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Land use change of Kitakyushu based on landscape ecology and Markov model

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Abstract: Based on four phases of TM images acquired in 1990, 1995, 2000 and 2005, this paper took Kitakyushu in Japan as a case study to analyze spatial change of land use landscape and corresponding effects on environmental issues guided by landscape ecology theory in virtue of combining technology of Remote Sensing with GIS. Firstly, land use types were divided into 6 classes (farmland, mountain, forestland, water body, urban land and unused land) according to national classification standard of land use, comprehensible ability of TM image and purpose of this study. Secondly, following the theory of landscape ecology analysis, 11 typical landscape indices were abstracted to evaluate the environmental effects and spatial feature changes of land use. Research results indicated that land use has grown more and more diversified and unbalanced, human activities have disturbed the landscape more seriously. Finally, transfer matrix of Markov was applied to forecast change process of land use in the future different periods, and then potential land use changes were also simulated from 2010 to 2050. Results showed that conversion tendency for all types of land use in Kitakyushu into urban construction land were enhanced. The study was anticipated to help local authorities better understand and address a complex land use system, and develop improved land use management strategies that could better balance urban expansion and ecological conservation.

Keywords: land use; landscape ecology; Markov model; Kitakyushu in Japan

1 Introduction

Land use change played vital roles in regional, social and economic development and global environmental changes (Turner *et al.*, 1993). On a global basis and a longer time frame, Raman Kutty and Foley (1999) noted that nearly 1.2 million km^2 of forests and woodlands, 5.6 million km^2 of grasslands and pastures have been converted into other types of land use during the last three centuries, cropland areas increased by 12 million km^2 during the same

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period. Currently, human transformations of the Earth's land surface are significant with 10%–15% in row-crop agriculture or urban-industrial areas and 6%–8% in pastureland (Vitousek *et al*., 1997). Concerning about the great land use changes caused by fast growing economy and accelerated industrialization and urbanization, international Geosphere-Biosphere Program (IGBP) and International Human Dimensions Program (IHDP) launched a plan of "Land Use/Cover Change (LUCC)" in 1995, since then LUCC has been an advanced and hot subject in global environmental change research. (Turner and Ruscher, 1988; Pereira and Duckstein, 1993; Henk and Latesteijn, 1995; Meyer and Turner, 1996; Dai *et al*., 2001; Oh, 2001; Geist and Lambin, 2001; Susanna and Chen, 2002; Quan *et al*., 2006; Luciana *et al*., 2007). Various methodologies and algorithms have been applied to derive land use change information from different remotely sensed data. In an international comprehensive view, studies on LUCC can be summarized as three core issues: dynamic analysis of process, driving forces, and global and regional models of LUCC (LI, 1995; Gautam *et al*., 2003; Kline, 2003; Patma *et al*., 2004; Erika *et al*., 2005; Shao *et al*., 2005; Vishvakarma *et al*., 2005). Nevertheless, there have been relatively few comprehensive studies to induce the landscape eco-environmental effect on the basis of land use change and to forecast dynamic change tendency in the future land use by Markov model (Asif *et al*., 2005; Huang *et al*., 2006).

The paper aimed to analyze the quantitative and spatial change of landscape features and corresponding effects on environmental issues in Kitakyushu of Japan under the guidance of landscape ecology theory, with four phases of TM images acquired in 1990, 1995, 2000 and 2005, by integrating technology of Remote Sensing with GIS. Then Markov model was employed to forecast the land use change tendency in the future. The study provided a better research case of revealing land use change in the industrialization and urbanization process in coastal region and research results were beneficial to promote the development and regional planning of Kitakyushu in Japan.

2 Study area and method

2.1 Study area

Kitakyushu (33°52'N, 130°49'E) is a city located in Fukuoka prefecture, Kyushu, Japan. Its total area is 486.81 km^2, population is 993,483 till October 2005, and population density is 2040.80 per km^2. From the view of topographic features, topographic relief in Kitakyushu is bigger, sea level elevation reaches above 900 m, mid-mountain and low-mountain accounting for 35% of the total regional area is the main topographic types (Figure 1). Kitakyushu borders on the main islands of Japan across Kanmon Strait and is adjacent to several other Asian countries, and particularly it is conveniently located at the straight line connecting two largest cities, Tokyo in Japan and Shanghai in China. Meanwhile, the eastern and northern Kitakyushu has long coast line. It is one of the most active areas in Kitakyushu and enjoys the fastest economic development. In the 2002, GDP is JPY3, 386,384 million, travel people is 1220 ten thousand. For a long time, the region has been chiefly aiming at economic growth and ignoring reasonable adjustment of land use structure. So, potential

