H-3.1 Long-term Projection of Land Use/Cover Change in the Asia-Pacific Region

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Abstract: The main goal of this sub-theme is to project the land use/cover status of the Asia-Pacific region at the years of 2025 and 2050. We developed a long-term projection model for land use/cover change named LU/GEC-I (Version 1) last year. The LU/GEC-I (Version 1) consists of four analytical processes: finding driving forces of land use/cover change; calibration of land use fraction function; assuming or scenario writing of future changes of driving forces; and, projection of future land use fraction at a particular area. To modify our model, we introduced a linkage model module representing labour, commodity and resources flows. The modified model is called LU/GEC-I (Version 2) temporarily. The Version 2 was applied to the Kansai District of Japan. In this projection, we assumed the physical driving forces, such as climate, elevation, water condition, etc., would not change though 2050. The outlines of the projection much depend on given future scenarios of driving forces, therefore, reasonable scenario writing is left to be the next target.

Another activity in this sub-theme is field surveys for typical areas in China and Indonesia to investigate driving forces of land use/cover changes and to collect data of land use/cover changes and related socio-economic data. We also conducted 2 km×2km Digital Mapping of Past and Latest Land Use in 4 Particular Parts of China where we can get the map at 1930s.

Key Words Land Use, Land Cover, Multiple Choice Logit Model, Linkage Model

1 Introduction

The objectives of the LU/GEC project are to analyze land use/cover changes in Asia and the Pacific regions, and to suggest sustainable policy options of land use/cover changes from the viewpoint of a global environmental conservation. For this purpose, both a modeling approach and a historical approach are adopted. In the modeling approach, the LU/GEC Basic Model estimating long-term changes in land use/cover has been elaborated and the database necessary for the prediction of land use/cover changes in Asia and the Pacific regions has been developed. For the historical approach, four regions in China have been selected as case-study areas and their land-cover maps for both the 1930's and the present have been digitized into grid data for long-term comparative analyses.

2 Structure of the LU/GEC Basic Model

This model is the macroscopic land use/cover change model which is intended to cover the semi-global area of Asia and the Pacific regions. Therefore, the model consists of the several region models, whose structures reflect the respective regional characteristics. The Linkage model combines these region models into one coherent system (See figure 1). For the present, the Urban region model, the Agricultural region model, and the Forestry region model are being elaborated.

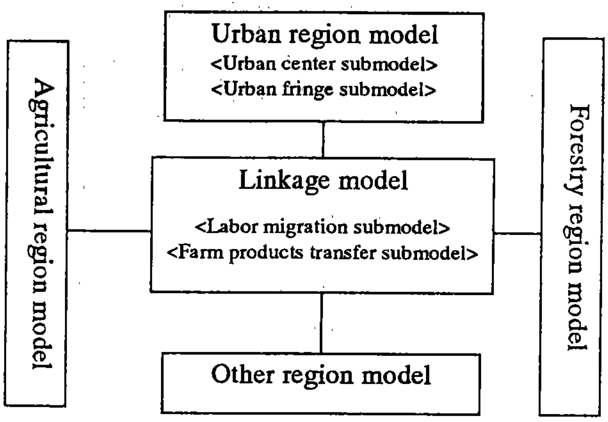


Figure 1. Framework of the Japan Basic Model.

The interrelations between the regions are reflected through the Linkage model. The Linkage model prescribes shipments of transferable resources such as population, labor force, water and products among the region models. This model gives each region model the external conditions.

2.1 Example of Modeling Approach

The Kansai district in Japan has been selected as a case-study area for the basic model. The Kansai district is the second largest metropolitan area in Japan, and consists of 138 municipalities of the Osaka, Kyoto and Shiga prefectures. Because this district consists of urban and suburban areas, only the urban region model is developed. The other region models and the Linkage model are still under consideration. All the necessary data of land use/cover, natural conditions and socio-economic data for the year 1970 and 1990 have been prepared for model building.

2.1.1 Structure of the land use change model

The operational structure of the basic model consists of two functions, namely the *land use ratio function f* and the *driving-force prediction function g*. They are shown by the following equations.

