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EVALUATION ON EXTENT CHANGE AND FUTURE DEVELOPMENT OF URBAN LAND USE USING GIS TECHNOLOGY

DongJie GUAN [1,*], XueRu ZHANG [1], HaiFeng LI [2], Takuro INOHAE [3], Tadashi NAGAIE [3] and Kazunori HOKAO [2]

ABSTRACT: Based on four phases of land use patterns obtained in 1976, 1987, 1997 and 2005 with integrating spatial technology of geographic information system(GIS), this paper studied the dynamic change and transformation of various land use types in Fukuoka, Japan. Firstly, the characteristics of quantitative and spatial change of land use in the past 29 years were described according to spatial distribution maps, and then changing of land use extent was evaluated by a dynamic change model. The results indicate that the grade value of land use extent was situated between 2 and 4, showing that the land use extent has been transferring from extensive type to urban use type; additionally, change amount and change rate of land use extent were both greater than 0, thus, the land use extent has been situated at a developing stage. Finally, a transfer matrix of Markov was applied to analyze the transferring process of each land use type and to forecast the tendency of future land use change. The forecasting results reveal that area of urban land will continually keep rising at a gradually decreasing speed. Therefore, it will be a long process for land use extent to reach to the urbanization level.

Keywords: Land use, geographic information system, dynamic change analysis, markov forecast

INTRODUCTION

Land use change played vital roles in regional, social and economic development and global environmental changes (Gilg, 2009). On a global basis and a longer time frame, 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 period, as was noted by Raman Kutty and Foley. Currently, human transformations of the Earth's land surface are significant with 10%–15% in row crop agriculture or urban-industrial areas and with 6%–8% in pastureland (Ramanukutty and Foley, 1999). Concerning about the huge land use changes caused by rapid growing economy and accelerated industrialization and urbanization, international Geosphere-Biosphere Program (IGBP) and International Human Dimensions Program (IHDP) have launched a plan of "Land Use/Cover Change (LUCC)" in 1995, since then LUCC has been an advanced and hot subject in global environment change research (Meyer, 1996; Geist, 2001; Susanna, 2002; Erika, 2005). 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 (Gautam, 2003; Luciana, 2007; Herold, 2002; Quan, 2006). Nevertheless, there have been few comprehensive studies to induce the landscape ecology environmental effect on the basis of land use change and to forecast dynamic change tendency in the future land use by Markov model.

In this paper, land use patterns of Fukuoka in Japan are established to analyze the spatial-temporal changing features from l976 to 2005. Subsequently, change of land use extent is evaluated by a dynamic change model. Then, the paper emphatically analyzed the transformation process of land use in the different periods and simulated the potential change of land use from 2005 to 2053 with a transfer matrix of Markov. The study aims to present a typical research case revealing the land use change during the process of industrialization and urbanization in coastal region.

[1] Hehai Department, Chongqing Jiaotong University, 66, Xufu Rd., Nan`an Dist., Chongqing 400074, P. R. China
[2] Faculty of Science and Engineering, Saga University, 1, Honjo, Saga 8408502, Japan
[3] Institute of Lowland and Marine Research, Saga University, 1, Honjo, Saga 8408502, Japan
[*] Corresponding author: guandongjie_2000@hotmail.co.jp
Note: Discussion on this paper is open until December 2012

METHODS

Study Area

Fukuoka (33°35'N, 130°24'E) situating on the northern seashore of Kyushu Island is the capital of Fukuoka prefecture in Japan, across the Korea Strait from South Korea's Busan (Fig.1). It is the most populous city in Kyushu and the largest metropolitan area with population of 2.5 million in west of Osaka city. The city was designated on April 1, 1972 by government ordinance and is part of the heavily-industrialized North Kyushu zone. Choosing such a city is applicable to present a typical research case revealing the land use change during the process of industrialization and urbanization in coastal region.

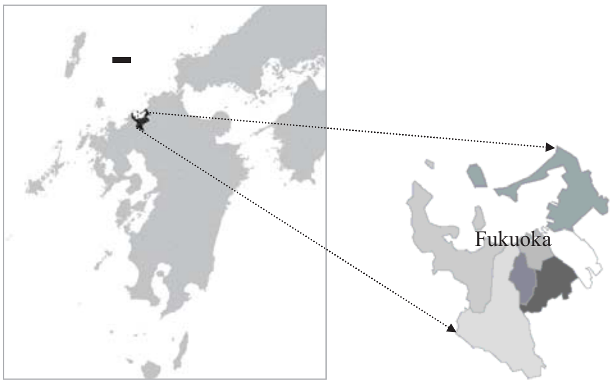

Fig. 1 Location of Fukuoka in Japan.