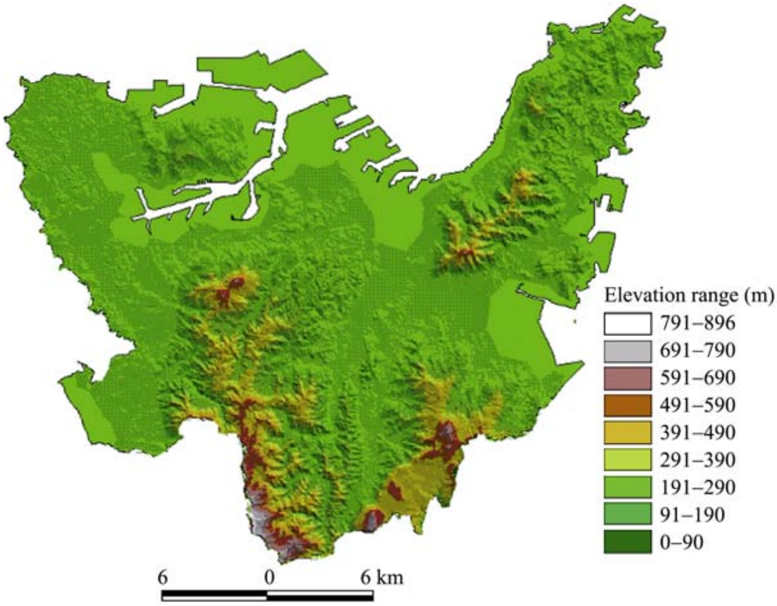

Figure 1 Topologic features of Kitakyushu city in Japan

disadvantages are threatening its urban ecological environment and sustainable economic growth.

2.2 Data sources and research method

The data used in the paper spanned 15 years which were divided into the year nodes of 1990, 1995, 2000 and 2005. The basic data originated from remote sensing data, topographic map and land use map. From these data sources, Landsat TM images of four different periods were acquired, then geometric correction and coordination transformation were carried out on images with ERDAS IMAGE software, and color composites were generated by displaying the bands 5, 4 and 3 as red, green and blue, respectively. Then, an image enhancement of intensifying visual distinction among features was performed to increase the amount of information that could be visually interpreted. In succession, image interpretation symbols of different image elements were added accompanying by field investigations. This could be consulted in the process of person-machine alternating visual operations. Finally, land use type was interpreted visually on the screen based on the TM images, land use spatial database and attribution database were set up, and land use figure of four different years were obtained (Figures 2a–2d).

Following the study purpose, land use types were divided into 6 classes (farmland, mountain, forestland, water body, urban land and unused land) according to national classification standard of land use and comprehensible ability advisement of TM image (Asif *et al*., 2005; Erna *et al*., 2006; Umeno *et al*., 2006). Research methods included three aspects: preprocessing of remote sensing image data; extraction of the landscape characteristics and analysis of changes in time and space; and Markov process analysis of land use changes (Table 1).