1) Land use ratio function $\mathbf{L(t)} = f\,(\mathbf{S_t}, \mathbf{n})$

2) Driving-force prediction function $S_t = g\ (S_0, t)$

3) Geophysical factors n : constant

t : time

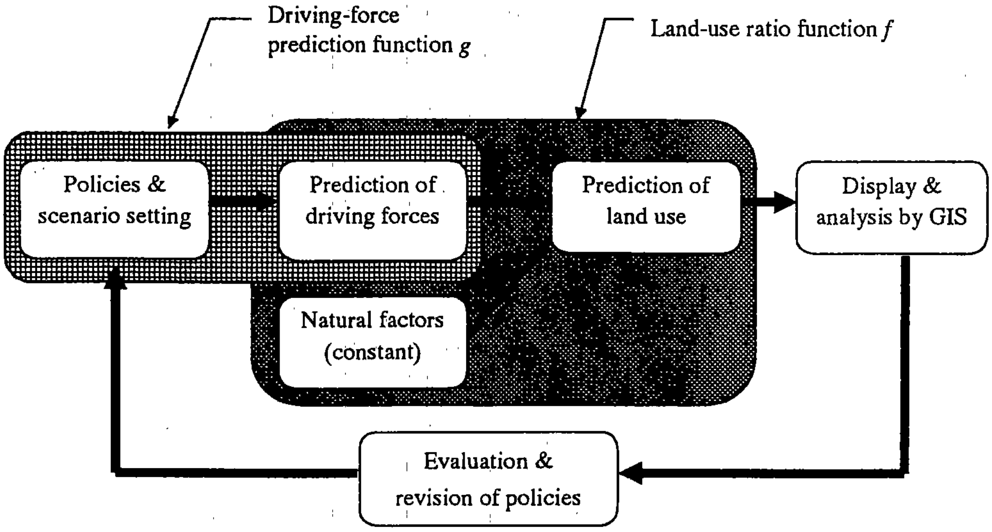


Figure 2. Land use ratio function and driving-force prediction model.

1) **Land use ratio function f:**

The function which estimates the ratios of land use/cover from both driving forces (socio-economic factors, and land use planning/policy factors) and geophysical factors. Because relationships between land use/cover and explanatory factors would be expected to be stable over a long period, we deal with this model as immutable functions.

2) Driving-force prediction function g:

This function is a dynamic model predicting future values of the major driving forces. The output values from this model are used for the input data of the above function f.

3) Geophysical factors:

These factors are treated as immutable factors because changes in these factors are expected to be relatively small over the period.

2.1.2 Land use ratio function "f"

Multi-nominal logit model is adopted for the land use ratio function. Table 1 shows the parameter values of the model which are calibrated by 276 samples (138 municipalities * 2 point of time) of the study area.

$$P_{ij} = \frac{\exp V_{ij}}{\sum_{i=1}^{4} \exp V_{ij}}, \qquad V_{ij} = \sum_{n=1}^{35} \theta_{in} \times X_{nj} + C_i$$

P_{ij} : the land use ratio of the i-th land use category (1 : farmland, 2 : forestry land, 3 : built up area, 4 : others) in the sample j (j = 1, .., 276), X_{jn} : the n-th explanatory variable(n = 1, .., 35) on the sample j, θ_{in} : parameter which reflect the relation between the n-th explanatory variable and the i-th land use category, Ci : constant for the i-th land use category.

Table 1. The parameters of multi-nominal logistic model (the Kansai district)

	Variables	Farmland	Forestry land	Built-up area
		θ1n (n = 1,..,35)	θ2n (n = 1,..,35)	θ3n (n = 1,..,35)
X1	Population density			6.84E-05
X2	Percentage of population under 64 years old	-4.59E-02	-7.24E-02	
X3	Farm-household ratio	5.55E-03		
X4	Percentage of full-time farm households			
X5	Percentage of part-time farm households (type 2)			
X6	Percentage of workers in secondary industry			
X7	Percentage of workers in tertiary industry			
X8	Percentage of female agricultural laborers	-9.16E-03		
X9	Percentage of employees in secondary industry			
X10	Percentage of employees in tertiary industry			
X11	Gross field husbandry product / farmland			
X12	Gross horticultural product / farmland	5.49E-03		
X13	Gross animal product / farmland		-4.51E-03	
X14	Average farm size	1.85E-03		
X15	Per capita gross farm products			
X16	Per capita farmland			
X17	Number of non-agricultural jobs per 100 people			
X18	Number of employees per one business firm			
X19	Distance to Kyoto / Osaka			
X20	Number of cars per person	1.585		2.647
X21	Land price			
X22	Ratio of Agriculture Promotion Area (a)	0.276		
X23	Ratio of Agricultural Land Zone (b)		-2.641	
X24	Share of Agricultural Land Zone (b) / (a)	0.758	0.772	
X25	Ratio of Urbanization Promotion Area (c)			
X26	Ratio of Urbanization Control Area (d)		-3.611	
X27	Share of Urbanization Promotion Area (c)/{(c)+(d)}	-2.470		
X28	Ratio of 0-3 degree slope area	0.209		
X29	Ratio of 3-8 degree slope area		0.436	
X30	Ratio of >15 degree slope area	-0.301		-0.295
X31	Ratio of 0-100m elevation area	0.300		
X32	Ratio of >200m elevation area	-0.292		
X33	Ratio of hill area	0.541		
X34	Ratio of tableland and terrace		-1.873	
X35	Ratio of lowland area		-1.784	
Const.		5.297	10.181	-0.156

