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An Application of the Land-Use Change Model for the Japan Case Study Area

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1. Introduction

In broad terms, the process of land-use change is determined by universal driving forces such as population increase, urbanization, industrialization, and so on. On the other hand, it also depends on local characteristics such as inherent socio-economic and natural conditions and behavioral characteristics of the people. To develop effective policy recommendations, land-use change models that are sensitive to local characteristics are needed for scenario evaluation.

In "*A theoretical consideration on the land-use change model for the Japan case study area*" (Kitamura et al., 1997) a methodology for modeling land use was proposed which could predict changes of major land uses by means of relatively simple procedures. The proposed framework consists of four main steps, namely statistical land-use analysis, calibration of a land-use ratio function, calibration of a driving force prediction model, and simulation and evaluation of policy implications [Kitamura et al., 1997]. The first step, i.e., land-use analysis, was described in Hoshino (1996). This paper deals with the remaining three steps of the study framework. The study area is the Kansai district in Japan, comprising of Shiga, Kyoto and Osaka prefectures.

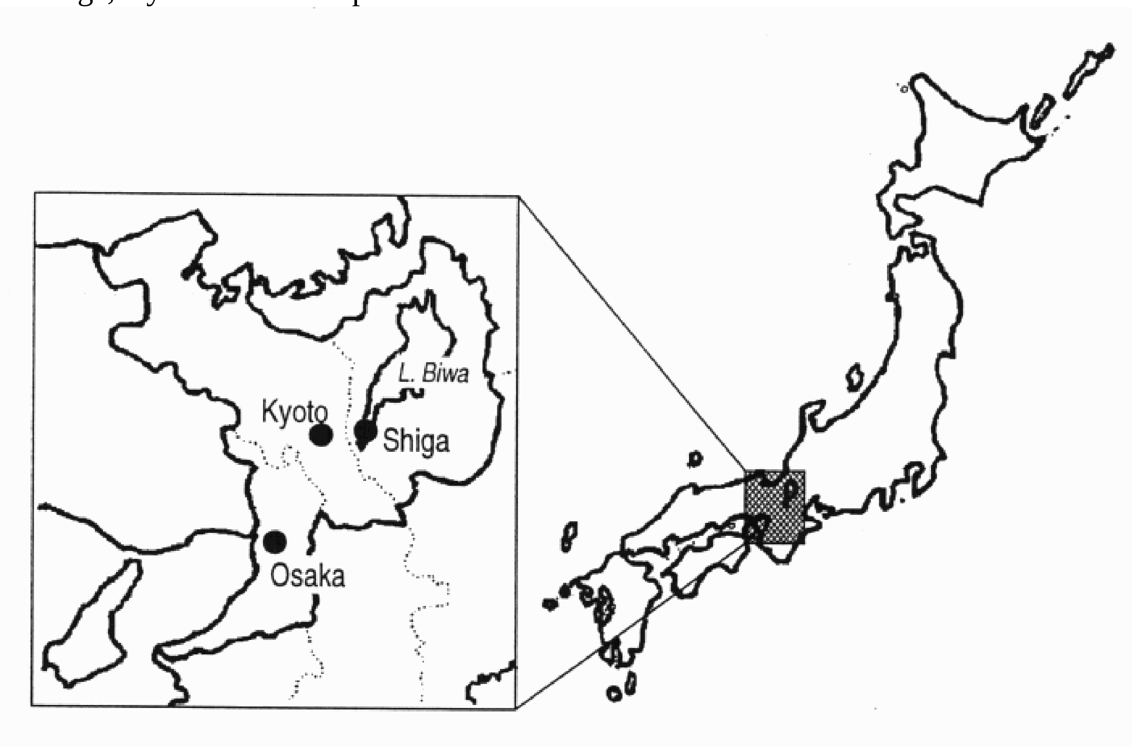

Figure 1. Study area (Kansai district, Japan)

Firstly, the land-use ratio function is estimated, and the applicability of the function is discussed. Secondly, the driving force prediction model is elaborated, and the validity of the model is also checked. Thirdly, simulation results for year 2050 and some policy conclusions are presented.

This paper adds original analyses and discussions to the research outputs of the Land Use and Global Environment Conservation (LU/GEC) project (1995-97) launched by the National Institute of Environment Studies, Japan.

2. Land-use ratio function

In this section we specify a *"land-use ratio function"* and examine its validity. The land-use ratio function denotes a function which estimates the area percentage of each land-use type from a set of associated factors[1].

2.1 Application of the multinomial logit model

The results of the Kansai land-use analysis, led to the conclusion that explaining the land-use distribution requires both natural and socio-economic factors, and that these relationships were stable during the study period [Hoshino, 1996]. Thus the parameters of the land-use ratio function can be assumed to be constant on a long-term basis.

A multinomial logit model was applied for estimating the land-use ratio function. The equations were specified as follows [Oota, 1984]. The dependent variable is a four-dimensional vector of land-use ratios, representing farmland, forest, built-up areas, and other areas.

$$P_{ij} = \exp(V_{ij}) / \sum_{l=1}^{4} \exp(V_{lj}) \qquad i = 1,...,4 \tag{1}$$

$$V_{ij} = \left(\sum_{k=1}^{35} \theta_{ik} X_{jk} \right) + C_i \qquad i = 1,...,3 \tag{2}$$

$$V_{4j} = 0 \tag{3}$$

Variables:

P_{ij} : the land-use ratio of *i*-th land use category in sample *j*

V_{ij} : the utility of *i*-th land-use category in sample *j*

X_{jk} : the *k*-th explanatory variable in sample *j*

Parameters:

θ_{ik} : parameter which reflects the relation between the *k*-th explanatory variable and the *i*-th land-use category

C_i : constant in *i*-th land-use category

Subscripts:

i: the *i*-th land-use category (*i* = 1 : farmland, *i* = 2 : forest, *i* = 3 : built-up area,

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[1] A wide variety of factors are related to actual land-use change. Here we consider natural, socio-economic and policy and planning factors.

i = 4 : other land)

j: the *j*-th sample (*j* = 1, 2, ..., 276)

k: the *k*-th explanatory variable (*k* = 1, 2, ..., 35)

2.2 Data and variables

For land-use data, we used National Land Information Data surveyed in 1976 and 1989 [National Land Agency, 1992; Japan Map Center, 1992]. The correspondence between the original land-use categories and those used in modeling is shown in Table 1. A socio-economic data base was compiled to correspond with land-use data[2].