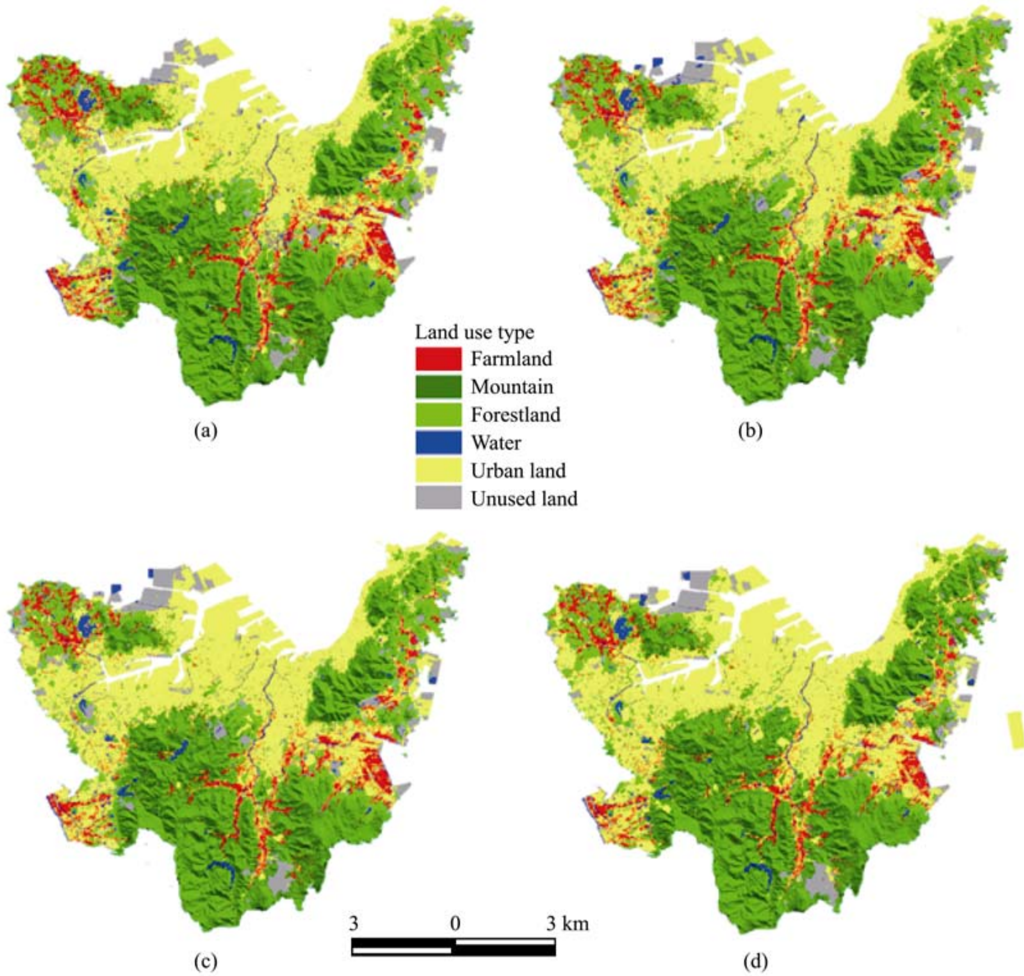

Figure 2 Spatial distribution of land use type from 1990 to 2005 in Kitakyushu city
(a) in 1990; (b) in 1995; (c) in 2000; and (d) in 2005

Table 1 Classification system of land use in Kitakyushu city

Land use type	General description
Farmland	Irrigated, level-terraced agricultural lands in river valleys, dry land, vegetable plot
Mountain	Forest areas and naked rock land above 80 m in elevation
Forestland	Forest areas below 80 m in elevation
Water body	Including river surface, pond surface, lake surface and ditch
Urban land	Including residential land, industrial land, commerce land, road land and public facilities
Unused land	Tidal flat land, barren land, sandy land, grassless land, raised path through fields and others

3 Analysis of landscape dynamic change

Landscape ecologic topic originated from land research and was extensively utilized for studies on land use, so its study objective was fixed on the land mosaic body (Fu, 2004). As far as a region was concerned, landscape ecological development was mainly restricted by natural environmental condition and natural resource. Besides these, spatial structure of different land use was achieved by overall land use shape which was synthetically reflected by interaction influence of socio-economic factors. The landscape ecology indices could be used to analyze changing conditions of landscape patches and predict changing tendencies of land use in the future, and spatial measure object of landscape ecology might be applied in the spatial analysis of land use vicissitude (Iverson, 1988; Herold *et al*., 2002; Honnay *et al*., 2003). According to difference of ecologic significance indicated by different landscape indices, the paper selected 11 landscape indices to reflect effects of land use change on ecologic issues with the support of Fragstats software (Table 2) (Mc Garigal, 1994).

Table 2 Description of landscape ecologic indices

Indices	Definition	Units
Number of patches (NP)	*Number of patches* is a measure for the extent of subdivision or fragmentation of patch type.	None
Percentage of landscape (PLAND)	*Percentage of landscape* quantifies the proportional abundance of each patch type in the landscape.	Percent
Mean patch size (MPS)	*Mean patch size* is a measure of the subdivision of class or landscape, larger mean patch size means that landscape shape is more regular.	None
Largest patch index (LPI)	*Largest patch index* quantifies the percentage of total landscape area comprised of the largest patch. It is the measure of dominance.	Percent
Area-weighted mean shape index (AWMSI)	*Area weighted mean shape index* is equal to 1 when all patches are circular (for polygons) or square (for grids) and it increases with increasing patch shape irregularity.	None
Landscape division index (DIVISION)	*Division* is based on the cumulative patch area distribution and is interpreted as probability that two randomly chosen pixels in the landscape are not situated in the same patch.	Proportion
Fragmentation index (FN)	*The fragmentation* is used to describe fragmental degree of the landscape incision. Higher fragmentation donates a worse regional eco-environment.	None
Fractal dimension (FD)	*Fractal dimension index* reflects shape complexity across a range of spatial scales (patch sizes).	None
Dominance index (DI)	*Dominance-index* is an index of biodiversity.	None
Shannon's diversity Index (SHDI)	*Shannon's diversity index* is used to describe the degree of abundance and uniformity of landscape type synthetically.	Information
Shannon's evenness Index (SHEI)	*Shannon's evenness index* measures the evenness of proportional distribution of patch type area.	None

3.1 Dynamic change of patch scale

During the process of landscape analysis, influence of landscape scale effect upon study results should be paid particular attention. Many proposed indices (such as the number of patch, fragmentation, border density, patches abundance degree and so on.) were easily influenced by landscape size and researchers' subjectivity, so that research results often lacked a certain standard and logical contrast. To conquer these shortages, each of typical characteristic in respect of landscape ecology was synthetically analyzed by applying multiple indices for achieving more scientific and reasonable research results.