2.1.3 Driving force prediction function "g"

For the prediction of the driving forces of land use changes, the following KSIM model is applied. Outputs of the driving-force prediction function "g" are substituted for the input data of the land use ratio function "f". Figure 3 shows an example of the future trajectories of the socio-economic driving forces of land use changes predicted by the function "g". The exogenous policy variables are also included in the system variables of the KSIM model. Effects of the respective policy options are evaluated by this model.

$$x_i(t+dt) = x_i(t)^{P_i(t)}$$

$$P_i(t) = \left\{1+\frac{dt}{2}\sum_{j=1}^{22}\left(\left|a_{ij}\right|-a_{ij}\right)\times x_j\right\} \Big/ \left\{1+\frac{dt}{2}\sum_{j=1}^{22}\left(\left|a_{ij}\right|+a_{ij}\right)\times x_j\right\}$$

$$0 \le x_i(t) \le 1 \quad (i = 1,\cdots,22),\ t \ge 0$$

xi : the i-th system variables. The system variables are normalized so that their minimum and maximum values are fixed at 0 and 1 respectively.

aij : the element of cross-impact matrix A. The aij means level of direct influence from a system variable xj to a system variable xi.

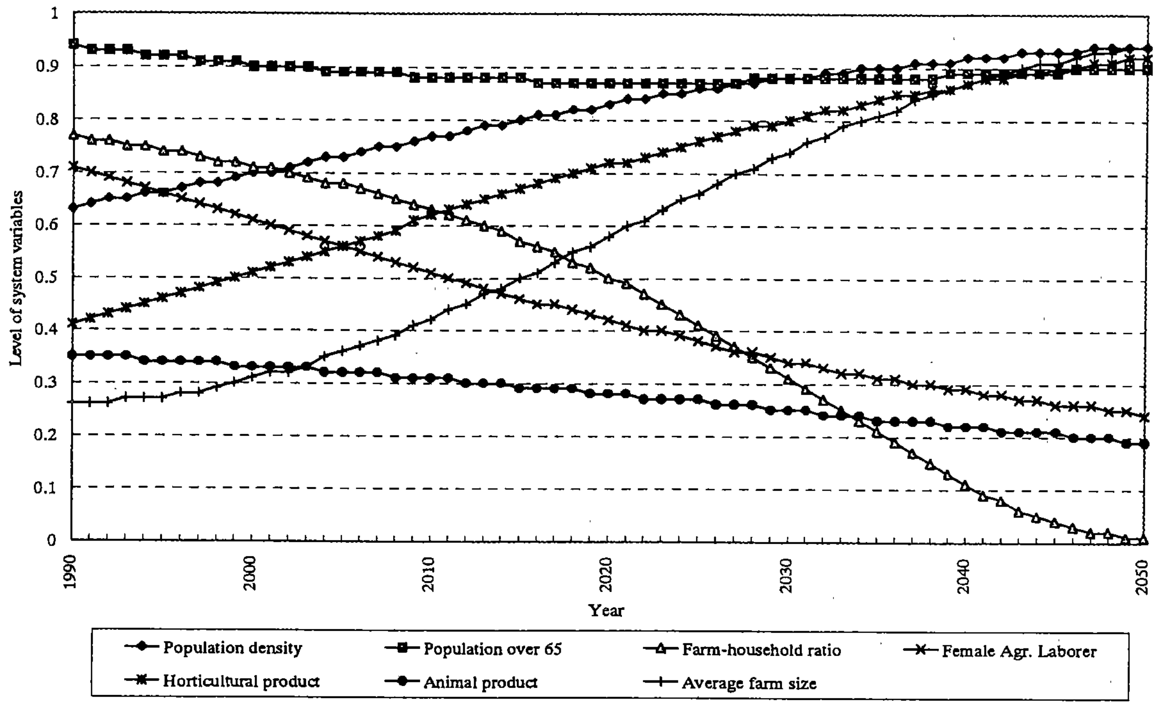


Figure 3. A prospective view of socio-economic driving forces