Table 2 shows a list of variables for the multinomial logit model. In total, some 35 explanatory variables were included. These variables can be classified into three groups. The first group includes factors corresponding to what may be termed socio-economic driving forces. The second group comprises of land-use planning and policy factors. Including these factors facilitates policy analysis. Variables such as number of vehicles per capita, land price, and legal agricultural- and city planning are included in this group. The third group of variables describes natural factors. Land-use distribution is primarily determined by these natural factors, which are essential to be included in the list of explanatory variables.

The study area was divided into 138 geographic units according to the boundaries of local municipalities. The data sets of the two time points were pooled as an unified data set for model calibration. Hence the total number of samples was j=1,…,276 (138 samples × 2 time points).

Table 1. Land-use categories used in the Kansai model

Categories in the original data (National Land Information System)		Categories used for modeling
1976	1989	
Paddy field Upland field Orchard Other tree crops	Paddy field Upland field Orchard Other tree crops	Farmland
Forest Barren Land	Forest Barren Land	Forestry land
Building site A Building site B	Building site	Built-up area
Trunk transportation land Other land	Trunk transportation land Other land	Other land
Lake River land A River land B Sea beach Sea water area	River land and lake Sea beach Sea water area	Excluded from our study

Source: [National Land Agency, 1992]

[2] Due to unavailability of data, in some cases 1975 data and 1990 data were used instead of 1976 and 1989, respectively.

Table 2. Variables used in the multinomial logit model

Dependent variables		
Y1	Farmland share	ratio (to total area)
Y2	Forestry land share	ratio (to total area)
Y3	Built-up area share	ratio (to total area)
Y4	Other land share	ratio (to total area)
Explanatory variables		
	Socio-economic driving forces	
X1	Population density	person / km^2
X2	Percentage of population under 64 years old	percentage (to total population)
X3	Farm-household ratio	percentage (to total households)
X4	Percentage of full-time farm households	percentage (to total farm households)
X5	Percentage of part-time farm households (type 2)[*1]	percentage (to total farm households)
X6	Percentage of workers[*2] in secondary industry	percentage (to total workers)
X7	Percentage of workers[*2] in tertiary industry	percentage (to total workers)
X8	Percentage of female agricultural laborers	percentage (to total agr. laborers)
X9	Percentage of employees[*3] in secondary industry	percentage (to total employees)
X10	Percentage of employees[*3] in tertiary industry	percentage (to total employees)
X11	Gross field husbandry product / farmland	1,000 Yen / are
X12	Gross horticultural product / farmland	1,000 Yen / are
X13	Gross animal product / farmland	1,000 Yen / are
X14	Average farm size	Are
X15	Per capita gross farm products	10,000 Yen / person
X16	Per capita farmland	area / person
X17	Number of employees[*3] per 100 persons	persons
X18	Number of employees per one business firm	persons
X19	Distance to Kyoto / Osaka	km (the shorter distance is adopted)
	Land-use policy & planning factors	
X20	Number of cars / population[*4]	cars / person
X21	Land price	Yen / m^2
X22	Share of Agricultural Promotion Area (a)[*5]	ratio (to total area)
X23	Share of Agricultural Land Zone (b)[*5]	ratio (to total area)
X24	Ratio of Agricultural Land Zone (b) / (a)	ratio
X25	Share of Urbanization Area (c)[*6]	ratio (to total area)
X26	Share of Urbanization Control Area (d)[*6]	ratio (to total area)
X27	Ratio of Urbanization Zone (c) / {(c) + (d)}	ratio
	Natural factors	
X28	Share of 0-3 degree slope area	share in total area
X29	Share of 3-8 degree slope area	share in total area
X30	Share of >15 degree slope area	share in total area
X31	Share of 0-100m elevation area	share in total area
X32	Share of >200m elevation area	share in total area
X33	Share of hill area	share in total area
X34	Share of tableland and terrace	share in total area
X35	Share of lowland area	share in total area

*1 “Part-time-farm household (type 2)” is a farm household whose main earnings come from the non-agricultural sector rather than from agriculture.

*2 “Workers” refers to the number of working persons according to place of residence.

*3 “Employees” refers to the number of working persons according to work place.

*4 “Number of cars per population” is handled as a policy variable in this study, because it reflects the tax policy, the traffic policy, and so on.

*5 The Agricultural Promotion Area Plan is a legal land-use plan authorized by the Agricultural Promotion Area Act. The *“Agricultural Promotion Area”* is designed by the Agricultural Promotion Area Plan, and major parts of the Agricultural Promotion Areas are designated as the *“Agricultural Land Zone”*. Agricultural promotion in this Zone is politically prioritized, so that being designated as the Agricultural Land Zone is an inevitable prerequisite for receiving any kind of agricultural investment subsidy extended by national and local governments. Conversion of agricultural land use to other land use is strictly controlled.

*6 The *“Urbanization Zone”* and the *“Urbanization Control Zone”* are designated in the Urban Planning Zone authorized by the City Planning Act. The Urbanization Area consists of built-up areas, and non-built-up areas which should be converted to built-up areas within 10 years. On the other hand, development activity in Urbanization Control Zone is strictly controlled.