Data Sources

In this paper, land use types are divided into 6 classes (agricultural land, forestland, water body, build-up land, public land and unused land) according to national classification standard of land use (Fig.2). The data covering 29 years was originated from remote sensing data, topographic map and land use map, and was sectionalized at the four year nodes of 1976, 1987, 1991 and 2005(Fig.3). From these data sources, we acquired spatial distribution map of land use in the four different periods by using GIS technology, then established the land use spatial database and attribution database.

Evaluation Model

Extent change model of land use is to emphatically study the synthetic result of extent change of 1and use type in a studied area. This model can not only reflect the extensity and the intensity of land use, but also depict the change tendency of land use. According to extent difference of human being's developing and utilizing against the land, Liu. et al put forward the quantitative analysis method and calculation formulas of land use extent from the viewpoint of ecology theory (Meyer and Turner, 1996; Ramanukutty and Foley, 1999; Liu and Buheaosier, 2000; Geist and Lambin, 2001), who divided different types of land use into four extent grades. Four grade indices are assumed to be 1, 2, 3, and 4, respectively, as shown in Table 1.

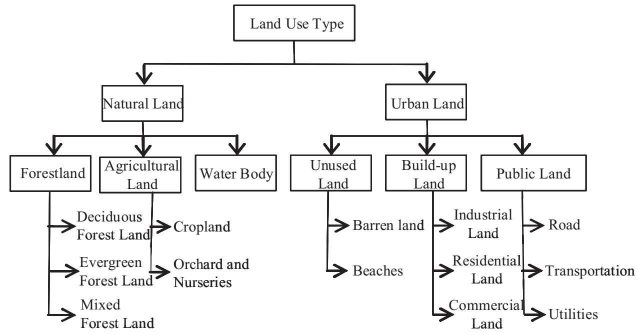

Fig. 2 Land use type in Fukuoka.

Table1 Classifications and grade values of land use extent.

Grade	Grade Type	Land Use Type
1	Unused	Barren Land, Beaches
2	Extensive	Forest Land, Water body
3	Intensive	Cropland, Orchard and Nurseries
4	Urban land	Industrial Land, Build-up Land, Road, Commercial Land, Transportation, Utilities

The formulas contain three components: index of land use extent, change amount of land use extent, and change rate of land use extent. The index of land use extent reflects the change extent of land use; the change amount of land use extent and the change rate quantify the composite level and changing trend of land use in the region (Zhu et al., 2003; Hu et al., 2006). The mathematics expressions are followed:

$$L = 100 \times \sum_{i=1}^{n} A_i \times C_i, \quad L \in [100, 400] \tag{1}$$

$$\Delta L_{b-a} = L_b - L_a = 100 \times [\sum_{i=1}^{n} (A_i \times C_{ib}) - \sum_{i=1}^{n} (A_i \times C_{ia})] \tag{2}$$

$$R = \frac{\sum_{i=1}^{n} (A_i \times C_{ib}) - \sum_{i=1}^{n} (A_i \times C_{ia})}{\sum_{i=1}^{n} (A_i \times C_{ib})} \tag{3}$$