Figure 4 shows the land use ratios in the year 2050 which are obtained by substituting the values of the driving forces calculated by the function "g" for the land use ratio function.

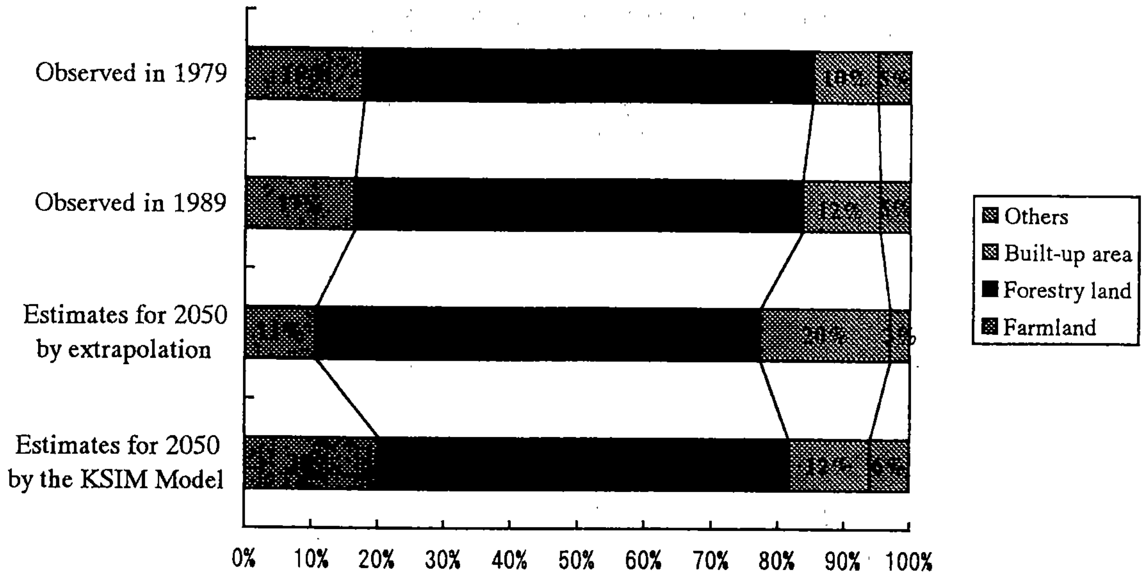


Figure 4. Estimated land use ratios for the year 2050

2.1.4 Simulation and policy implication

Eight policy options for land use controls are respectively estimated by the function "g" and the results are converted into the effects on land use by the function "f" (See Table 2). It is interesting that the influences of the respective policy options are different to each other.

Table 2. Comparison of the effects by the land use policy options

Policy options	Land use ratio: Farmland	Forestry land	Built-up area	Others
a) Increase of population density	- -	0	+	+
b) Enlargement of farm size	+ +	- -	(-)	0
c) Improvement of accessibility to Osaka	-	-	+ +	0
d) Large number of car per person	(+)	- -	+ +	0
e) High land-price policy	- -	+ +	(-)	0
f) Enlargement of "Agriculture Promotion Area"	+	- -	+	0
g) Enlargement of "Agricultural Land Zone"	+ +	-	-	0
h) Enlargement of "Urbanization Promotion zone"	0	- -	+	+

N. B. : Symbols (++, +, (+), 0, (-), -, --) in the table show the direction and the relative degree of the effects by the respective land use policy.

