Study on Regional Agro-ecological Risk and Pressure Supported by City Expansion Model and SERA Model - A Case Study of Selangor, Malaysia

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Abstract. This study revealed the influence of city expansion on the agro-ecological risks through the analysis and prediction of city expansion in different periods and study on the change of risk and pressure on the regional agricultural eco-environment. The city expansion of Selangor, Malaysia (as a case) was predicted based on relevant spatial and attribute data as well as simulation prediction models of city expansion. Subsequently, the ecological risk and pressure in the study area as well as on regional agricultural land use was assessed through the realization of factors of SERA Model. The results showed that the risk and pressure on agricultural land use was consistent with the level of the urbanization. With the expansion of urban area, the ecological risk on agricultural land use in the study area became greater. The risk and pressure on agricultural land use with city expansion was well analyzed with SERA model.

Keywords: City expansion, Ecological risk, Remote sensing, SERA model

1 Introduction

Urbanization aggravation leads to a series of ecological problems, such as land degradation, climate change, etc. The major manifestation of urbanization is the spatial urbanization. With the continuous expansion of urban area, much useable land of other types is occupied. It results in the despoliation of the space and resources of eco-environment, the destruction of the regional eco-environment and brings risks to the regional agro-ecological. The in-depth study on relations between the city expansion and the regional eco-environment, along with the further study on the risks and pressure on agricultural eco-environment would lay the theoretical foundation to improve the agricultural eco-environment and to realize the sustainable development of agriculture.

Agricultural eco-environment is a part of the regional eco-environment. However, the relationship between the agricultural eco-environment and the city expansion has not yet been put forward directly. Based on the neural network, some scholars made quantitative analysis on the cultivated land security with the support of the spatial information technology and the study didn't include the time characteristics (Qian Yurong, 2009). The study on the relationship between environment and city expansion was a qualitative description originally. For instance, Shi Dengrong *et al.* made qualitative analysis on the ecological problems like atmospheric environment, soil quality, land resources, etc. as well as the social issues caused by urbanization(Shi Dengrong, 2001). However, this qualitative study neither meets the needs of study on city expansion, nor provides assessment methods and tools in the urban planning of the regional environmental sustainability for the planners and policy makers. The development of the remote sensing technology provides more effective ways and means to obtain the data of city expansion. Thus, the quantitative study on relationship between city expansion and eco-environment was paid attention to by more and more researchers on the urban remote sensing and the eco-environment. The study on relationship between city expansion and eco-environment was divided into three aspects: study on relationship between city expansion and eco-environment based on the spatial heat environment, which mainly studied the influence of the urban heat island on eco-environment (Lo CP, 1997; CHEN YUNHAO, 2002); study on relationship between city expansion and eco-environment with the introduction of the eco-environmental index based on the remote sensing data (Wilson, 2003; YUE WENZE, 2006); study on relationship between the spatial form of city expansion and eco-environment, which was mainly from the perspective of spatial patterns with the support of spatial information technology.

Study on relationship between the spatial form of city expansion and eco-environment was based on the theory of land use change to study the influence of the city expansion spatial form on eco-environment through the variation characteristics of urban spatial form. It gave a certain division standard of evaluating grade (Ma Ronghua, 2001). Some scholars adopted Ecological Risk Index (ERI) Model and determined the intensity parameters of the ecological risk to complete the digital simulation of the ecological space distribution (Wei Shichuan, 2008). However, the experts' judgment about the intensity parameters of ecological risk in the study increased human disturbance degree in risk value, and the performance of the risk value in space can not be refined. And most of the study on city expansion and regional eco-environment based on GIS and RS was study on spatial change on the ground of the administrative boundaries; some scholars began the regional ecological risk assessment according to the landscape units, but the interaction among ecological units as well as the pressure mechanism on the eco-environment imposed by city expansion was not taken into account in this pattern of environment assessment (MA Shu-ting, 2004). Li Jinggang *et al.* built the ecological risk assessment model for natural/semi-natural landscape space under the urbanization based on the meso-scale according to the principle of "pressure, exposure and stability". An ecological risk assessment of the urbanization process was conducted in Beijing. Its model was described as follows (Li Jinggang, 2008):

$$V = A + F - I - N \quad . \tag{1}$$

In the formula, V refers to ecological risk of landscape space; A, F, I, and N refers to 4 factors of the external accessibility of the landscape, the external pressures, the internal stability and the neighborhood stability respectively.