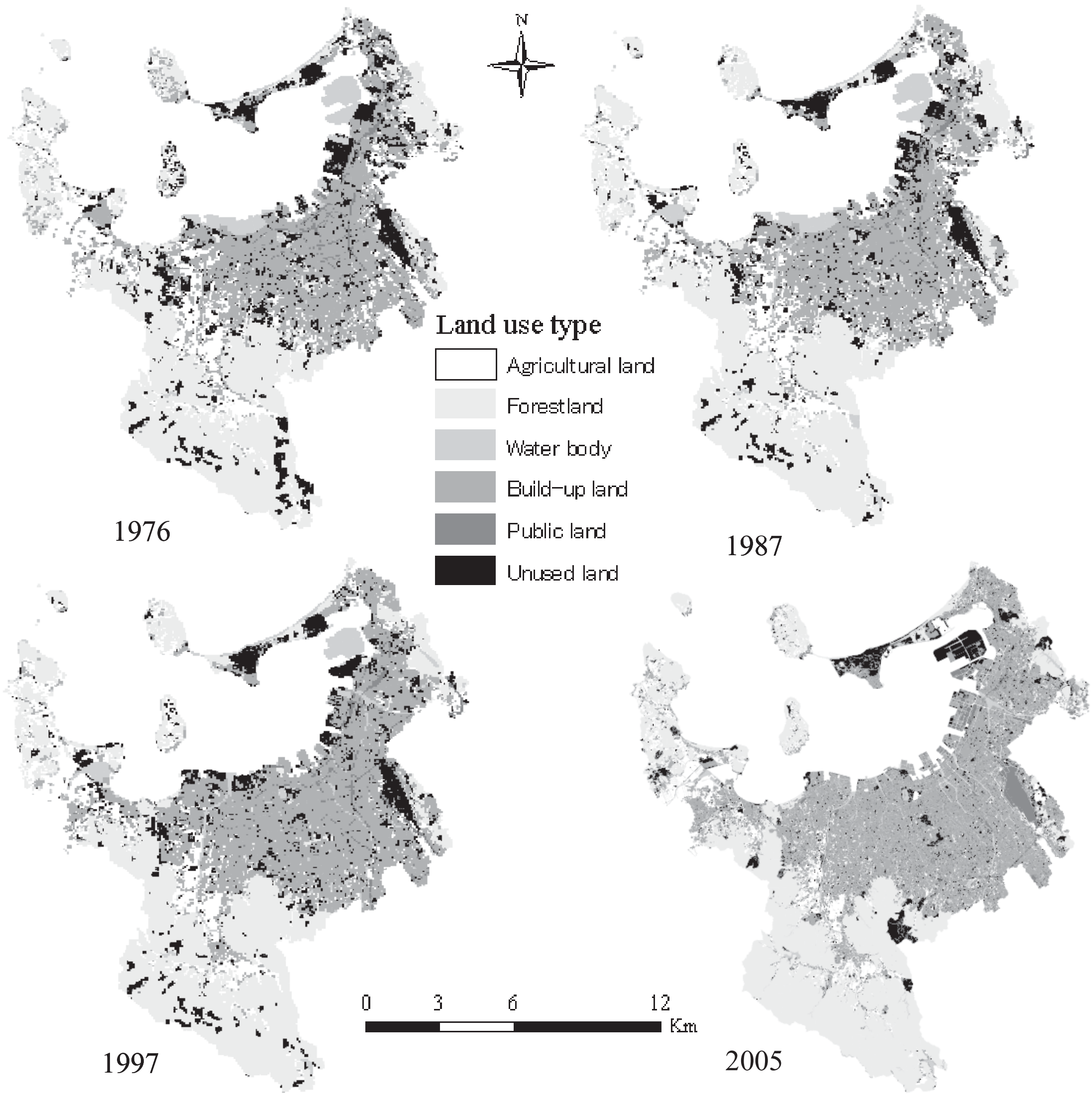

Fig. 3 Spatial distribution of land use types from 1976 to 2005 in Fukuoka.

Where, L is the index of 1and use extent; A_i is the i grade value of 1and use extent; C_i is the area percentage of i grade land use extent; n is the grade number of land use extent; $\Delta L_{b\text{-}a}$ is the change amount of 1and use extent; C_{ia} is the area percentage of i grade land use extent at the beginning of studied period; C_{ib} is the area percentage of i grade land use extent at the end of the studied period; R is the change rate of 1and use extent. If the change amount and the change rate are positive, the land use of the region is in a development period; otherwise, it is in a declining period.

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 is assumed to only depend on current state (and not on previous ones)(Fischer and Sun, 2001). At first, original transfer probability matrix of land use type need be defined before using Markov process. Its mathematics expression is followed:

$$P = (P_{ij}) = \begin{vmatrix} P_{11}P_{12}...P_{1n} \\ P_{21}P_{22}...P_{2n} \\ ... \\ P_{n1}P_{n2}...P_{nn} \end{vmatrix} \tag{4}$$

In the above matrix, P_{ij} is probability for transformation of ith type land into jth type land from prophase to telophase; n is amount of land use type in the studied area. P_{ij} should meet the following conditions:

$$0 \le P_{ij} \le 1(i, j = 1,2,3,...,n) \tag{5}$$

$$\sum_{i=1}^{n} P_{ij} = 1(i, j = 1,2,3,...,n) \tag{6}$$

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

$$P(n) = P(n-1)P_{ij} \tag{7}$$

P(n) is probability of current state; *P(n-1)* is probability of preliminary state.

