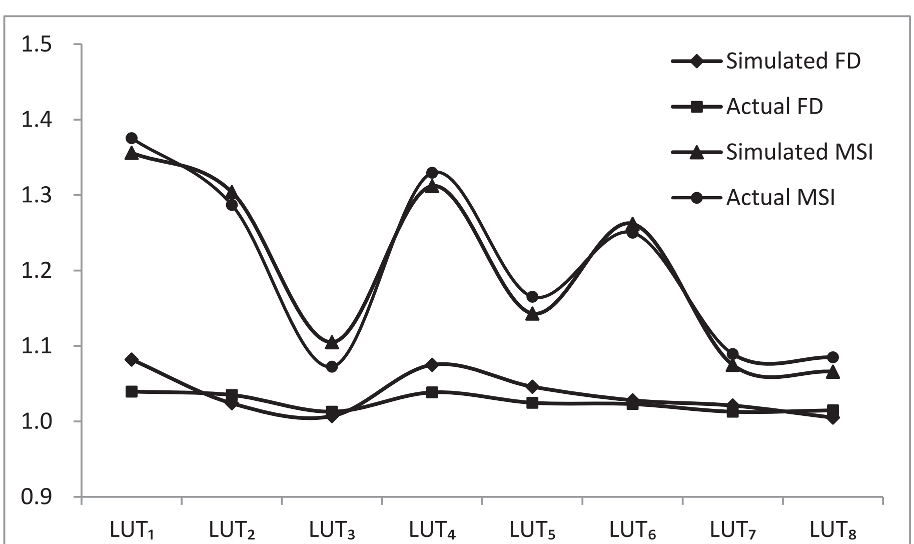

Fig. 6. Comparison of simulated and actual spatial pattern changes of LUTs in 2015.

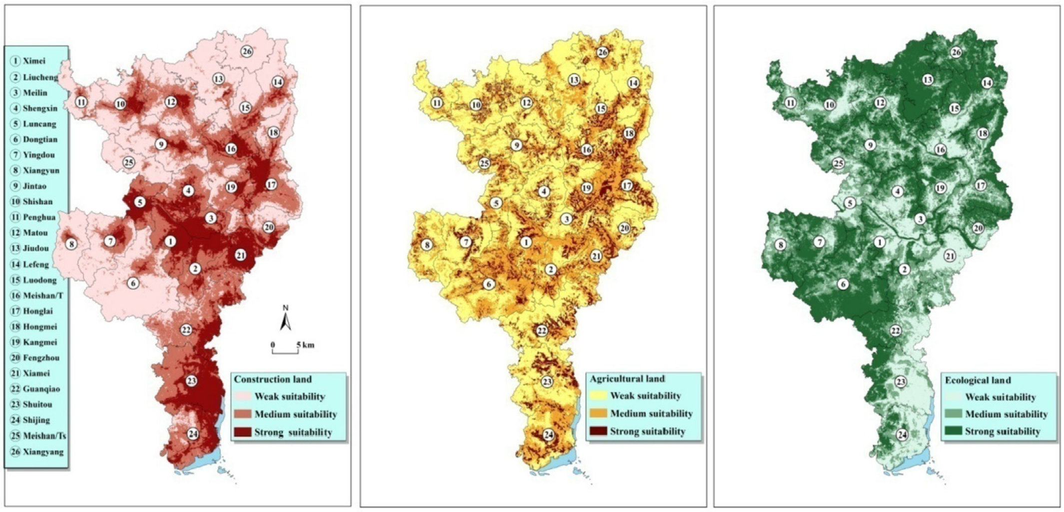

Fig. 7. Spatial distribution of construction land, agricultural land and ecological land suitability in Nan'an City. The grades are drawn according to the suitability scores which are divided by natural break point method.

Table 6
Area proportions of construction land, agricultural land and ecological land suitability in Nan'an City.

LUTs	Constructive land suitability			Agricultural land suitability			Ecological land suitability		
	Strong	Medium	Weak	Strong	Medium	Weak	Strong	Medium	Weak
LUT_1	3.94	0.07	0.00	0.02	1.97	2.01	0.02	0.21	3.77
LUT_2	7.85	3.26	0.24	0.09	5.63	5.63	0.08	0.81	10.46
LUT_3	1.57	2.14	0.71	0.13	2.05	2.23	0.11	0.89	3.42
LUT_4	3.08	8.16	6.22	12.94	4.42	0.10	0.83	12.35	4.28
LUT_5	1.37	4.97	2.47	0.94	5.88	1.99	0.97	6.98	0.86
LUT_6	1.71	14.79	30.35	0.18	11.69	34.97	39.20	7.59	0.05
LUT_7	0.53	1.34	1.74	0.09	1.96	1.55	2.48	1.01	0.12
LUT_8	0.17	0.75	2.57	0.01	0.43	3.06	0.31	1.01	2.17
Total (%)	20.22	35.48	44.30	14.40	34.05	51.55	44.00	30.85	25.15

that forest is the best for ensuring regional land use ecological security. The areas of cultivated land and orchard in medium-grade land are 12.35% and 6.98% respectively, and this has important significance to the regional land use ecological security.