2.3 Estimation of the land-use ratio function

The model was estimated from the pooled data by a backward step-wise method. The significance level of each parameter θ_{ik} were estimated by t-statistics. At first, we set the significance level to 5%. But there were only a few variables which could pass the test at the 5% level, and many variables which were considered very important as driving forces of land-use change were not adopted at that level. Therefore, we had to relax the criterion for selection of explanatory variables. The altered conditions were that the t-statistics should be more than 0.2, and that the sign (+ and -) of a parameter should be consistent with theoretical considerations. The model was estimated again using the above conditions and finally we obtained satisfactory results.

The coefficient of determination of the model is very high, with an R-square of 0.965. Table 3 lists the estimated parameters. Note that the magnitude of the coefficients in the table does not indicate the degree of contribution of the respective variable because those values depend on the scale of the original variables.

2.3.1 Decisive factors for farmland distribution

The most important socio-economic factors which positively impacted on the share of farmland were farm-household ratio, horticultural product per farmland, and average farm size. Negatively-affecting factors were the percentage of the population under 64 years old, and the ratio of female agricultural laborers. Among the natural factors, the share of 0-3 degree slope area, share of 0-100m elevation area and the share of hill area positively affected farmland, and the share of areas with slopes >15 degree, and the share of land with >200m elevation negatively affected farmland.

And, among the land-use policy and planning factors, the number of cars, the ratio of *Agricultural Promotion Area* and share of *Agricultural Land Zone* were positive factors and the share of *Urbanization Promotion Area* was a negative factor. It was confirmed by the estimated parameters that agricultural zoning has made to some extent a contribution to farmland conservation. It is interesting as well as quite natural that the share of *Urbanization Promotion Zone* to *City Planning Are*a negatively impacted on the farmland ratio.

2.3.2 Decisive factors for forestry land distribution

Among the socio-economic factors, percentage of population under 64 years old and animal product per farmland were adopted and both made a negative contribution to the forestry-land ratio. On the other hand, among the natural factors, share of 3-8 degree slope positively affected distribution of forestry land. The share of tableland and terrace and share of lowland area negatively affected the share of forestry lands. These natural factors seem reasonable. Among the land-use policy and planning factors, the share of the *Agricultural Land Zone* was adopted as a positive factor and the ratio of *Urbanization Control Area* acted as a negative factor.

2.3.3 Decisive factors for built-up area distribution

Only three variables were adopted in the land-use ratio function for built-up area. Population density was the only socio-economic factor which positively affected distribution of built-up area. Share of >15 degree slope area was the only natural factor. Built-up area avoided such steep-slope areas. Among the land-use policy and planning factors, the number of cars per person was adopted. The diffusion of cars positively affected distribution of built-up area. But none of the land-use policy and planning factor was adopted at all.

Land price and accessibility conditions were thought of as being the most important policy factors, but they were not adopted in any land-use ratio component. The reason was inferred that other factors that correlated with these variables were adopted instead. When we consider that the land-use ratio function has an excellent fit while satisfying the condition of empirically plausible signs of parameters, we can conclude that a highly reliable functional relationship was established.

Table 3. The parameters of the multinomial logit model

	Variables	Farmland θ1k (k = 1,..,35)	Forestry land θ2k (k = 1,..,35)	Built-up area θ3k (k = 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 / population	1.585093		2.64725
X21	Land price			
X22	Share of Agricultural Promotion Area (a)	0.2758883		
X23	Share of Agricultural Land Zone (b)		-2.641541	
X24	Ratio of Agricultural Land Zone (b) / (a)	0.757966	0.7723287	
X25	Share of Urbanization Area (c)			
X26	Share of Urbanization Control Area (d)		-3.611125	
X27	Ratio of Urbanization Area (c) / {(c) + (d)}	-2.470223		
X28	Share of 0-3 degree slope area	0.2089456		
X29	Share of 3-8 degree slope area		0.435915	
X30	Share of >15 degree slope area	-0.301017		-0.295218
X31	Share of 0-100m elevation area	0.3003105		
X32	Share of >200m elevation area	-0.2918214		
X33	Share of hill area	0.5412822		
X34	Share of tableland and terrace		-1.872898	
X35	Share of lowland area		-1.783901	
Const		5.297296	10.1808	-0.1562014

N.B. An empty cell indicates that the variable was not selected by the step-wise procedure.

3. Driving force prediction model

In the previous section, the major factors determining the distribution of land use were identified and selected as explanatory variables. In the next step, we project future values for these factors in order to estimate future land-use. In addition, some policy variables also need to be included in the model to assess policy alternatives. In this section, a driving force prediction model which provides future values of the driving forces[3] is presented.

3.1 Application of the KSIM method

We have selected the KSIM (Kane's Simulation) method as a driving force prediction model. The KSIM method consists of the following equations [Sawaragi, and Kawamura, 1981; Ishitani and Ishikawa, 1992]. Values of the system variables for the next time period ($x_i(t+dt)$[4]) are obtained by applying equation (4). $P_i(t)$ express the magnitude of influence received from other system variables. The values of $P_i(t)$ are dependent upon the elements of the cross impact matrix $A=(a_{ij})$ and values of the system variables x_i. In the case that a system variable receives more positive influence from the other variables than negative ones, the denominator of equation (5) becomes large, and $P_i(t)$ is less than 1. In that case, since the system variables are bounded between 0 and 1 (see condition (6)), the value for the next year $x_i(t+dt)$ increases. If negative impacts dominate, then the value of $P_i(t)$ is more than 1, and the value for the next period decreases.

$$x_i(t+dt) = x_i(t)^{P_i(t)} \text{ for all } x_i (i = 1,\dots,N) \quad (4)$$

$$P_i(t) = \left\{1 + dt/2\sum_{j=1}^{N}(|a_{ij}| - a_{ij})x_j\right\} \Big/ \left\{1 + dt/2\sum_{j=1}^{N}(|a_{ij}| + a_{ij})x_j\right\} \quad (5)$$

$$0 \le x_i(t) \le 1 \text{ for all i } (i = 1,\dots,N) \text{ and } t \ge 0 \quad (6)$$

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

a_{ij} : elements of the cross-impact matrix A. Element a_{ij} denotes the level of direct influence of a system variable x_j on a system variable x_i.

t : time variable.