From the current remote sensing study on relationship between city and eco-environment, it can be seen that taking remote sensing as the support, the ecological assessments from the perspective of the regional spatial pattern do not reflect the relationship between the spatial urbanization and the eco-environment clearly; the ecological risk assessments with single scale do not meet the needs of study any more; as to the eco-environment assessments based on the means of remote sensing, most of them have adopted the single factor assessment model, because the multi-factor assessment model of the eco-environment is too simple; as to the remote sensing analysis of eco-environment with the introduction of the eco-environment assessment model under city expansion, the assessment model is too complex and involves too many socio-economic indicators difficult to obtain. The assessment factors like the biomass dynamic changes and the net primary productivity, etc. obtained by the remote sensing methods are not applied effectively; meanwhile, the eco-environmental risk assessment under city expansion based on the remote sensing is not proposed directly.

Taking Selangor, Malaysia as the case, through the analysis of relationship between city expansion and eco-environment, with the support of RS technology, the study was based on the remote sensing assessment model of ecological risk, namely, SERA model, under city expansion and analyzed the influence on the agricultural eco-environment imposed by city expansion to determine the risk and pressure on the agricultural eco-environment imposed by city expansion. It would provide technical support to improve agricultural eco-environment.

2 Methods

The ecological risk and pressure of the study area based on SERA model was simulated in this study. Then, the ecological risk and pressure on agricultural land use in the period of study was analyzed through the ecological risk and pressure imposed of the entire study area.

2.1 Overview and Data of the Study Area

The study area includes Selangor, Malaysia and the capital Kuala Lumpur and the administrative capital Putrajaya, with a total area of approximately 8,214km^2. The study area is located at 101°41′E, 3°09′N on the southwestern coast of Malaya near the equator; the northwest, north, and northeast areas of the study area are occupied by hills and mountains; Klang River and its tributaries Gombak River converge in the city and flow into from the southwest of the Malacca Strait. The climate there is tropical rainforest climate with high temperature and rainy throughout the year; its average temperature is 25℃-30℃; the rainfall is abundant, and the annual average rainfall is 2000mm-2500mm; the rainy months are from March to April and from September to November. There is ample sunshine with high temperature during the day and relatively cool in the afternoon and evening in the study area. This area is often attacked by a sudden storm. The main cash crops in the area are oil palm, rubber trees etc.

The data adopted in this study included spatial data, socio-economic data and field survey data. As the area of Selangor, Malaysia and the capital Kuala Lumpur is large, and 2-scene data covering the entire state was required, the spatial data included 12-scene Landsat TM/ETM images of numbering 127/57 and 127/58 in six periods of 1990, 1991, 1994, 1996 , 1998 and 2002, vectorgraph of the entire administrative division, river network, road network, digital elevation model (DEM), the land use type map in 1996; the socio-economic data originated mainly from the "Malaysia Plan" made by the Malaysia Statistical Bureau, including basic socio-economic indicators; the field survey data included the coordinate points of unchanged regions and the economic center regions required for radiometric normalization of remote sensing image supported by DGPS. This study classified the land use based on segmentation results of the Mean-shift algorithm.

2.2 Prediction of City Expansion in the Study Area

The urbanization intensity index (UII) is one of the important measurement indicators reflecting the expansion characteristics of urban land use, the formula is described as (2):

$$UII_{i,t\sim t+n} = [(ULA_{i,t+n} - ULA_{i,t}) / n] \times 100 / TLA_i \qquad (2)$$

Where, $UII_{i,t\sim t+n}$, $ULA_{i,t+n}$ and $ULA_{i,t}$ respectively refers to the UII of the spatial unit i within the period of $t \sim t+n$ and the area of the urban land use in the year $t+n$ and t. TLA_i refers to the total area of the spatial unit i (Liu Shenghe, 2000).

The data of Table 1 was obtained from the classification results of land use type. It can be seen from Table 1 that city expansion of Selangor from 1990 to 2002 was extremely rapid. From 1994 to 1998, the city expansion area was 331.02km^2 and the annual average expansion intensity was close to 10%. The study area was in the phase of high-speed expansion from 1990 to 2002. The high-speed expansion of land use for urban construction in the study area imposed great pressure on agricultural eco-environment. It became one of the important factors of the risk and pressure of agricultural eco-environment. The prediction of land use for urban construction would provide scientific and effective theoretical basis for the risk and pressure assessment on agricultural land use in the study area.

By building CEM (City Expanding Model in Metropolitan Area) model of the entire Selangor State, namely, city expansion in metropolitan area, the city expansion was predicted in Selangor in this study. An expanded model of the CA model, CEM model was proposed by He Chunyang *et al.* which combined the system dynamics with the traditional CA model to simulate city expansion in metropolitan area. Considering the relevant image data, spatial data and attribute data of Selangor, Malaysia and the capital Kuala Lumpur, CEM model was set to predict the city expansion of Selangor (Chunyang He, 2008; Shi Xiaoxia, 2008). The city expansion of Selangor in 2020 was predicted with the residential map layer of Selangor in 2002 as the original map layer. The predicted results are shown in Fig. 1.