4.2. Land use conflict status and its theoretical transformation trend

The spatial distribution characteristics of LUC zones in Nan'an can be obtained via the empirical model of Fig. 3. According to Fig. 8 and the field investigation, it was found that the spatial distribution, land composition, conflict performance and conflict intensity of different LUC zones were quite different. The I accounts for 2.04% and are scattered across all areas except the central townships; the corresponding LUTs are mainly unused land, other construction land (mainly for funeral land) and rural residential land. Due to the low level of human development and utilization, there is generally no land use conflict, so the current land use pattern can be maintained.

The II accounts for 18.24%, and shows the distribution characteristics of “global dispersion, local agglomeration”. LUTs are diverse and the area proportions of construction land, agricultural land and ecological land are similar. The increase in the degree of land development and utilization by humans has led to weak conflicts, which are manifested by mutual interference between construction land, agricultural land and ecological land. Land use can be appropriately shifted to a higher degree of suitability, but given the needs of sustainable development, ecological land is preferred under the same suitability level.

The III_1 accounts for 5.74% and is concentrated in the economically developed areas of central and southern Nan'an. LUTs are mainly urban land and rural residential land. The conflict is manifested by the expansion of rural residential areas into agricultural land and ecological land. Due to the strong suitability of construction land in the area, residential areas can be appropriately expanded according to the overall land use planning. The III_2 accounts for 0.38%, and is limited to some marginal towns. LUT is mainly cultivated land, and the conflict manifests itself as the intrusion of human agricultural production into the surrounding ecological land. The land use in this area should take advantage of agricultural planting, by scientifically and rationally developing the cultivated land resources. The III_3 accounts for 24.56%, and are mainly concentrated in the western and northern regions where the economy is more basic. LUTs are dominated by forest and water, and the conflict is manifested as the contradiction between ecological protection and development. New construction land should be strictly prohibited in this district, to strengthen ecological protection; the policy of returning farmland to forests should be implemented; and residents should be encouraged to gradually withdraw through the increasing vs. decreasing balance policy.

The IV_1 accounts for 9.62%, and is interlaced with the III. LUTs are mostly construction, followed by cultivated land. The conflict is manifested as the contradiction between the expansion of construction land and the protection of cultivated land. The land use in

Table 7
The land use conflict status and the theoretical trend of land use change.