3.2 Calibration of the KSIM model

The calibration procedures of the KSIM model were as follows. The KSIM method heavily relies on expert judgment. Therefore, an iterative process is quite important. We

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[3] In this paper, the explanatory variables of the land-use ratio function are considered as the driving forces of land-use change.

[4] In order to distinguish the system variables from the explanatory variables of the logit model (X_j), we use a small letter x for the system variables of the KSIM model.

briefly explain the steps involved:

1) Selection of the system variables
2) Determination of maximum and minimum values of each original variable
3) Specification of the cross-impact matrix
4) Prediction of driving forces with the KSIM model
5) Repeat steps 1) to 4) until satisfactory results are obtained.

3.2.1 Selection of the system variables

22 elements were selected as the system variables of the driving force prediction model. 19 of these variables are the same as the explanatory variables of the land-use ratio function. In addition, some modifications were introduced as follows:

Accessibility and land prices were introduced as additional variables. Distance to Osaka / Kyoto was not adopted as a explanatory variable, but accessibility to an urban center was regarded as one of the most important factors for land-use change. Thus a measure of "accessibility to Osaka"[5] was added to the system variables to reflect the indirect impact of accessibility on land-use change through other variables. Control of land price is thought to be a very typical land-use policy. Thus we also added this variable to enrich the scope for policy analysis. Since the share of *Agricultural Land Zone* (X24) can be calculated from other variables (X22 and X23), we omit it from the system variables. Furthermore, the ratio of *Urbanization Area* (X25) was included instead of the ratio of *Urbanization Control Area* (X26) which was believed to be more clearly defined and easier to use. In addition, the value of variable X26 can be calculated from values of X25 and X27.

In summary, seven variables used in the driving forces prediction model relate to socio-economic conditions, seven variables represent land-use policy and planning factors, and eight variables denote natural conditions.

3.2.2 Determination of maximum and minimum levels of each variable

Initial values for the KSIM system variables are calculated according to equation (7). The original variables are bounded by the respective minimum- and maximum values, X_i^{min} and X_i^{max}. Therefore these limiting values are quite important. We carefully considered past trends, current situations and future possibilities of the respective variables. Table 4 shows the minimum-, maximum- and initial values for the system variables.

$$x_i^0 = \left\{X_i^0 - X_i^{\min}\right\} / \left\{X_i^{\max} - X_i^{\min}\right\} \qquad (7)$$

x_i^0: initial value of the *i*-th system variable

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[5] In this study, the "accessibility to Osaka" is defined as the reciprocal of the average of the each municipality's time distances to Osaka. To measure its actual value is very difficult, since it differs by each inhabitant, each travel means and temporal traffic conditions so on. However, in this study, it is not required to measure it, because the "accessibility to Osaka" is not used in the land-use ratio function, hence only the difference from 1990 is needed. Therefore the hypothetical value is used in this study. We assumed that the possible maximum value in future was 100, relatively the value of the 1990's was 20. For example 40 means that the "accessibility to Osaka" is improved to two times of the 1990's and the average time distance to Osaka is reduced to the half of the 1990's.

X_i^0: initial value of the *i*-th (original) variable

X_i^{min}: minimum value of the *i*-th (original) variable

X_i^{max}: maximum value of the *i*-th (original) variable

3.2.3 Specification of the cross-impact matrix

The cross-impact matrix for the KSIM model was established according to the following principles. Table 5 shows the final cross-impact matrix.

1. We evaluate the degree of direct influence on a scale from -3 to 3[6]. If there is considered to be no impact relationship, the corresponding element of the matrix, a_{ij} is set to 0. The specification of the cross-impact matrix was established by the members of the basic model group of LU/GEC.
2. It was assumed that variables representing natural conditions do not receive any impacts from other system variables[7]. Therefore, during the projection period, these variables remain constant. However, their impacts on other system variables are maintained during the projection period.
3. Policy factors are dealt with as endogenous variables. In other words, we assume that the policy variables themselves may change through the influence of other factors.[8]

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[6] A positive value of a_{ij} means that the system variable x_j has a positive effect on x_i, and a negative a_{ij} means that x_j has a constraining effect on x_i.

[7] Row elements of natural conditions in the cross impact matrix are fixed at zero levels.

[8] For example, local governments review and modify their *Agricultural Promotion Area Plans* and *City Plans* every five or ten years. In such reviews, zoning descriptions may be changed according to the actual state of land-use and changes of socio-economic factors. However these modifications are usually small. For this reason the differences between minimum and maximum values of the planning factors shown in Table 4 are relatively small.

Table 4. Minimum, maximum & initial values of variables in the driving forces prediction model.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1990 value	1227	89.03	3.53	64.10	7.05	3.05	88.72	20	0.31	877715	0.30	0.11	0.15	0.28	0.44	0.10	0.33	0.40	0.35	0.12	0.12	0.34
Minimum value	1100	75.00	2.00	50.00	5.00	2.00	50.00	18	0.30	600000	0.25	0.10	0.14	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum value	1300	90.00	4.00	70.00	10.00	5.00	200.00	100	0.50	1E+06	0.35	0.13	0.18	0.40	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Initial value	0.63	0.94	0.77	0.71	0.41	0.35	0.26	0.02	0.03	0.46	0.49	0.44	0.20	0.04	0.44	0.10	0.33	0.40	0.35	0.12	0.12	0.34

Table 5. Cross-impact matrix for KSIM model.