RESULTS ANALYSIS

Change Characteristic Analysis of Land Use

The paper computed the area change of all land use types in the past 29 years. As shown in Fig.4, the area changes of all land use types in the past 29 years were obvious: (1) agricultural land and unused land from l976 to 2005 were reduced by 9% and 8%, respectively; (2) change of water body and forestland was only decreased a little; (3) build-up land public land from 1976 to 2005 remarkably increased by 39% and 6%. In a general view, one can see in Fig.5 the extension trend occurring the edge of urban area.

Spatial distribution of land use types in Fukuoka city at the four different periods were also obtained in virtue of GIS spatial technology. From Fig. 3, we can see that spatial pattern of land use in the four periods was chiefly characterized as the changes of patches distribution. Agricultural land, forestland and unused land patch showed continual fragmentation and dispersion, indicating that the human's exploration extent and utilizing intensity became larger and larger (Sedjo and Simpson, 2007). The increasing patch numbers and patch areas of build-up land and public land showed their concentrated spatial distribution patterns (Cheshire, 1999).

Extent Change Analysis of Land Use

To analyze the differences of land use extent between Fukuoka and other cities in Japan, the paper comparably analyzed the land use extent with Shinkamigo, Kitakyushu and Maebaru as reference cities. According to Eq.(1), the indices of land use extent at four year nodes were computed, as seen in Fig.6. The data showed that land use extent in the four cities appeared an increasing tendency. The indices value of land use extent was situated between 2 and 4, which showed that the land use extent had been transferring from extensive type to urban use type. The detailed sequence of land use extent was as followed: Fukuoka > Maebaru > Kitakyushu > Shinkamigo. Change amount and change rate of land use extent were also evaluated according to Eq.(2 and 3). From Fig.7 and Fig.8, it is found that, R and ΔL_{b-a} values were greater than 0 in 1976-1987 and in 1987-1997, suggesting that land use extent had been situated in the developing stage. R and ΔL_{b-a} values of Kitakyushu were lower than 0 in 1997-2005, which implied that land use extent had been situated in a declining stage. In total, the positive variation value from 1976 to 2005 reflected that the 1and use extent of Fukuoka city has been at a developing stage, and land use extent of Fukuoka city in the 29 years had been gradually increasing.

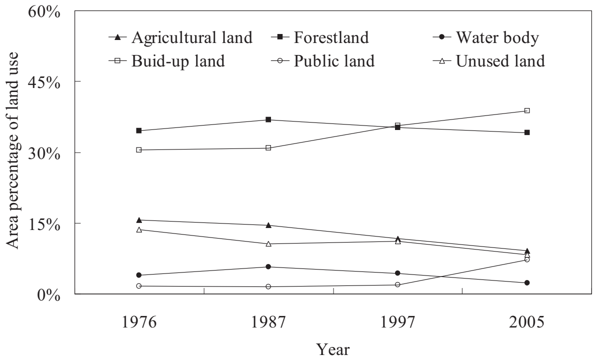

Fig. 4 Area percentage change of land use type in Fukuoka.

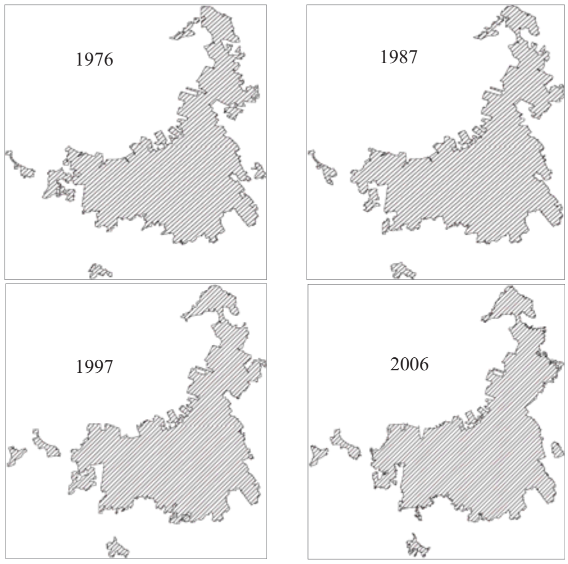

Fig. 5 Extension images of urban land use in Fukuoka from 1976 to 2006.