Types		Spatial distribution	Land composition	Conflict performance	Conflict intensity	Land use change trend
I		Sporadic distribution	Unused land, other construction land, rural residential land	No land use conflict	No	Maintain current land use patterns
II		Global dispersion, local agglomeration	Three land use categories are not much different	Mutual interference between three land use categories	Milder	Appropriately change to higher suitability within the scope determined by spatial planning, but ecological land is preferred under the same suitability
III	III_1	Centralized distribution in developed areas	Urban land, rural residential land	Residential land expansion affects agricultural land and ecological land	Mild	Settlement land can be moderately expanded according to the overall land use plan
	III_2	Partially distribution in some marginal towns	Cultivated land	Invasion of human agricultural production to the surrounding ecological land		Take advantage of agricultural planting and scientifically develop cultivated land resources
	III_3	Centralized in backward area	Forest, water	The contradiction between ecological protection and development and construction		Forbid development of construction land, to strengthen ecological protection; implement the policy of returning farmland to forests; and encourage residents to gradually withdraw through the increasing vs. decreasing balance
IV	IV_1	Intertwined with the III_1	Construction land mostly, followed by cultivated land	The contradiction between construction land expansion and cultivated land protection	Moderate	Moderate increase in urban land of economically more advance towns, while agriculture-lead towns also needed to guarantee agricultural security
	IV_2	Between ecological and construction advantage zone	Forest dominated and a small amount of aquaculture	Construction land's invasion of ecological land under the drive of economic benefits		New construction land should not break through the delineated ecological protection red line; minimize the pollution of water bodies by fish farming
	IV_3	Intersect with the III_3	Cultivated land, forest	Mutual interference between agricultural land and ecological land		Reversibility between cultivated land and forest is strong, and the land use is rationally changed according to land remediation planning, returning farmland to forests, etc.
	IV_4	Similar to the II, but closer to the human activity zone	Primarily orchard, forest and cultivated land second, and construction land is third	Increased competition between the three land use categories but not endangering ecological safety		Land use can be transformed according to current land use patterns in the context of ecological priority
V	V_1	Sporadic distribution around the economically developed towns	Forest, orchard and construction land	Urban land and rural residential land occupation of agricultural land and ecological land	Intense	Constrained conversion can be carried out according to the urban development orientation and the comprehensive rural remediation type
	V_2	Scattered distribution in the south-central towns	Cultivated land	The contradiction between national grain demand and inefficient use of cultivated land		Give priority to cultivated land, actively adopt land remediation and high-efficiency agriculture to improve the cultivated land use efficiency, and prohibit new construction land from occupying cultivated land
	V_3	Convergence with the V_2	Forest dominated, followed by water	Over-exploitation of agriculture land leads to ecological fragmentation		It is forbidden to increase construction land and increase ecological subsidies to encourage low-efficiency farmland to return to forests
VI	VI_1	Roughly embedded inside the IV_1	Cultivated land is dominant, construction land is second	The contradiction between construction land and agricultural land is intensified	More intense	Changing in the orientation of urban development
	VI_2	East River and West River banks	Forest, water	The threat of construction land expansion to forest and water bodies		Implement protection of shelterbelts and water bodies, and strictly forbid the expansion of settlement land into ecological land
	VI_3	Sporadic distribution in the less developed regions	Cultivated land	Mutual embezzlement of agricultural land and ecological land		In accordance with the principle of "agriculture is suitable for agriculture, and forest is suitable for forest"
VII		Scattered distribution on the East River and West River banks	Small areas of cultivated land, forest, orchard and construction land	Functional overlap of agricultural planting, settlement expansion and ecological protection	Extreme	Implement one-way transformation to ecological land

this area can be converted according to the town development orientation, that is, economic development leading area can increase the urban land appropriately, while areas of agricultural production leading area are needed to ensure the safety of agricultural land. The IV_2 accounts for 7.90% and is distributed between the ecologically superior zone (III_3) and the construction advantage zone (III_1 and IV_1), marking the transition zone between human industrial production and ecological protection. LUTs are mainly forest and include a small amount of aquaculture water. The conflict is manifested as the intrusion of construction land into ecological land, driven by economic benefits, but without yet reaching crisis level in the study area. Newly developed construction land in the area should not break through the delineated ecological protection red line and should minimize the pollution of water bodies by fish farming. The IV_3 accounts for 8.54%, and intersects with the III_3, which is the transition zone between human agricultural production and ecological protection. The LUTs are mainly cultivated land and forest, and the conflict manifests itself as the mutual invasion of agricultural land and ecological land. Since the reversibility between the them is strong, land use can be readily changed according to land remediation planning and returning farmland to forest. The IV_4 accounts for 5.82%. The distribution of this area is similar to that of the II, but it is smaller and restricted closer to the human activity zones. LUTs are diverse but mostly orchard, followed second by forest and cultivated land and with a lesser amount of construction land. The intensity of competition between the three land use categories increases but does not jeopardize ecological security. Land use can be transformed according to current land use patterns in the context of ecological priority.

The V_1 accounts for 2.36%, and is scattered around the economically developed central towns. LUTs are mainly forest, orchard and construction land. The conflict is manifested as the