			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
X1	A	Population density	-1	1	0	0	0	0	0	2	0	-2	0	0	2	0	3	-2	-3	2	-3	-1	-1	3
X2	B	% of population < 64 years old	0	-1	0	-1	0	0	0	1	0	-1	0	0	2	0	1	-1	-3	3	-3	0	0	3
X3	C	Farm-household ratio	-1	0	-1	1	1	1	-1	-1	0	-1	1	1	-1	-1	-2	2	2	-2	2	1	1	-2
X8	D	% of female agricultural laborers	0	0	0	-1	0	0	0	1	0	0	0	0	0	0	-1	0	1	0	1	0	0	-1
X12	E	Gross horticultural product / farmland	1	0	0	0	0	-1	0	1	0	0	0	0	0	0	1	0	-1	1	-1	-1	-1	1
X13	F	Gross animal product / farmland	1	0	0	0	-1	0	0	1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
X14	G	Average farm size	-1	0	-2	-1	1	1	-1	1	0	-1	2	2	0	0	3	-2	-3	3	-3	-1	-1	3
X19	H	Accessibility to Osaka	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-1	0	-1	0	0	0
X20	I	Number of cars / population	0	1	0	0	0	0	0	1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
X21	J	Land price	2	1	-1	0	0	0	0	2	1	-1	0	0	-1	0	1	-1	-3	1	-3	0	0	2
X22	K	Share of Agricultural Promotion Area	0	0	0	0	0	0	0	-1	0	-1	-1	0	0	0	2	-1	-1	2	-1	0	0	2
X23	L	Share of Agricultural Land Zone	-1	0	0	0	1	1	0	-1	0	-1	-1	2	-1	0	2	-1	-2	2	-2	0	0	2
X25	M	Share of Urbanization Area	2	0	0	0	0	0	0	1	0	2	-1	-1	-1	-1	2	-1	-3	2	-3	0	0	2
X27	N	Urbanization area / city planning area	2	0	-1	0	-1	-1	0	1	0	2	-1	-1	2	-1	1	-1	-2	1	-1	0	0	1
X28	O	Share of 0-3 degree slope area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X29	P	Share of 3-8 degree slope area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X30	Q	Share of >15 degree slope area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X31	R	Share of 0-100m altitude area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X32	S	Share of >200m altitude area	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X33	T	Share of hills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X34	U	Share of tableland and terrace	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X35	V	Share of lowland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.3 Prediction of driving forces with the KSIM model

The initial values and parameter values shown in Table 4 and 5 are used in equation (4) and (5), to project values for the driving forces using annual time-steps between year 1990 to 2050.

Figure 1-1 shows trajectories of the seven KSIM system variables representing socio-economic driving forces. In future, population density will gradually increase and the share of population under 64 years old will level off[9]. Due to "retirement" of the (type 2) part-time farm households from farming activities, the number of farm households will decrease. Thus the farm household ratio will decrease steadily, and the average farm size will increase. The share of female agricultural laborers is projected to decrease in future[10].

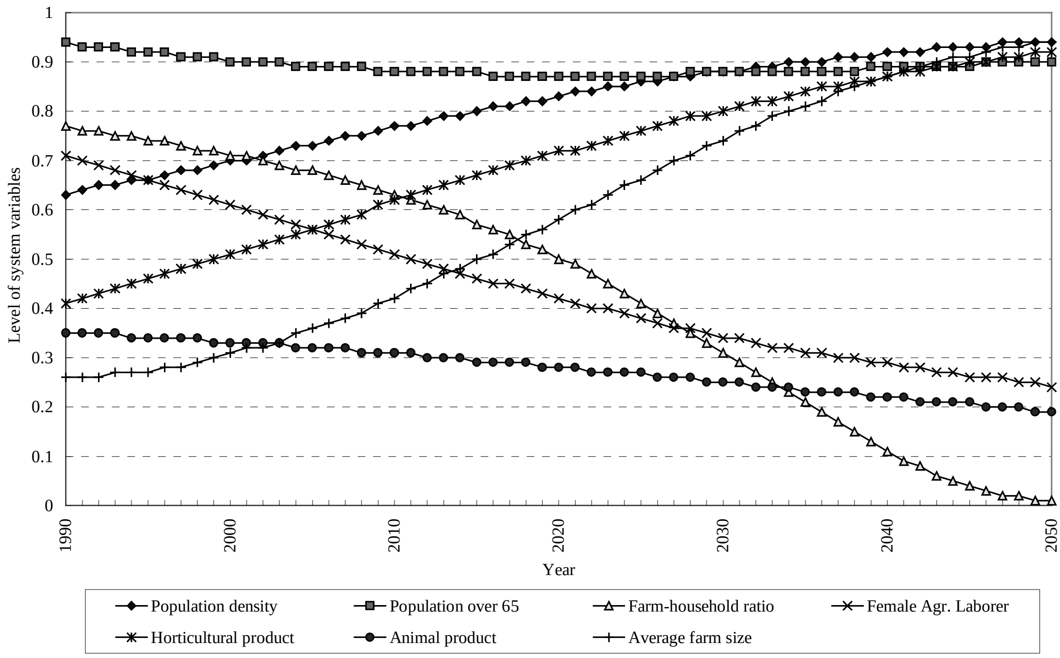

Figure 1-1. KSIM projections of some socio-economic driving forces

At an early stage of urbanization, the ratio of female agricultural laborers had increased because of the outflow of male agricultural laborers to non-agricultural sectors. The female share in the study area in 1990 was 64.1%, i.e., almost two out of three agricultural laborers are female. But the female share is expected to fall to "one

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9 Percentage of 15-64 year-old population will decrease in the beginning but will turn to increase around 2020. This trajectory shows that until 2020, aging of population would progress but after that aging would decline. This is consistent with the expected future change in age structure of population.

10 These optimistic results were obtained because the model more or less overestimated the effects of the policy for improvement of agricultural structure by the government. Thus the model parameters need to be re-examined.

out of two" in 2050[11]. On the other hand, in urban fringes with limited farmland, the importance of horticulture will increase, whereas animal production will decrease.