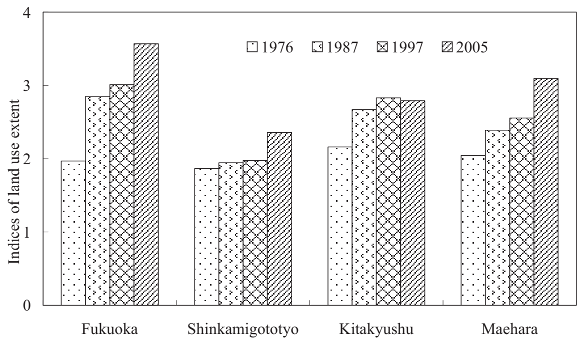

Fig. 6 Indices of land use extent from 1976 to 2005.

Table 2 Change matrix of land use from 1976 to 1987

1987/1976	Agricultural land	Forestland	Water body	Build-up land	Public land	Unused land	Total
Agricultural land	79.09	4.40	0.78	10.09	0.82	4.82	15.68
Forestland	0.86	94.59	0.41	1.66	0.05	2.42	34.56
Water body	0.78	2.58	89.70	1.87	0.08	5.00	4.00
Build-up land	3.88	3.25	4.94	83.09	0.88	3.95	30.53
Public land	4.27	0.58	0.78	35.15	50.29	8.93	1.61
Unused land	4.08	17.03	2.36	20.37	1.63	54.53	13.62
Total	14.54	36.81	5.70	30.94	1.45	10.57	100.00

Table 3 Change matrix of land use from 1987 to 1997

1997/1987	Agricultural land	Forestland	Water body	Build-up land	Public land	Unused land	Total
Agricultural land	71.95	0.02	0.28	18.20	1.23	8.32	14.53
Forestland	0.42	94.07	0.21	2.70	0.07	2.54	36.81
Water body	0.00	1.98	73.92	4.88	0.77	18.46	5.70
Build-up land	3.16	0.00	0.00	96.33	0.39	0.11	30.94
Public land	0.00	0.00	0.00	0.00	100.00	0.00	1.45
Unused land	0.56	4.37	0.03	18.53	1.18	75.32	10.57
Total	11.64	35.20	4.34	35.68	1.94	11.19	100.00

Table 4 Change matrix of land use from 1997 to 2005

2005/1997	Agricultural land	Forestland	Water body	Build-up land	Public land	Unused land	Total
Agricultural land	62.14	11.64	1.21	15.73	2.09	7.19	11.64
Forestland	1.82	85.44	0.37	4.40	0.62	7.34	35.20
Water body	3.31	10.52	33.30	24.28	3.67	24.92	4.34
Build-up land	2.23	1.24	0.90	84.87	8.29	2.45	35.68
Public land	4.18	2.73	2.73	58.53	20.09	11.73	1.94
Unused land	2.43	16.18	1.45	25.99	29.39	24.56	11.19
Total	9.17	34.20	2.25	38.76	7.26	8.35	100.00

Note: In Tables 2-4, the rows denoted the 1and use form i at time k. The ranks denoted the land use form j at time k+1. Aij 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.

Markov Process of Land Use Change

Transformation matrix of land use

Land-use maps in the different periods were spatially overlaid and operated with GIS technology, transfer matrixes of land-use types in each period were obtained. As seen in Table 2, Table 3 and Table 4, the total region transformation tendency of land use types from 1976 to 2005 appeared an unbalanced tendency of unidirectional-transformation, which led to that the transformation tendencies for all land use types into build-up land and public land were enhanced.

Dynamic change tendency of land use

By means of forecast model of Markov process, every a certain period was taken as a step distance, potential land-use changes were simulated from 2005 to 2053 in Fukuoka. As shown in Fig.9, by the 2053 year, agricultural land, forestland and unused land will keep decreasing tendency. Change of water body area will continually keep relatively stable. Build-up land and public land will annually increase. Based on the forecast result of land use change in the future, the indices of land use extent from 2005 to 2053 were computed, as seen in Fig. 10. The data show that land use extent from 2005 to 2053 in Fukuoka is enhanced.