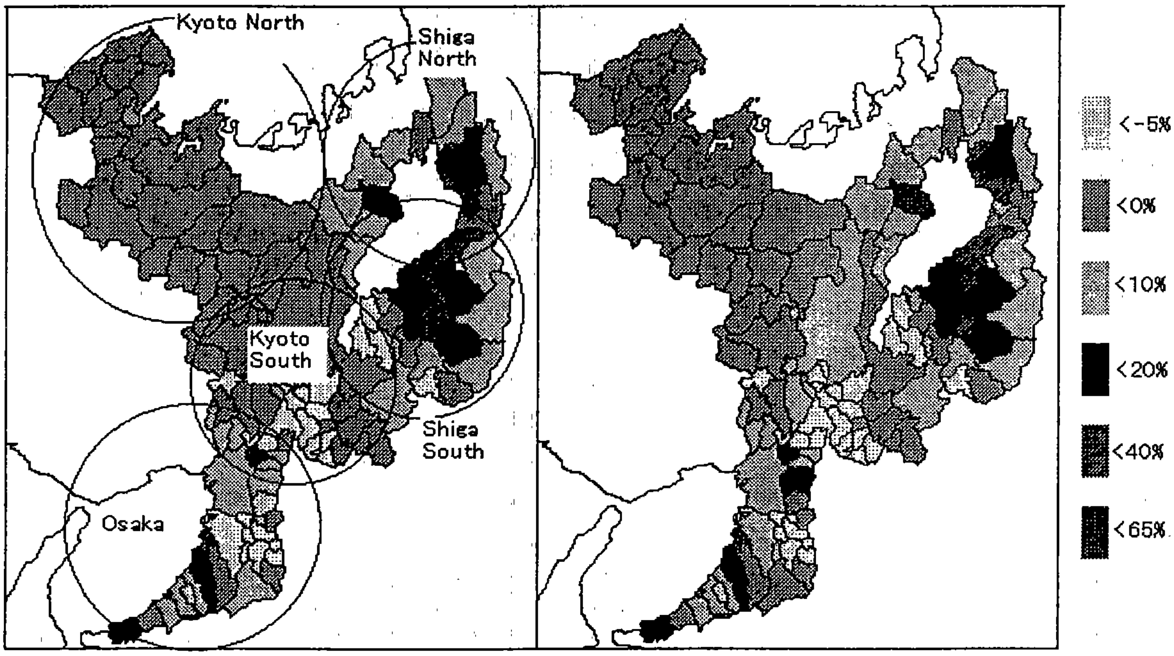
2.1.5 Spatial structure of land use change

If the values of the driving forces for each municipality would be estimated by some means and other, the predictions of land uses by municipality are available. Table 3 and Figure 5 show the spatial features of the effects for land-price policy. It is possible to implement the fine evaluation of policy effects.

Table 3. Spatial distribution of predicted land use change.

Land-price policy		Osaka	Kyoto South	Kyoto North	Shiga South	Shiga North
Driving forces by trend method	Farmland	↗	↘	↘	↗	↗
	Forestry land	↗	↘	↘	↘	↘
	Built-up area	↗	↗	↗	↗	↗
	Other land use	↘	↘	↗	↘	↘
Land price × 0.8	Farmland	-	-	+	+	+
	Forestry land	-	-	+	+	+
	Built-up area	+	+	-	+	-
Land price × 1.2	Farmland	-	-	+	-	+
	Forestry land	-	-	-	+	+
	Built-up area	+	-	-	-	-

N. B. : Arrows (↗ and ↘) show land use changes from 1990 to 2050 and signs (+ and -) show effect of the land-price policy.



prices in 2050 are fixed at 80 % of those in 1990. Land prices in 2050 are fixed at 120 % of those in 1990.

Figure 5. Influence of land-price policy on farmland change.

2.2 Summary

(1) Depending on the static relationships between land use and associated factors, that is to say, the temporal stability of land use structure, we built up the land use ratio function. The function that contains a well-balanced combination of socio-economic driving forces, policy

factors, natural conditions was able to be identified by applying multi-nominal logit model. The model parameters were reasonable and the reproducibility of the model was very good.

(2) We experimentally produced the driving force prediction function by applying the KSIM method in order to provide future values of explanatory variables for the land use ratio function. The parameters for the driving force prediction function were set up by our empirical judgments. The future trajectories of the variables looked rather plausible.

(3) Using the driving force prediction function, the effects of eight land use policies as driving forces were examined. We ascertained that one policy measures would bring about various pervasive effects on the other driving forces through cross impact process. Generally speaking, control of population density, accessibility and land price, and the designation of Urbanization Areas has a wide range of pervasive effects, whereas effects of agricultural policies such as control of the average farm size, the designation of Agricultural Promotion Areas and the Agricultural Land Zone are limited within agricultural sector.