Figure 1-2 shows respective trajectories of the seven land-use policy and planning factors in the KSIM model. It suggests that the area included in land-use zoning would increase in future. It is plausible that the area of *City Planning* would enlarge with population increase. On the other hand, areas covered by the legal agricultural land-use plan are expected to expand as well[12]. This is not inconsistent with experience. For example, the share of *Agricultural Promotion Area* and the share of *Agricultural Land Zone* in 1975 were 0.28 and 0.10 respectively and those in 1990 were 0.30, and 0.11, respectively. Both indicators have increased in the past while the number of farm households and the extent of farmland have decreased. The land price in our projection increases, keeping pace with the factors representing land-use planning. Finally, the number of cars and the accessibility to Osaka are projected to gradually increase.

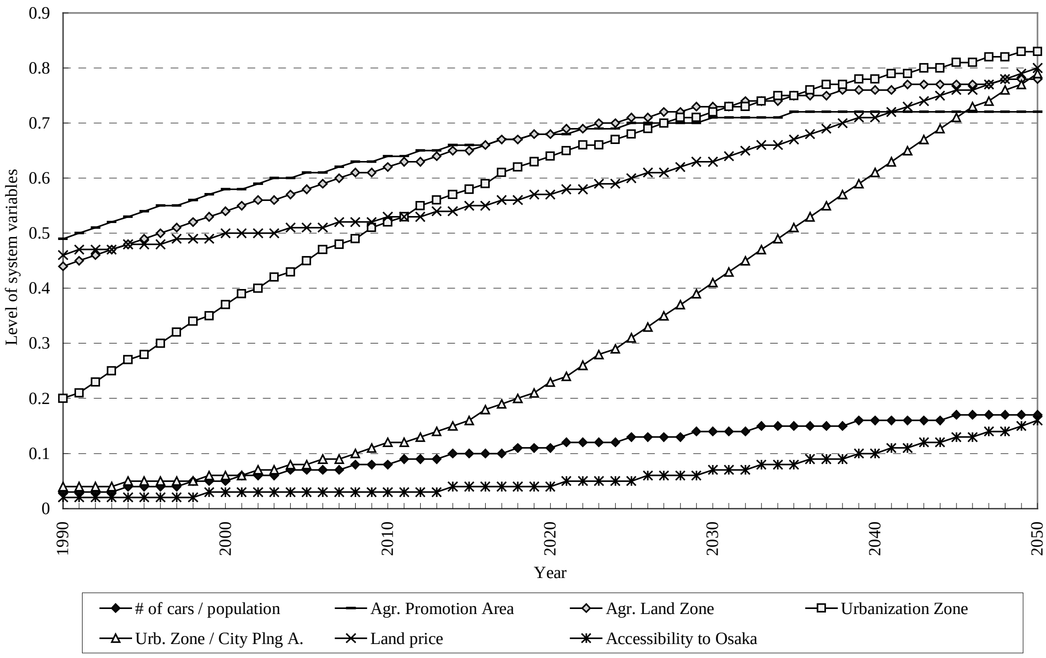

Figure 1-2. KSIM projections of land-use policy & planning factors

Table 6 compares observed trends (1975-1990) with future changes (1990-2000) projected by this model. Except for three variables, the share of female agricultural laborers (D), gross horticultural product per unit of farmland (E), and share of *Urbanization Promotion Area* (N), the observed trends are generally in agreement with the predicted changes.

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11 We fixed the maximum vale for ratio of female agricultural laborers at 70 % and mimimum value at 50 %. Thus the predicted value in 2050 by the KSIM model (that is 0.24) is equivalent to 54.8 % [= 50 % + 0.24 × (70 % - 50 %)].

12 However the predicted 2050's values of the two ratios are respectively 0.32 and 0.12 (Table 7, normal estimates), and they will not increase so largely.

The trajectories shown in Figure 1-1 and 1-2 are therefore thought to be reasonable. In addition, the estimates of the near future generally coincide with past trends. Hence, we conclude that our simple model is capable of projecting plausible future levels of the driving forces. However, there still is ample scope for improvement of the empirical parameters such as maximum and minimum values of the system variables and the elements of the cross impact matrix.

Table 6. Comparison between observed trends and predicted future trends.

		Values in 1975	Values in 1990	Observed Trends (1975-1990)	Future Trends by KSIM (1990-2000)
A	Population density (persons / km^2)	1170.0	1227.00	+	+
B	% of population under 64 years old	93.0	89.00	-	-
C	Farm-household ratio (%)	5.8	3.50	-	-
D	% of female agricultural laborers	48.9	64.10	+	-
E	Gross horticultural product / farmland (1000 Yen / a)	9.8	7.10	-	+
F	Gross animal product / farmland (1000 Yen / a)	7.8	3.10	-	-
G	Average farm size (a)	56.0	88.70	+	+
H	Accessibility to Osaka ((km)	N/A	N/A	N/A	+
I	Number of cars / population (cars / person)	0.24	0.31	+	+
J	Land price (1000 Yen / m^2)	251.395	87.714	+	+
K	Share of Agricultural Promotion Area	0.290	0.300	+	+
L	Share of Agricultural Land Zone	0.100	0.110	+	+
-	Ratio of Agricultural Land Zone (L/K)	0.370	0.377	+	+
M	Share of Urbanization Area	0.136	0.147	+	+
N	Urbanization Area / City Planning Area	0.297	0.284	-	+

4. Simulation and policy conclusions

In the previous section, the driving force prediction model was used to estimate future levels of important land-use change driving forces. These values are input into the land-use ratio function, to project scenarios of future land-use distribution in the study area. Using these two associated models, we evaluate the likely impacts of several land-use policies.

4.1 Predicted future of land-use

At first we briefly examine results of a reference projection. Figure 2 shows observed values of land-use ratios in 1976 and 1989, linear trend extrapolations for 2050, and values predicted by the KSIM model. From 1976 to 1989, farmland, forestry land and other land-use have decreased by 0.8 %, 0.1 % and 0.3% respectively, and the built-up area has increased by 1.7 % of total area (i.e., this category expanded almost 20 percent). Considering that the period between the two time points is only 13 years, the land-use changes were rather rapid[13].