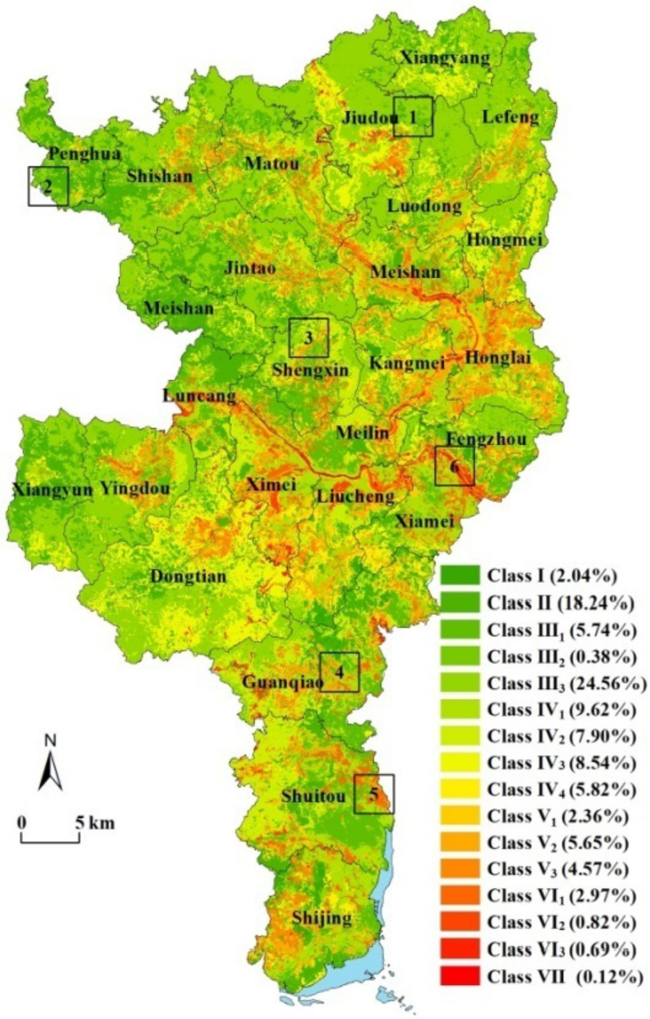

Fig. 8. Spatial distribution of LUC zones in Nan'an city.

occupation of agricultural land and ecological land by urban land and rural residential land. The former conversion can be constrained according to the town development orientation and urban planning, and the latter conversion can be constrained according to the rural comprehensive consolidation type. The V_2 accounts for 5.65%, distributed at the peripheries of the central and southern townships and representing the main grain producing area in Nan'an. LUTs are mainly cultivated land, and the conflict is manifested by the contradiction between the national grain production capacity and the inefficient use of cultivated land. Land use should be prioritized to change to cultivated land; measures such as land remediation and high-efficiency agriculture should be actively adopted to improve the efficiency of cultivated land; and new construction land should be banned from occupying cultivated land. The V_3 accounts for 4.57%, and its distribution is similar to that of the V_2. LUTs are mainly forest, followed by water. The conflict is mainly caused by the over-exploitation of agriculture, which leads to the fragmentation of ecological land. New construction land should be forbidden as far as possible; ecological subsidy should be strengthened to encourage the conversion of inefficient farmland to forests; and the regional ecological landscape pattern should be reconstructed.

The VI_1 accounts for 2.97%, which is roughly embedded in the IV_1. LUT is mainly cultivated land, followed by construction land. The contradiction between construction land and agricultural land is further aggravated. Due to the poor suitability of ecological land, the direction of land use can still be changed according to the town development orientation. The VI_2 accounts for 0.82%, and is mainly distributed adjacent to the East River and West River banks. LUTs are mostly forest and waters. The conflict is manifested as the threat of construction land expansion into forest and water bodies, which has to some extent jeopardized the sustainable use of regional land. Therefore, land use must implement the protection of shelter forests and water bodies, and it is strictly forbidden to convert ecological land to new residential land. The VI_3 accounts for 0.69%, and is scattered in the western and northern parts of the region. LUT is mainly cultivated land. Due to the weak suitability of construction land in the area, land use only needs to implement spatial control of various LUTs, and can be transformed in accordance with the principle of "agriculture is suitable for agriculture, and forest is suitable for forest".

The VII accounts for 0.12%, scattered along both sides of the East River and West River banks. LUTs include a small amount of cultivated land, forest, orchard, and construction land. The conflict is manifested by the spatial overlap of agricultural planting, settlement expansion and ecological protection. Since the area has an important fresh water supply function, land use should be implemented in a one-way transformation to ecological land based on a sustainable development concept.

The spatial distribution, land composition, conflict performance, conflict intensity and theoretical trends of land use change in different LUC zones are shown in Table 7.

4.3. Multi-scale analysis of land use scenarios

This paper uses the CA-Markov module in Idrisi to perform simulation operations. The number of CA cycles was set to 5, 20 and 35, as appropriate, to obtain LUSs and cell unit numbers in 2020, 2030 and 2050, respectively. Fig. 9 shows that the characteristics of land use agglomeration are more obvious in the context of sustainable use, which indicates that the current "three lines and one boundary" (the red line of farmland protection, the red line of basic farmland protection, the red line of ecological protection and the boundary of urban development) has a strong binding effect on land use, while the constraint on LUCs further strengthens spatial control. In all cases, the urban land and rural residential land increased significantly and expanded outwards, forming more obvious concentration centers such as the central city group, the southern coastal group and the northern comprehensive group in economically relatively active areas, indicating that the main direction of future land use in the region must keep meeting the needs of urban and rural residential land. Cultivated land and gardens are mainly distributed in valleys such as East River, West River, Taoxi River and Meixi River, and in townships such as Jintao Town and Dongtian Town, and are located in the transition zone between urban and rural residential land and ecological land. The spatial agglomeration characteristics of forest land are not significant and its spatial connectivity is poor. Forest is mainly distributed in Dongtian Town, Xiangyun Town and Yingdu Town in the west and Jiudu Town, Lefeng Town and Xiangyang Township in the north. These areas are at higher altitude or in important water source areas, and it is difficult or restricted to develop and utilize land.