At the level of patch, eight landscape indices were selected: number of patch (NP), percentage of landscape (PLAND), mean patch size (MPS), largest patch index (LPI), area-weighted mean shape index (AWMSI), division (DIVISION), fragmentation index (FN) and fractal dimension (FD). Landscape ecology characteristics were analyzed by using the eight indices. The results are as follows:

(1) As shown in Figure 3a, in recent 15 years, farmland area in Kitakyushu decreased rapidly, which indicated that human's exploration and utilization intensity against farmland became much larger, some farmland were transformed into lands for other uses. NP and FN indices increased, which showed that fragmentation degree changed to a lower degree; DIVISION index was larger than that in 1990, which showed that patch distribution became more dispersible; MPS and LPI indices decreased, which indicated that intensity of human activity was weakened; AWMSI and FD indices became big, which indicated that shape of patch became complex and irregular.

(2) As shown in Figures 3b–3c, change of forestland index was obvious. Area of forestland and mountain land appeared annually decreasing tendency in a period of 15 years. NP and FN indices rose and MPS index descended, which indicated shape of patch became more fragmentized, fragmentation degree of patch was higher because of government's intervention and human's disturbance; LPI of forestland descended, which indicated that disturbance of human to forestland became more and more serious; on the contrary, LPI of mountain rose, which indicated that intensity of human activity to mountain disturbance was weakened; decreasing AWMSI and increasing DIVISION index presented that patch shape grew simple and patch distribution got concentrated.

(3) As shown in Figure 3d, change of water body area was relatively stable, only 43 hm^2 was reduced during 15 years, NP and FN indices decreased, which showed patch was getting more and more fragmental, ecological environment of water body was getting better; meanwhile, patch shape was proved to disperse from decreasing MPS and increasing DIVISION index; rising LPI reflected man-made perturbation to water body became more and more frequent; FD and AWMSI appeared a decreasing tendency to a larger extent, which indicated that shape of water body tended to be simple and regular.

(4) As shown in Figure 3e, area of urban land has been rising in the 15 years; main reason was that urban construction of Kitakyushu accelerated the regional economic development and 1ed to rapid rise of urban land. FD and AWMSI appeared a rapid rising tendency from 1990 to 2005, indicating that human disturbed landscape in simplex and unsymmetrical ways. This would result in decrease of landscape stability and flexibility. NP index firstly rose and then descended, FN and DIVISION always descended, these changes came from which patch fragmentation degree was weakened; increasing MPS and decreasing LPI reflected that disturbance of human activity to urban land was more frequent.

(5) As shown in Figure 3f, dynamic change degree of unused land was remarkable during the study period, PLAND descended, and area of unused land also decreased by 2767 hm^2 since 1990. They indicated unused land was exploited and transferred to other land use types. NP, FN and DIVISION descended at a rapid speed, which showed landscape tended to the centralized distribution, landscape fragmentation degree reduced; FD and AWMSI decreased, which reflected patch shape tended to be simple and regular; increasing LPI and MPS demonstrated that human being's cultivation degree became more and more higher against unused land.