The third bar in Figure 2 shows land-use shares in year 2050 estimated by trend extrapolation assuming that the past rates of change continue until the target year. The graph shows that built-up area would increase greatly, whereas the farmland area would decrease. However, considering that the rates of change during the reference period were rather rapid because of the fast growing economy and that population in Japan is expected to begin decreasing by 2025, we think that such drastic changes in future would not take place.

The fourth bar in Figure 2 shows the results of the Kansai land-use change model (the driving force prediction model and the land-use ratio function). This result shown corresponds to a case assuming that the present policy of land use would be continued. Because we do not have any definite information about future land-use policy, we currently regard this projection to be the most reliable distribution of land use. The graph shows that the future distribution would be fairly similar to the present situation.

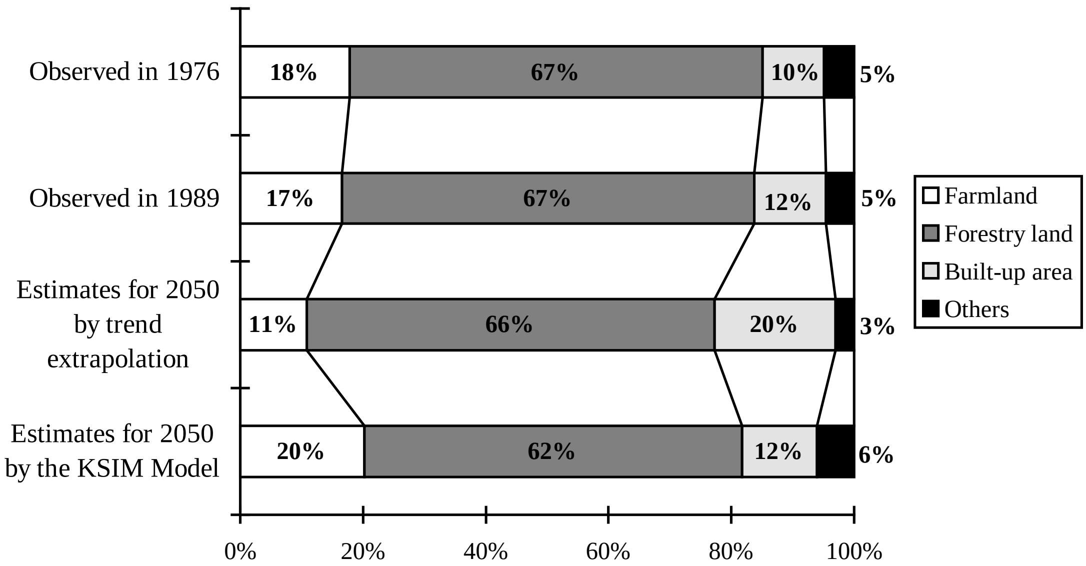

Figure 2. Estimated land-use shares in year 2050

Farmland, built-up area and other land use are estimated to increase, while forestry land would decrease. In other words, further development of land-use would take place at the expense of forestry land. Trunk transportation land is included in the category of other land use, and it is thus empirically understandable that other land use would increase as well. The prospect of farmland increase is contrary to the actual situation. This derives from the fact that values of the driving forces such as ratio of male

[13] This period marked a transition from rapid economic growth to moderate economic growth. There was residual heat of rapid economic growth left, and land development was still active to some extent.

agricultural laborers[14], average farm size, ratio of *Agricultural Promotion Area* and ratio of *Agricultural Land Zone* are predicted to increase until year 2050, as was discussed in the previous section.

4.2 Policy options for land-use control

Policy measures and their setting which we define for this analysis are as follows:

a) Control of population density: (+10% or -10%)

b) Control of average farm size: (5.0 ha or 0.5 ha)

c) Control of accessibility (time distance): (1/2 or the same)

d) Control of land price: (+30% or -30%)

e) Control of the number of cars: (1.6 times or the same)

f) Control of *Agricultural Promotion Area*: (+20% or -20%)

g) Control of *Agricultural Land Zone*: (+20% or -10%)

h) Control of *Urbanization Area*: (+20% or -10%)

Items a) and b) refer to control of socio-economic factors. Items c) to h) denote control of policy and planning factors. The numerical values in parentheses indicate the tested options of each policy measure. Observed values in 1990 are used to set the baseline values. Each policy measure is tested for two alternative options. Considering the scope for change of each policy measure, we define the alternative levels of the policy options.

4.3 Prediction of driving forces under different policy options

Trajectories of the system variables corresponding to each set of policy measures are exogenously fed to the driving force predictive model. The policy variables are controlled so as to attain the target value in the final simulation year 2050. It is assumed that the system variables influence the other variables of the KSIM model in the same way as before. Thus the column elements of the respective variables in the cross impact matrix are left as in the base case.

Table 7 lists the levels of driving forces projected under different scenarios for the year 2050. Percentages show the difference in the levels of system variables produced by the two alternative settings of each policy measure. In the following, we mention qualitative characteristics of the policy effects reflected in the values of the driving forces.

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14 As a system variable, ratio of female agricultural laborers was adopted.

Table 7. Comparison of policy options: Level of system variables projected by the KSIM method in year 2050.