From the overall trends of the cell units in Table 8, the areas of urban land and rural residential land are increasing, while areas of other construction land, orchard, water and unused land are decreasing, and the variation trend of cultivated land and forest in different scenarios and periods vary widely. From the perspective of cell unit number in the three periods, land use in 2020 had mainly

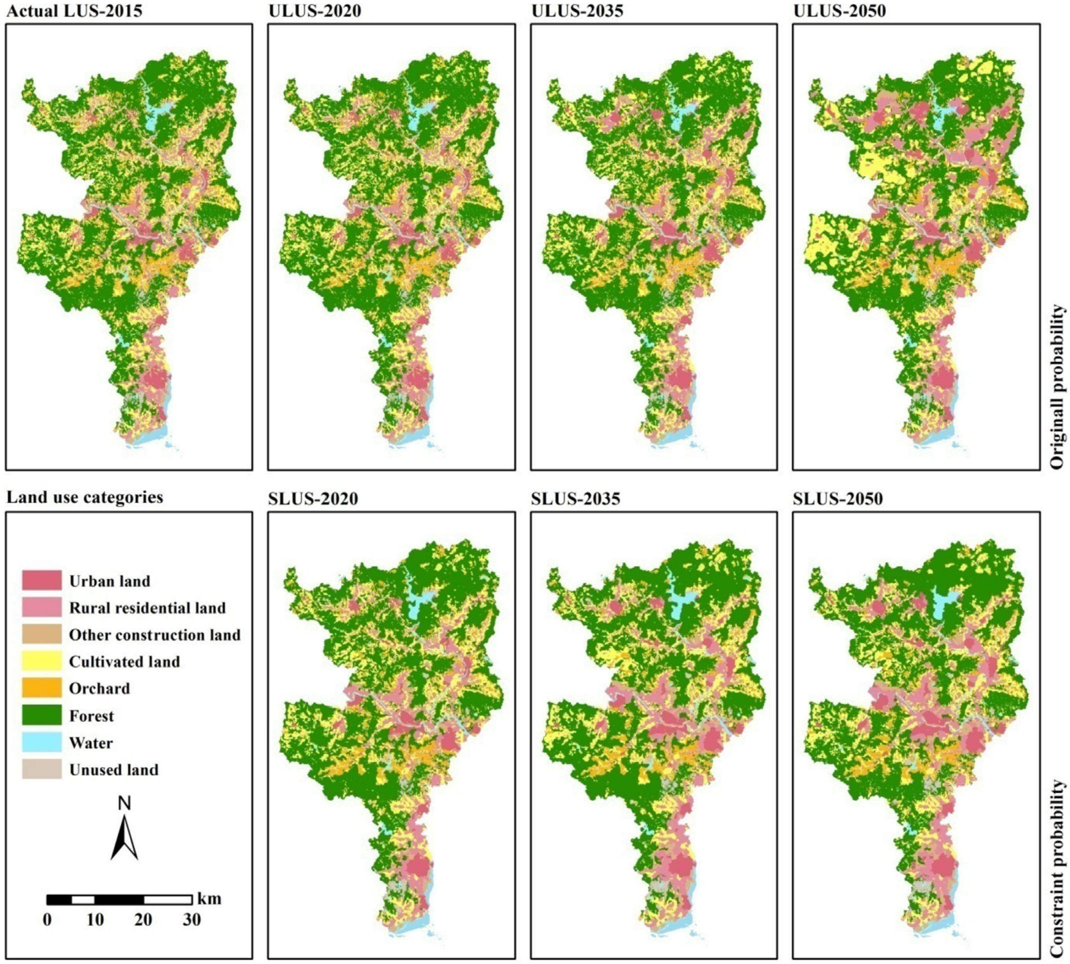

Fig. 9. Spatial pattern of LUTs under different LUSs.

Table 8
The number of cell units of LUTs under different LUSs.