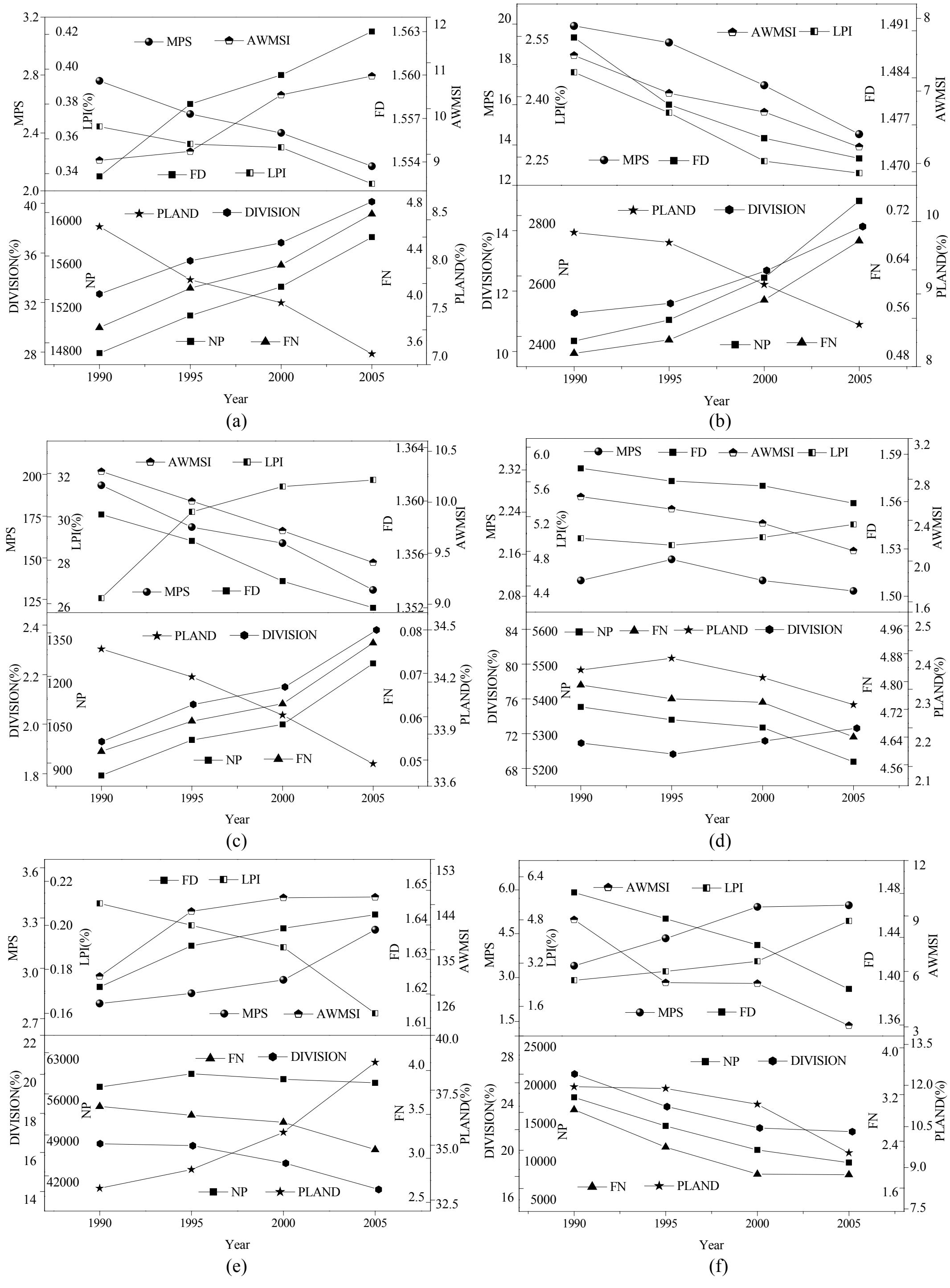

Figure 3 Landscape index analysis of land use type in Kitakyushu
(a) farmland; (b) forestland; (c) mountain; (d) water; (e) urban land; and (f) unused land

3.2 Dynamic change of landscape scale

At the scale of landscape, 10 landscape indices were selected to analyze dynamic change characteristics of total land use in Kitakyushu (number of patch (NP), mean patch size (MPS), largest patch index (LPI), area-weighted mean shape index (AWMSI), division (DIVISION), fragmentation index (FN), fractal dimension (FD), Shannon's diversity index (SHDI), Shannon's evenness index (SHEI) and dominance index (DI)). The results are shown in Figure 4.

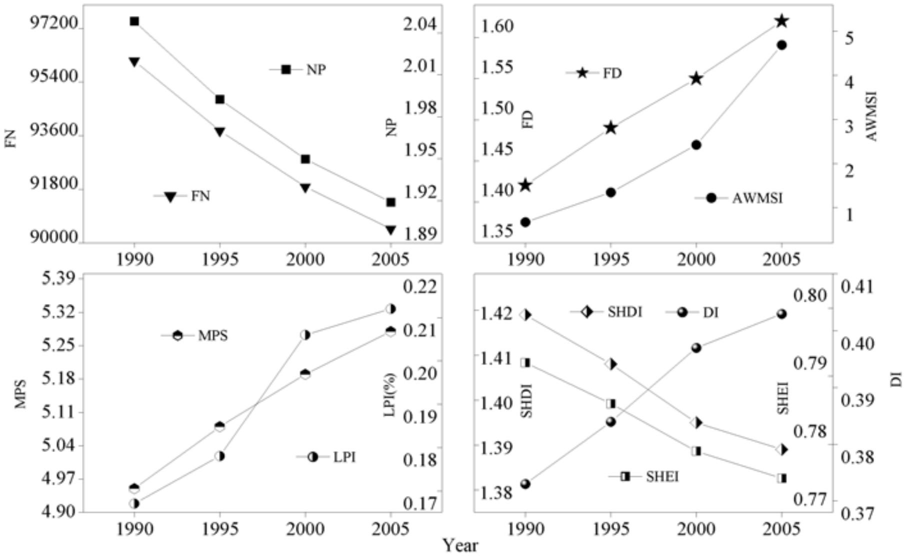

Figure 4 Landscape index analysis of total landscape in Kitakyushu

Total patch number dropped from 97448 to 91367, FN index decreased, which showed landscape tended to centralized distribution, degree of landscape fragmentation reduced. It is evident that this change resulted from the following two reasons. Firstly, urban built-up area was expanded; secondly, areas of public land and unused land were increased. AWMSI and FD indices exhibited increasing tendency, which indicated landscape shape tended to be complex, human activity enhanced the development and exploitation degree of local land. MPS and LPI increased, which indicated that intensity of human activity was intensified. Rising DI reflected landscape type appeared the non-equalization in spatial distribution; one or several element dominance in the landscape was heightened, connectivity of total landscape was enhanced. Decreasing SHDI and SHEI indicated heterogeneity degree of landscape dropped, landscape type had a developing tendency towards simplification or non-equalizing direction, which directly reflected that built-up land and public land were increased, forestland and farmland were massively reduced. However, ant-jamming ability of landscape and stability of entire ecosystem were reduced.