(4) We estimated land use ratios for the year 2050 by applying the predicted values of the driving forces to the land use ratio function. We examined what kind of changes are expected in land use when certain policy measures are executed. In other words, characteristics of each policy measures were made clear. Thus, by the above simple procedures, we could develop a land use change model that reflects the local conditions of the region, and is effective for local land use policy.

3 Historical View of Land Use Change in North-East China

3.1 Introduction

Land use in much of North-East China in the 1930s has been reconstructed and compared with that of today. North-East China, which was once called Manchuria in Japan or elsewhere, was a place of invasion and colonization by Japan till the end of World War II. This region currently comprises of Liaoning, Jilin and Heilongjiang Province and Neimongol Autonomous Region. The study area corresponds to the area covered by the 1:100,000 topographic maps produced by Japan in the 1930s, and it covers 81% of Liaoning, 76% of Jilin, 27% (southern part) of Heilongjiang, and 9% (eastern part) of Neimongol. The study area covers the entire Northeast Plain, the Changpai Shan Mountains in the east, and the barren Neimongol arid region in the west.

3.2 Data and method of analysis

Some 420 maps at 1:100,000 have been used as basic source of land use information. The survey for this map series was mostly carried out between 1932 and 1935, i.e. soon after the notorious Manchurian Incident. The maps thus produced belong to what are called "gaiho-zu" in Japan. The land use classification in this map series is close to that used in the 1:50,000 topographic maps of pre-war Japan.

Each map is first colored according to the land use or land-cover type identified from the symbols and other clues on the maps, then digitized and recorded in laster form for each of grid squares drawn on the maps. The size of a grid square is approximately 2cm×2cm on the map, or 2km×2km on the ground. The land use information recorded for each grid square includes the land use at the top-left corner, 1st, 2nd and 3rd largest uses and all other uses within the grid square.

The data files produced as above are assembled into a system called LUIS-C, or Land Use Information System for China. LUIS-C has a number of programmes which are easily operated by menu-selection procedures. It enables one to produce various kinds of maps as listed below.

1) Dominant land use in each grid square.
2) Land use existing in each grid square (including trace elements).
3) Land use at each grid point.
4) Complexity of land use structure in each grid square.
5) Combination of different types of land use

LUIS-C also offers area of each land use type for each province, as shown in Table 4.

Table 4. Land Use Structure in the Study Area in North-East China in the 1930s (km^2)

Land Use Type	Whole	Jilin(76%)	Liaoning(81%)	S.Heilon(27%)	E.Neimo(9%)
Urban	**15161**	**6022**	**3590**	**4196**	**1353**
settlement	2894	839	1006	932	117
road	12030	5106	2511	3180	1233
railway	237	77	73	84	3
Agricultural	**152563**	**40385**	**52710**	**48930**	**10538**
paddy field	217	41	20	146	10
dry field	152303	40323	52677	48778	10525
orchard	0	0	0	0	0
other tree crops	6	6	0	0	0
grassland	37	15	13	6	3
Forest	**95461**	**51712**	**18841**	**23536**	**1372**
broad-leaved	56292	22498	17597	14888	1309
coniferous	582	127	202	223	30
mixed	38587	29087	1042	8425	33
Other	**212886**	**40929**	**41591**	**44594**	**85772**
rough land	190043	36762	38620	35317	79344
rocky land	5621	232	1255	33	4101
wetland	12494	2643	767	7200	1884
water	4728	1292	949	2044	443
No Information	**5308**	**3701**	**1607**	**0**	**0**
Total	**481379**	**142749**	**118339**	**121256**	**99035**

(after Himiyama et. al., 1995)

note; The figure in ( ) is the percentage of the area covered in each province.

The figures in the Table4 are purely based on the data produced in the current study, so they should be regarded as such. It is noted that the 1:100,000 maps ignore plots smaller than 100-200m, hence the types of land use that tend to exist in small plots tend to have smaller areal figures than real. LUIS-C is revised from time to time with additional data and programmes. It will become available to the academic community in 1997.

The 1930s figures are compared with the figures of 1990 which have been taken from "Land Use in China" (Wu & Guo eds., 1994). The land use classifications of the two data sources are not exactly the same, but it is nevertheless possible to compare the two data sets in some ways. Other major information sources for the study include "1:1,000,000 Land Use Map of China" .