LUTs	2015	ULUS-2020		SLUS-2020		ULUS-2035		SLUS-2035		ULUS-2050		SLUS-2050	
		Cells	PR	Cells	PR	Cells	PR	Cells	PR	Cells	PR	Cells	PR
LUT_1	8035	8895	4.29	9371	6.66	9857	9.09	11211	15.84	11785	18.70	12888	24.21
LUT_2	22841	24096	6.26	25034	10.94	25005	10.79	27569	23.58	29609	33.76	29330	32.37
LUT_3	8969	5814	−15.74	6799	−10.82	6737	−11.13	8649	−1.60	8233	−3.67	9555	2.92
LUT_4	34907	36452	7.71	35524	3.08	36609	8.49	34274	−3.16	36756	9.22	33813	−5.46
LUT_5	17524	16406	−5.58	16046	−7.37	14887	−13.15	14961	−12.78	17413	−0.55	14372	−15.72
LUT_6	93984	98370	21.88	97234	16.21	97563	17.85	93934	−0.25	86935	−35.16	90927	−15.25
LUT_7	7265	5466	−8.97	5402	−9.29	5101	−10.79	5217	−10.21	5049	−11.05	5075	−10.92
LUT_8	6965	4824	−10.68	4913	−10.23	4564	−11.98	4508	−12.25	4543	−12.08	4363	−12.98

Note: PR is the proportion of changing cell numbers to total cell numbers, and the value is ‰.

changed from other construction land, water and unused land to urban land, rural residential land, cultivated land and forest. In 2035, it had mainly changed from orchard, water and unused land to urban land and rural residential land. In 2050, it had mainly transformed from urban land, forest land, waters and unused land to urban land and rural residential land. Based on cell unit numbers, the increasing proportions of urban land and rural residential land under the SLUS were greater than those in the ULUS, and the reduction in proportion of other construction land was less in the SLUS. The change of orchard was opposite to that of other construction land. The changes of cultivated land and forest in SLUS were smaller than those under ULUS. The changes in water area and unused land were largely the same in both scenarios.

Differences in the spatial details between ULUS and SLUS can be analyzed at the district scale in Fig. 10. We have selected six regions from different LUC zones for more detailed analysis in Fig. 8.

➢ The first area is the II in the south of Jiudu Town. LUTs are mainly cultivated land and orchard. Because of the weak suitability and low competition level of the three land use categories in the area, land use remains basically unchanged with or without conflict constraints.
➢ The second area is the III_2 located in the northern part of Penghua Town. The urban development occurs in prime ecological