Table 1. City expansion intensity in the study area from 1990 to 2002

	1990-1994	1994-1998	1998-2002
Expansion area (km^2)	153.41	331.02	188.26
Annual average expansion intensity (%)	5.50	9.72	3.98
Annual expansion area (km^2)	38.35	82.75	47.06
Expansion type	High-speed	High-speed	High-speed

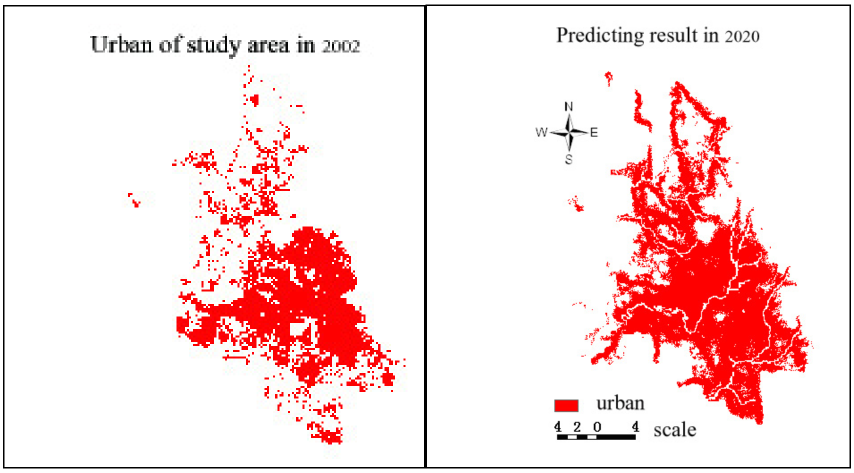

Fig. 1. Land use situation of Selangor State for city building and the predicted results in 2020.

2.3 SERA Model

The pressure of city expansion on regional eco-environment is reflected by SERA model. The remote sensing model of the spatial ecological risk assessment, namely, SERA model, in this study is the assessment model based on landscape units (x, y). The ecological risk and pressure P on meso-scale landscape units (x, y) is reflected by the interaction of P_A, the spatial driving force of the landscape unit, P_{AI}, the spatial influencing factor of macro-scopical region driving force, P_R, the spatial risk resistance on the landscape unit (x, y), P_{RI}, the spatial influencing factor of macro-scopical regional resistance, P_E, the characterization factor of ecological risk based on the remote sensing of landscape unit (x , y), P_{SI} , the comprehensive influencing factor of the regional ecological risk assessment, and P^0 , the adjustment coefficient of model. The ecological risk and pressure *P* is described as in formula (3):

$$P = \frac{(P_A P_{AI} - P_R P_{RI}) + P_E}{2} \cdot P_{SI} \cdot P^0 \quad . \tag{3}$$

P_A , the spatial driving force of the landscape unit, includes the interrelations of DR , the relations between the landscape unit and the nearest road, DG , the relations between the landscape unit and the geometrical gravity centre of main plaque of construction land, FL , the relations between the landscape unit and construction land, and DW , the relations between the landscape unit and the spatial heat environment. DR and DG the influence of distance and co-react in spatial landscape drive, and FL and DW , the relationship of distance and area and co-react; P_{AI} includes SA , the patch size index of city construction land in the study area from a macro-perspective and SF , the patch shape index of city construction land in the study area. P_R includes SD , the patch density index in the landscape unit, namely, its own stability of the landscape unit and SI , the slope; NS , the stability of neighborhood of a landscape unit. P_{RI} is determined mainly by FN , the influence coefficient of fragmentation of ecological landscape. P_E is mainly reflected as the eco-environment index based on remote sensing. The comprehensive influencing factor of the model is reflected as UZ , the pressure on eco-environment imposed by human activities as well as lot of waste produced with the growth of economy.

Accordingly, the remote sensing assessment model of ecological risk and pressure on the landscape was described as formula (4):

$$\begin{aligned} P &= (P_A P_{AI} - P_R P_{RI}) \cdot P_{SI} \cdot P^0 \\ &= \frac{1}{2}\left[\left(\frac{1}{n_{Ai}}\sum_{i=1}^{n} P_{Ai}\right) \cdot \left(\frac{1}{n_{AIj}}\sum_{j=1}^{n} P_{AIj}\right) - \left(\frac{1}{n_{Ri}}\sum_{i=1}^{n} P_{Ri}\right) \cdot \left(\frac{1}{n_{RIj}}\sum_{j=1}^{n} P_{RIj}\right) + P_E \right] \cdot P_{SI} \cdot P^0 \cdot \\ &= \frac{1}{2}\left[\begin{array}{l} \left(\sqrt{\frac{1}{2}\left[\frac{1}{2}(DR+DG) + \frac{1}{2}(FL+DW)\right] \times \frac{1}{2}\left[SA+SF\right]} - \right. \\ \left. \sqrt{\frac{1}{3}(SD+SI+NS) \times FN}\right) + \frac{1}{2}(LA+CW) \end{array} \right] \cdot (UZ) \cdot P^0 \end{aligned} \tag{4}$$