4 Markov process of land use change

4.1 Markov model

Markov process is a kind of special random moving from one state to another state at each time step. A *first-order Markov model* is a model of such a system in which probability distribution over next state was assumed to only depend on current state (and not on previous ones) (Veldkamp *et al*., 2001; Fischer *et al*., 2001; Pijanowski *et al*., 2002). This characteristic of Markov process is appropriate to application change of land use structure, because dynamic change of land use also possesses the properties of Markov process under certain conditions: 1) within a certain region, different land use types may be transformed into each other; 2) mutual conversion process between land use types includes many incidents which are difficult to be described precisely by a special function; and 3) during study periods, average transfer state of land use structure is relatively stable and accordant with requirements of Markov Chain.

At first, original transfer probability matrix of land use type needs to be defined before Markov process. Its mathematics expression was expressed as follows:

$$P = (P_{\mathrm{ij}}) = \begin{vmatrix} P_{11} P_{12} \cdots P_{1n} \\ P_{21} P_{22} \cdots P_{2n} \\ \cdots \\ P_{n1} P_{n2} \cdots P_{nn} \end{vmatrix} \tag{1}$$

In the above matrix, P_{ij} was probability of the ith type land transformation into the jth type land from prophase to telophase; n was land use type of the study area.

P_{ij} should meet the following conditions

$$0 \le P_{ij} \le 1 (i, j = 1, 2, 3, \cdots, n) \tag{2}$$

$$\sum_{i=1}^{n} P_{ij} = 1 (i, j = 1, 2, 3, \cdots, n) \tag{3}$$

According to non-aftereffect of Markov process and probability formulas of Bayes condition, forecast model of Markov was obtained:

$$P_{(n)} = P_{(n-1)} P_{ij} \tag{4}$$

$P_{(n)}$ was state probability of any times

$P_{(n-1)}$ was preliminary state probability

4.2 Transformation matrix of land use

Remote sensing image or land use map in different periods were spatially superimposed and operated with GIS technology, transfer matrixes of land use types in each period were obtained, and then land use change process was further analyzed. The paper applied operation method of map algebra to calculate transfer matrix of land use map during two periods, then land space and number change condition of 15 years in the study area were analyzed (Tables 3–5).

Table 3 The land use change matrix A from 1990 to 1995 in Kitakyushu (hm^2)

1990 \ 1995	Farmland	Forestland	Mountain	Water	Urban land	Unused land	Total
Farmland	2958.85	189.60	110.67	78.86	544.23	181.99	4064.20
Forestland	146.58	3707.90	105.07	68.02	494.72	225.12	4747.41
Mountain	105.86	164.71	15800.04	40.81	370.73	95.96	16578.10
Water	63.82	92.89	83.64	687.33	111.72	93.55	1132.96
Urban land	342.39	380.90	291.27	199.85	14558.84	154.01	15927.26
Unused land	183.50	147.41	114.08	74.83	258.82	4982.63	5761.26
Total	3800.99	4683.41	16504.77	1149.71	16339.06	5733.25	48211.19

Table 4 The land use change matrix B from 1995 to 2000 in Kitakyushu (hm^2)

1995 \ 2000	Farmland	Forestland	Mountain	Water	Urban land	Unused land	Total
Farmland	2895.29	88.56	76.00	62.08	646.92	32.14	3800.99
Forestland	126.05	3849.88	134.85	91.15	385.44	96.05	4683.41
Mountain	47.12	47.05	15770.17	81.90	495.81	62.73	16504.77
Water	15.31	10.00	10.95	785.59	304.38	23.48	1149.71
Urban land	280.68	236.70	240.87	9.98	15263.37	307.46	16339.06
Unused land	318.44	167.10	166.09	91.81	58.54	4931.27	5733.25
Total	3682.88	4399.28	16398.93	1122.52	17154.45	5453.12	48211.19

Table 5 The land use change matrix C from 2000 to 2005 in Kitakyushu (hm^2)

2000 \ 2005	Farmland	Forestland	Mountain	Water	Urban land	Unused land	Total
Farmland	3225.70	35.06	6.34	5.32	380.68	29.78	3682.88
Forestland	26.51	3951.35	6.27	0.01	336.70	78.44	4399.28
Mountain	13.95	43.87	16121.85	0.96	140.87	77.43	16398.93
Water	0.04	0.16	41.12	1068.06	9.98	3.15	1122.52
Urban land	92.43	102.00	62.58	1.94	16825.63	69.88	17154.45
Unused land	70.10	5.07	21.95	13.49	999.91	4342.61	5453.12
Total	3428.73	4137.51	16260.10	1089.78	18693.78	4601.29	48211.19

Note: In Tables 3–5, the rows denoted the 1and use form i at time k. The ranks denoted the land use form j at time k+1. A_{ij} was the area of the land use form that was converted from i at time k to j at time k+1.The summation of rows and ranks denoted the total area of each land use form at time k and k+l, respectively.