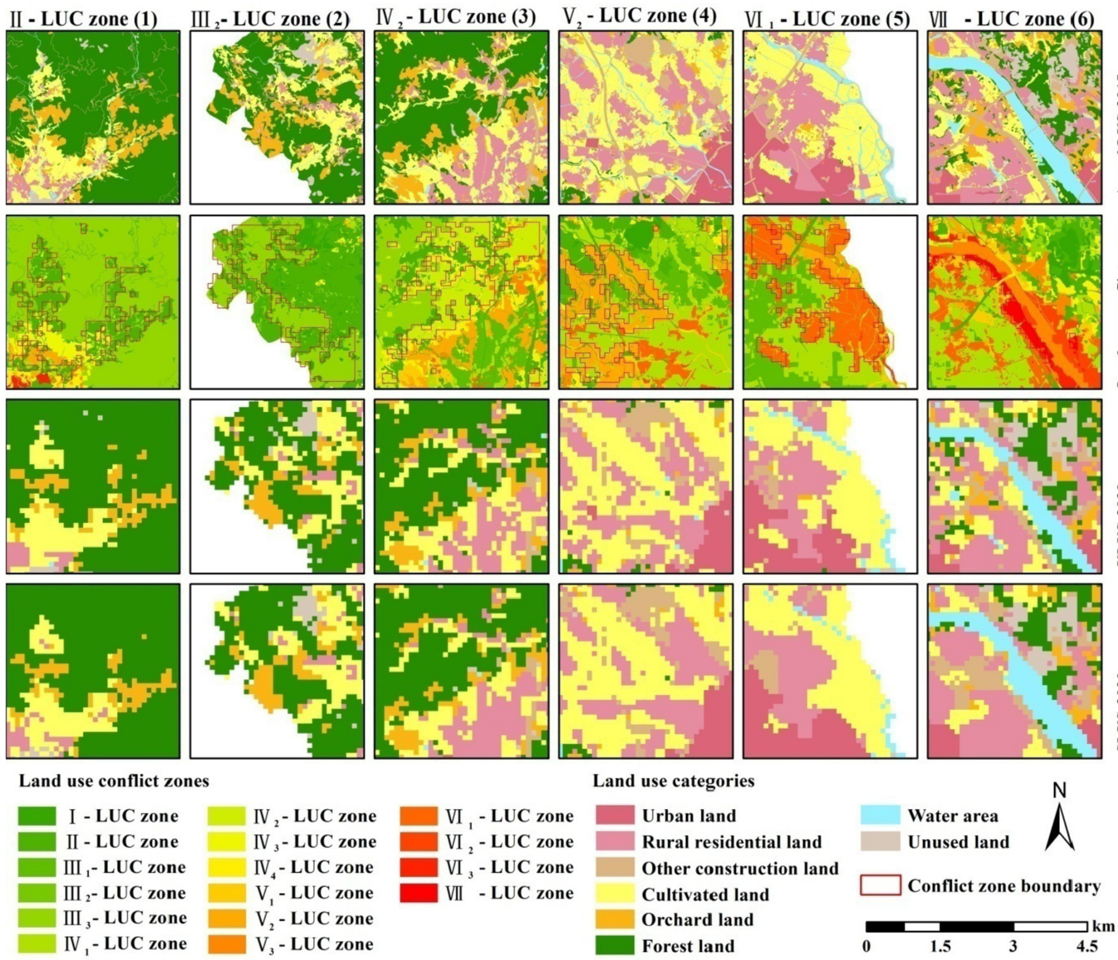

Fig. 10. Comparative analysis of spatial details of ULUS and SLUS.

conservation areas, and the land use is dominated by forest with a high level of fragmentation. In the ULUS, the conversion of land use according to the original probability will lead to further increases infragmentation. In the context of SLUS, the fragmentation of ecological land is significantly improved due to the adoption of policies such as prohibiting new construction land and returning farmland to forests to guide the transformation of land use to forest.

- The third area is the IV_2 in the Shengxin Town. LUT is mainly forest and there is the risk of disorderly expansion of urban and rural residential land in the southeast. Land use must maintain regional security and meet the development needs of new construction land. Comparing the two LUSs, the scales of construction land and ecological land under the SLUS both expand and the concentrations are higher.
- The fourth area is the V_2 located to the northwest of central Guanqiao Town. LUT is mainly cultivated land. The goal of land use is to ensure national food security and improve the efficiency of cultivated land output. To this end, it is necessary to control the boundary between basic farmland and construction land, and adopt measures such as land remediation and high-efficiency agriculture to improve the efficiency of cultivated land.
- The fifth area is the VI_1 to the northeast of central Shuitou Town. LUTs are mainly cultivated land and construction land. Since Shuitou Town is the leading economic development area determined by Nan'an City, land use will be preferentially transferred to urban land without breaking through the urban boundary and basic farmland protection boundary. To a certain extent, this is in line with the land use protection policy and the regional social and economic development needs.
- The sixth area is the VII in the upper reaches of the Jinjiang River in Xiamei Town. This area is not only the core area for water source protection, but also an important vegetable production area close to the town. At the same time, it faces the risk of being occupied by urban land. In the context of SLUS, due to the one-way transformation of land use to ecological land use, the regional land use pattern has been well maintained.

5. Discussion

The study of LUCs is a common concern in the academic world. The exploration to the conflict state is the basis for understanding the organization, coordination and allocation of regional land use, and it is also a major scientific objective for solving the problems of disordered land resources development, heavy ecological and environmental costs, and continuous deterioration of resource competition in the process of regional sustainable development (Campbell et al., 2000; Yu and Lv, 2006). The southeast coastal area represents a frontier between the rapid advancement of urbanization and industrialization in China and a typical area of rural transformation and development, where LUCs are more prominent (Huang et al., 2012). In order to explore the conflict status in the region and guide the governance of LUCs, this paper builds an empirical model of conflict identification and intensity diagnosis based on suitability criteria, and proposes a method of SLUS simulation based on conflict governance.

Land use suitability is the result of a combination of internal and external factors. This paper selects the suitability evaluation indicators for construction land, agricultural land and ecological land from natural factors, location factors, social factors and policy factors. The impact of these indicators on land use suitability has been confirmed by a large number of documents (El Baroudy, 2016; Fu et al., 2018; Gong et al., 2012; Kalogirou, 2002). Based on the evaluation results, the land use landscape fragmentation degree in Nan'an City is relatively high, and the overlapping, crowding, agglomeration and transformation characteristics of construction land, agricultural land and ecological land are significant, which implies that there may be fierce competition and conflict. The empirical model divided conflict intensity into 7 levels, and the LUCs zones are divided into 16 types according to the “dominant land + conflict intensity”. The spatial distribution, land composition, conflict manifestation and intensity of different LUC zones vary greatly. Therefore, it is necessary to adopt measures such as returning farmland to forests, increasing vs. decreasing population balance, ecological subsidies, industrial support, and developing characteristic agriculture according to local conditions to meet the differential needs of land use. Whether these differentiated governance strategies can promote the sustainable use of regional land needs to be tested by simulating land use patterns in different scenarios (Sahoo et al., 2018; Shan et al., 2017; Tudor et al., 2014). In this paper, the land use change rules are formulated according to the “distribution-land type-performance- intensity” of LUCs. The CA-Markov model simulation analysis showed that the LUCs would be further aggravated due to the lack of any targeted governance strategy, characterized by disorderly expansion of construction land, marginalization of agricultural land and fragmentation of ecological land. On the contrary, under the adoption of targeted and differentiated governance strategies, the concentration of land use has been significantly improved, and the direction of land use transformation is more in line with the needs of sustainable development. The comparative analysis of the two scenarios makes us realize that formulating scientific and effective control programs based on the regional and phased nature of LUCs to weigh the interests of stakeholders in the process of land use should become the basic concept of conflict management (Van Leeuwen, 2010).