Where, $P > 0$

3 Assessment Results of Agro-Ecological Risk in the Study Area

Based on the theory of the CA model and the landscape ecology, each factor in the model were realized concretely by combining with the actual situation and data in the study area. Based on SERA model and with the landscape unit area of 300m×300m the spatial ecological risk of the study area in 1990, 1991, 1994, 1996, 1998 and 2002 was assessed. The results range was 0~1 and was classified into 5 grades according to 0~0.2, 0.2~0.4, 0.4~0.6, 0.6~0.8 and 0.8~1. Fig.2 (a) and (b) refers to spatial risk assessment results of cultivated land in the study area in 1990 and 2002 respectively. Table2 refers to the ecological risk grade variation of the cultivated land in the study area in 1990, 1994 and 2002.

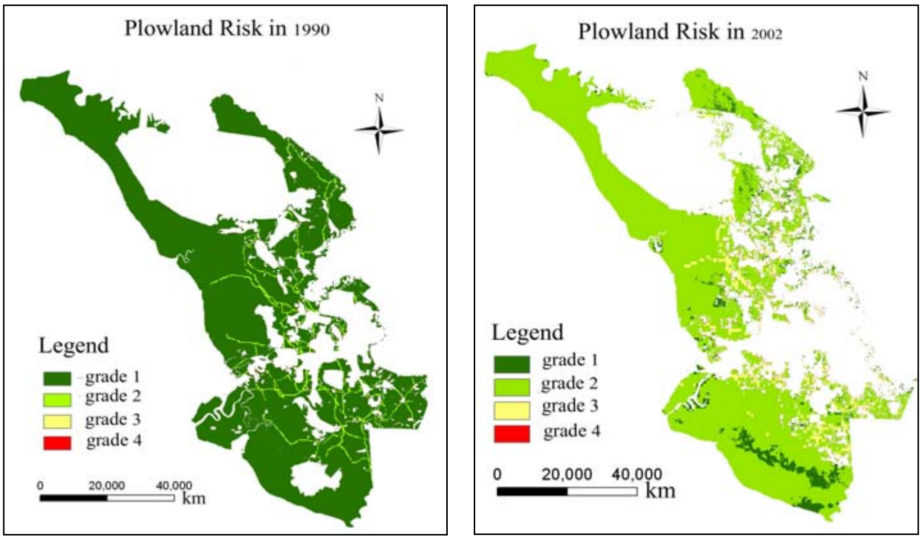

Fig. 2. The ecological risk variation in the study area in 1990 and 2002

Table 2. Ecological risk grade variation of the cultivated land in the study area (the number of landscape units)

Year	Total cultivated land	Primary risk	Percentage (%)	Secondary risk	Percentage (%)	Tertiary risk	Percentage (%)
1990	4805161	4636729	96.49	168432	96.49	0	0
1994	4491520	2894320	64.44	1575904	64.44	21296	0.47
2002	4030752	288464	7.16	3546752	7.16	195536	4.85

(1) It could be seen from Fig. 2 and Table 2 that ecological risk grade of the cultivated land in the study area in 1990 was obviously low and was mainly primary risk without the occurrence of tertiary risk area. The secondary risk dominated in

2002 with the occurrence of tertiary or higher risk areas in different regions. The risk value of cultivated land and the risk grade were ever-increasing.

(2) It could be seen from Table 3 that the pixel number in remote sensing images of city construction land in the study area increased from 775,368 in 1990 to 1,522,789 in 2002. Its percentage increased from 8.49% to 16.67%. Meanwhile, cultivated land was ever-shrinking. The pixel number decreased from 4,763,258 in 1990 to 4,103,960 in 2002. Its percentage reduced by 7.22%.

Table 3. Variation of residential land and cultivated land from 1990 to 2002

Year	Residential land		Cultivated land	
	Area (pixel number)	Percentage (%)	Area (pixel number)	Percentage (%)
1990	775368	8.49	4763258	52.15
1991	1073515	11.75	4326125	47.36
1994	945818	10.36	4505771	49.33
1998	1313614	14.38	4365608	47.80
2002	1522789	16.67	4103960	44.93

(3) Through the prediction results of city expansion, it could be known that there would be a further expansion of city construction land by 2020. With the constant expansion of city construction land, agricultural land would be occupied continuously, which led to the constant decrease of cultivated land. The agricultural land in study area would be threatened seriously both on its quantity and eco-environment.

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