Based on change condition of land use, the general change tendency of land use was as follows during the 15 years: (1) mountain and urban land were two main land use types in Kitakyushu, their land area sum accounted for 70% of the total amount. Fluctuation of mountain land was small, it only appeared a little decreasing tendency from 1990 to 2005, and reduced mountain land was mainly converted into urban land and forestland; urban land increased rapidly by 2766.516 hm^2 during the 15 years, it accounted for 17% of the area in 1990, meanwhile these increasing land mainly came from farmland, forestland and unused land, among them the converted farmland was 1571.83 hm^2, occupying 39% of the farmland area in 1990, forestland occupied 26% of the area in 1990. It indicated that enlargement of urban land was at the expense of invading and occupying forestland and farmland. (2) Change of farmland and forestland showed annual descending tendency during the 15 years. Decreased farmland and forestland area reached to 635,610 hm^2 and 610 hm^2 respectively, and the decreased farmland was mainly transferred into forestland and urban land. Farmland has been descended due to policy of converting farmland to urban land. Decreased forest-land was converted into farmland and urban land, which showed that developments of agri-culture and city were at the cost of forest resource. Meantime, in order to control the de-creasing tendency, about 1039 hm^2 of urban and unused land were transferred into forestland during the 15 years. (3) Change of water body area was relatively stable. There was a little descending tendency from 1995 to 2005. This was mainly due to increase of irrigated farm-land and garden farmland. (4) Unused land area decreased 1160 hm^2 during the 15 years, the changed unused land was transferred into farmland and urban land, which showed the land resource was used to enlarge urban land and farmland for management purpose.

4.3 Dynamic change tendency of land use

By means of forecast model of Markov process, specific operational procedures were carried on. Every certain time (namely, duration was five years) was taken as a step distance, potential land use changes were modeled from 2010 to 2050 based on Markov process and GIS technology. As shown in Figure 5, development tendencies of the future 40 years were that farmland, forestland and unused land kept a decreasing tendency, but decreasing speed obviously became slow, which indicated that occupied extent and intensity of farmland would become small. Change of water body area and mountain area will continually keep relatively stable. Urban land annually increased, major driving force was the rapid urban economic development. The rate of urban spatial expansion always changed with the fluctuation of economic development. In the 1990s, Kitakyushu's economy rapidly developed. Gross National Product (GNP) per capita was 18500 $ in 1990 and greatly increased up to 59400 $ in 2005. With the rapid development of economy, urban industrial structure was significantly changed. During this period, the ratio of agriculture to GNP was substantially decreased， while the ratio of industry to GNP was dramatically increased. The rapid growth of ratio of industrial product to GNP certified a rapid development of industry during the studied years. This demanded more 1ands for the expanding industry. Consequently, several industrial estates have been established during the last decades. With construction of the industrial estates, the built-up land use substantially increased. The rapid economic development also brought up increases in investment of housing construction, which led to the expanding of urban space at an accelerated rate. Briefly, urban economic development, especially the rapid industrial process, led to the establishment of industrial estates, boom of real estate and increase in urban land use. From the respect of total study area, it was the strongest tendency to convert urban land among all change situation of land use type, a certain proportion of other land types transformation into urban land existed in every stage, which reflected that there would be a powerful tendency to conversion of other land types into urban land in the future, also that Kitakyushu was still at the rapid urbanization stage.

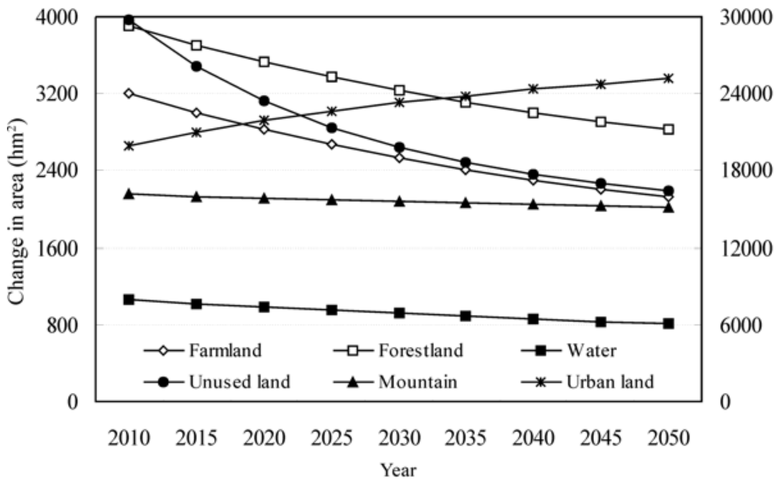

Figure 5 The land use change from 2005 to 2050 in Kitakyushu (hm^2)