Through the suitability evaluation of land use and the simulation analysis of LUC scenarios, it is found that China is in an important period of simultaneous “urbanization” and “ruralization” (Liu and Li, 2017; Ma et al., 2018). The scale of urban land and rural residential land is expanding, directly promoting China's sustained and steady economic growth. At the same time, two social problems that cannot be ignored have materialized. The first is the problem of “advanced urbanization”. The long-term bias towards prioritizing industrialization development, the dependence of local governments on land finance, and the restriction of the urban and rural dual household registration system have led to the urban population lagging behind the development of land urbanization (Chen et al., 2016). This is one of its important manifestations, and has led to the blind expansion and disorderly spread of urban construction land, and the loss of a large area of high-quality cultivated land (Cao et al., 2014; Chen et al., 2016). The second is the problem of “hollowing” in rural areas. The development of urbanization has led to the migration of the rural population to urban areas. The non-agriculturalization of the rural population has caused the problem of houses with empty rooms, there has been a tendency to build new houses rather than demolish existing houses, and the construction of new houses has expanded to the periphery (Long et al., 2012). This is one of the important manifestations of “hollowing”. It has also been noted that the rural population migration is not linked to the reduction of rural residential land use, resulting in a large amount of land resources becoming idle and wasted (Long et al., 2012).

Land use multi-suitability is one of the root causes of LUC (Wang et al., 2012). Identifying LUCs through suitability evaluation and simulating land use sustainable development scenarios under conflict constraints could provide theoretical and methodological support for preventing or solving LUCs. Nevertheless, it should be noted that China has a vast territory with large regional differences; therefore, when constructing a land use suitability evaluation index system, regional indicators that affect land use should be selected based on the theory of human-land relationship. In addition, the classic LUS prediction model provides “top-down” and “bottom-up” algorithms (Liu et al., 2017), and the present paper does not compare and analyze the simulation effects of different algorithms, which may reduce the empirical significance of this study. Only by carrying out further theoretical analysis and empirical research on the above issues can the research results be more convincing.

6. Conclusions

Social and economic development leads to land multi-suitability. Identifying the LUC zones through the suitability appraisal is a feasible approach with important practical significance under the current situation of contradiction between humans and land. This paper uses multi-criteria analysis to construct a land-use suitability evaluation index system for construction land, agricultural land and ecological land. Based on the permutation and combination rule, an empirical model of conflict identification and strength diagnosis is constructed and, by applying the restrictive conditions of land use and the state of land use conflict, the land use constraint transformation rules were formulated. A CA-Markov model was then used to simulate the land use pattern at the end of the next three five-year plans. An empirical case-study of Nan'an, a typical region on the southeast coast, shows that the constructed empirical model and the proposed sustainable method can better reveal current land use status in China's rapid urbanization areas.

The spatial gradient characteristics and agglomeration characteristics of construction land suitability in Nan'an in 2015 are significant and show good spatial connectivity. The spatial distribution of agricultural land suitability is relatively scattered, showing high fragmentation degree and poor spatial connectivity. The suitability of ecological land and construction land show evident spatial complementarity. The proportions of LUC zones at the different conflict intensity levels (from lowest to highest intensity) are 2.04%, 18.24%, 30.68%, 31.88%, 12.58%, 4.47% and 0.12%, respectively. The land use simulation scenario reveals that the areas of urban land use and rural residential land are increasing and expanding outward. The trends in cultivated land and forest land areas are uncertain. Other construction land, orchard, water bodies and unused land are easily converted into other LUTs. Detailed analysis of the LUSs show that the current land use pattern has already jeopardized the land sustainable use. If no targeted governance strategy is adopted, LUCs will be difficult to mitigate and may be aggravated further. To this end, it is necessary to adopt differentiated measures to promote the transformation of regional land use that is consistent with the sustainable development of the social economy.

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