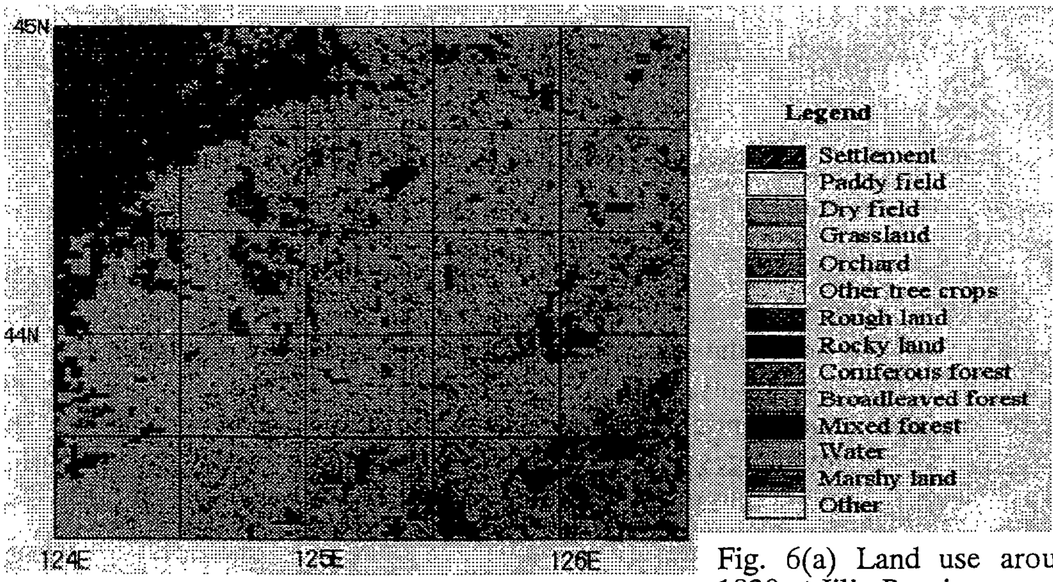


Fig. 6(a) Land use around 1930 at Jilin Province

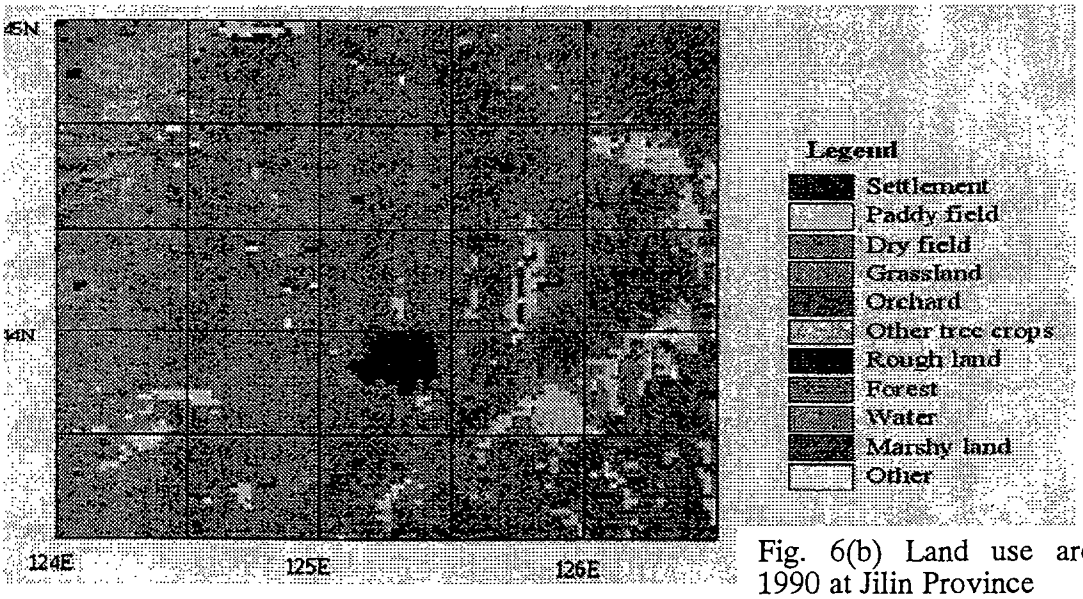


Fig. 6(b) Land use around 1990 at Jilin Province