CONCLUSIONS

In this paper, we take Fukuoka as case study to carry out extent change analysis and forecast assessment of urban land use. The main works and results can be summarized as follows:

During the studied period of 1976-2005, both area and spatial distribution of every land use type in Fukuoka exhibited some changes to different extents. Land use extent in Fukuoka was situated at a developing period from intensive use extent to urban use type. Forecast results of land-use changes in the period of 2005-2053 show that the areas of agricultural land, forestland and unused land will still be decreased at slow speeds; build-up land and public land will annually increase; change of water body area will continually keep stable. Moreover, land use extent in the near future will be inclined to urban use type, and transferring speed of land use extent obviously becomes slow, which induces that it will take a long time for land use extent to access the urban use type.

This study demonstrates changes of land use in the viewpoints of temporal and spatial, extensive and intensive, extent and rate, current and future. Such a research theme should be beneficially addressed to better understand a complex land use system, and corresponding results could be considered during the advanced land use management and region planning for harmonizing the balanced development between urban expansion and ecological conservation.

ACKNOWLEDGEMENTS

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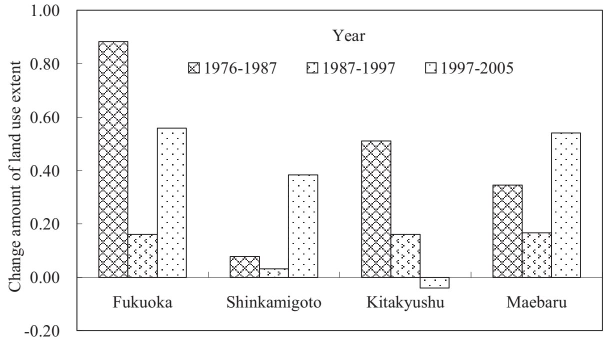

Fig. 7 Change amount of land use extent from 1976 to 2005.

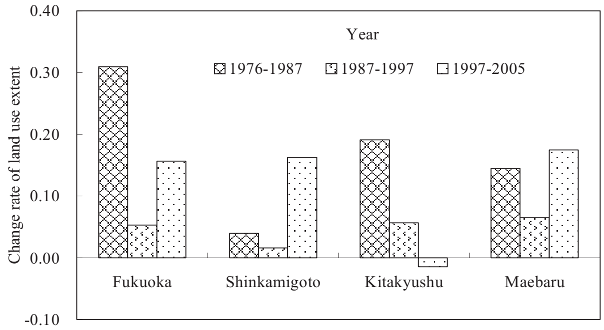

Fig. 8 Change rate of land use extent from 1976 to 2005.

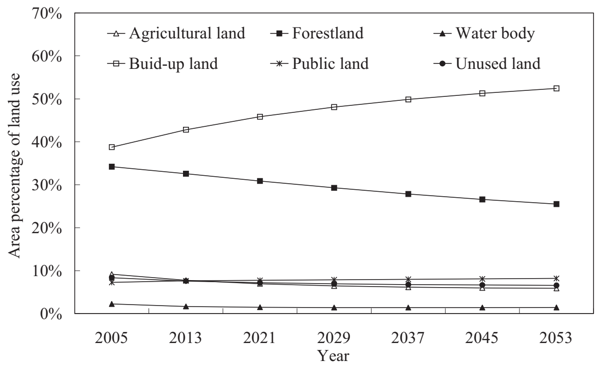

Fig. 9 Forecast results of land use in Fukuoka.

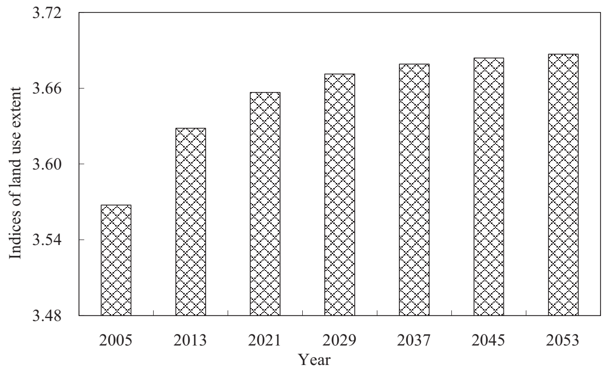

Fig. 10 The indices of land use extent in Fukuoka.

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