Note: left Y axis showed farmland, forestland, water and unused land area; right Y axis showed mountain and urban land area

5 Discussion and conclusions

(1) The dynamic changes of regional landscape indices can indicate the transformation of regional ecological functions, meanwhile, these characteristics of transformation changes among various landscape types are beneficial to reveal sustainability of land use and level of regional ecosystem function, to detect out change tendency of regional ecological environment and its inner factors. In this paper, land use change situation of Kitakyushu city in the past 15 years was analyzed by 11 indices. In summary, in view of land use landscape types, obvious difference of indices change existed in different landscape types, which demonstrated that distribution of land use types was inclined to more dispersed, decreasing connectivity among them and complicated spatial pattern. As a result, ecosystem stability of regional landscape and sustainability of land use were reduced. On the other hand, FN index decreased and AWMSI, FD, MPS and LPI increased, which showed land use tended to centralized distribution and complication, human activity enhanced development and exploitation degree of local land. Rising DI, decreasing SHDI and SHEI reflected that land use type appeared non-equalization in the spatial distribution. According to change of these landscape indices, ant-jamming ability of land use landscape and stability of entire ecosystem environment in Kitakyushu city were weakened. It's evident that the following three reasons resulted in these changes. Firstly, population growth indirectly resulted in increasing of residence land and patch number. Secondly, industrialization and urbanization have been accelerated owing to development of regional economy, which has made land use change more extensively and diversely. Thirdly, policies driving resulted in which the region has been chiefly aiming at economic growth and ignoring reasonable adjustment of land use structure. Based on the above conclusions, it was recommended that mode of land use should be adjusted at landscape scale to rehabilitate and reconstruct the landscape ecosystems in Kitakyushu city.

(2) Transfer matrix of Markov was first applied to analyze change process of land use at different periods. The research results showed the changing tendency for all types of land use into urban construction land was enhanced. To some extent, the study indicated Kitakyushu was still at the rapid urbanization stage. Then, Markov process together with GIS technology was also used to simulate the potential land use changes from 2006 to 2050. According to the results, percentages of farmland and forestland and mountain and urban land will be 4.41%, 5.85%, 31.35% and 52.19%, respectively, of total land area in 2050. Economic efficiency of land use would be improved with the rapid increase of urban land. However, local ecological conditions would be deteriorated by decrease of forestland

(3) The study on the regional landscape pattern change was meaningful to understand dynamic change causes, transformation mechanisms and tendency of land use patterns. During the analysis, disturbance and damage to natural environment by human activities were announced for driving some latent and regular laws against irregular landscape. Meanwhile Markov model was employed to forecast the land use change tendency in the future, forecasting results were valuable for policy decision on the local urban sprawl and ecological conservation. At present, rapid socio-economic development and industrialization, especially in the developing countries, has imposed significant pressure on the land use structure, terrestrial and aquatic ecosystems, and induced instability of ecosystem structure and fragility of ecological environment. Therefore, this research has an important signifi-

cance to provide theory support for seeking scientific method and reasonable scale of resource to improve regional ecological environment and sustainability of land use.

(4) When landscape analysis was carried out, many proposed indices (such as, number of patch, fragmentation, border density, patches abundance degree, and so on.) were easily influenced by landscape size and researchers' subjectivity, so that research results often lacked some a certain standard and logical contrast. To conquer these shortages, each of typical characteristic in respect of landscape ecology was synthetically analyzed by applying multiple indices. However, since landscape pattern index is more efficient to show large-scale landscape pattern changes (>1:5000), in the small-scale research fine change extraction of landscape pattern isn't accurate, in this case, some other methods need to be combined to complete the analysis.

In this paper, transformation probability of various land use types during 15 years was forecast by theoretic tendency value calculation of land use variance on Markov model that was a random without aftereffect, which effectively made up the deficiencies by applying the total area changes of various lands to explain their variances. In addition, theoretic tendency value was statistically independent. Therefore, it was appropriate that inter-transforming information of land use types was digitized into typical theoretic tendency value for their comparisons, which overcame the disadvantages of their being unable to be directly compared due to different initial years. However, only if condition of dynamic changes is relatively stable, Markov model can more accurately reflect dynamic change of the type. Also, if forecast is a long-term process, different interference conditions will induce different forecast result. Therefore, when employing Markov process, first of all, its application precondition and credibility of forecasting results need to be testified by a large amount of data analysis and evaluation; and then Markov model need to be further amended according to essence and requirement of different detailed study cases.

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