System variables	A	B	C	D	E	F	G	H	I	J	K	L	-	M	N
	Population density	% of population under 64	Farm household ratio	% of female agricultural laborers	Gross horticultural product/ farmland	Gross animal product/ farmland	Average farm size	Accessibility to Osaka	Number of cars/	Land price	Share of Agricultural Promotion Area (a)	Share of Agr. Land Zone (b)	Ratio of Agr. Land Zone (b) / (a)	Share of Urbanization Area (c)	Urbanization Area / City Planning Area
Case of policy options	person/ km^2	%	%	%	1,000 Yen/a	1,000 Yen/a	Are		cars/ person	1,000 Yen/m^2	ha/ha	ha/ha	ha/ha	ha/ha	ratio
Values in 1990	1227	89.0	3.5	64.1	7.1	3.0	89	20	0.31	878	0.299	0.113	0.378	0.148	0.285
Base case estimates	1288	88.5	2.0	54.8	9.6	2.6	191	31	0.33	1080	0.322	0.123	0.383	0.173	0.375
a+) Pop. density × 1.1	**1300**	88.5	2	54.8	9.6	2.6	191	31	0.33	1080	0.322	0.123	0.383	0.173	0.375
a-) Pop. density × 0.9	**1100**	86.9	3.3	54.2	8.8	2	196	18	0.36	714	0.334	0.129	0.387	0.143	0.28
	15.5%	1.8%	-65.0%	1.1%	8.3%	23.1%	-2.6%	41.9%	-9.1%	33.9%	-3.7%	-4.9%	-1.0%	17.3%	25.3%
b+) Farm size 5.0 ha	1288	88.5	2	54.8	9.6	2.6	**500**	31	0.33	1074	0.322	0.123	0.383	0.173	0.375
b-) Farm size 0.5 ha	1290	88.5	2.3	54.8	9.6	2.6	**50**	31	0.34	1056	0.322	0.123	0.383	0.173	0.369
	-0.2%	0.0%	-15.0%	0.0%	0.0%	0.0%	**235.6%**	0.0%	-3.0%	1.7%	0.0%	0.0%	0.0%	0.0%	1.6%
c+) Accessibility × 2	1298	89.4	2	61.4	9.9	3.9	190	**40**	0.39	1188	0.283	0.107	0.378	0.179	0.398
c-) Accessibility × 1	1286	88.4	2	54.2	9.6	2.5	191	**20**	0.33	1050	0.325	0.124	0.382	0.172	0.369
	0.9%	1.1%	0.0%	13.1%	3.1%	53.8%	-0.5%	**64.5%**	18.2%	12.8%	-13.0%	-13.8%	-1.0%	4.0%	7.7%
d+) Number of cars × 1.6	1290	88.7	2	56.6	9.7	2.9	191	63	**0.5**	1164	0.311	0.12	0.385	0.176	0.387
d-) Number of cars × 1.0	1288	88.5	2	54.6	9.6	2.5	191	25	**0.3**	1044	0.324	0.124	0.383	0.172	0.371
	0.2%	0.2%	0.0%	3.6%	1.0%	15.4%	0.0%	122.6%	**60.6%**	11.1%	-4.0%	-3.3%	0.5%	2.3%	4.3%
e+) Land price × 1.3	1282	88.2	2	54.8	9.6	2.5	188	27	0.32	**1200**	0.315	0.12	0.38	0.176	0.388
e-) Land price × 0.7	1296	89	2.6	55.2	9.7	2.7	196	40	0.4	**600**	0.336	0.128	0.381	0.164	0.298
	-1.1%	-0.9%	-30.0%	-0.7%	-1.0%	-7.7%	-4.2%	-41.9%	-24.2%	**55.6%**	-6.5%	-6.5%	-0.3%	6.9%	24.0%
f+) Agr.Prom.Area × 1.2	1288	88.5	2	54.8	9.6	2.6	194	30	0.33	1074	**0.35**	0.122	0.347	0.172	0.369
f-) Agr.Prom.Area × 0.8	1290	88.8	2	55	9.6	2.6	178	31	0.33	1086	**0.25**	0.128	0.512	0.176	0.389
	-0.2%	-0.3%	0.0%	-0.4%	0.0%	0.0%	8.4%	-3.2%	0.0%	-1.1%	**31.1%**	-4.9%	-43.1%	-2.3%	-5.3%
g+) Agr. Land Zone × 1.2	1288	88.5	2	54.8	9.6	2.6	193	30	0.33	1074	0.322	**0.13**	0.404	0.172	0.371
g-) Agr. Land Zone × 0.9	1290	88.8	2	55	9.6	2.6	169	31	0.33	1086	0.321	**0.1**	0.312	0.177	0.393
	-0.2%	-0.3%	0.0%	-0.4%	0.0%	0.0%	12.6%	-3.2%	0.0%	-1.1%	0.3%	**24.4%**	24.0%	-2.9%	-5.9%
h+) Urban. Area × 1.2	1288	88.5	2	54.8	9.6	2.5	191	30	0.33	1062	0.322	0.124	0.384	**0.18**	0.374
h-) Urban. Area × 0.9	1202	81.2	3	54.4	9.4	2.2	190	21	0.31	990	0.324	0.129	0.398	**0.14**	0.28
	6.7%	8.2%	-50.0%	0.7%	2.1%	11.5%	0.5%	29.0%	6.1%	6.7%	-0.6%	-4.1%	-3.7%	**23.1%**	25.1%

N.B. Shaded parts in the table refer to controlled policy options. Percentages are calculated by [{(Policy option +) - (Policy option -)} / Normal estimate] × 100%

a) *Population density*

If population density were to increase above base case levels, a variety of effects would be triggered: an increase of the land price (J), expansion of the city planning area (M and N), a decline of the farm-household ratio (C), the improvement of the accessibility to Osaka (H), and further intensification of livestock production (F).

b) *Average farm size*

An increase of average farm size has only little pervasive effects on other factors except a decline of the farm-household ratio (C).

c) *Accessibility*

Improvement of the accessibility to Osaka would push up the diffusion rate of cars (I) and would raise the land price (J). This would accelerate the decline of female agricultural laborers (D), and would limit both the *Agricultural Promotion Area Plan* and *Agricultural Land Zone* (K and L). Finally, it would also stimulate an expansion of animal production.

d) *Number of cars*

A policy that allows higher car densities brings about improvement of accessibility (H), and pushes up the land price (J).

e) *Land price*

Land-price policy has considerable effects on accessibility, diffusion of cars, farm-household ratio and city planning. The land-price support policy promotes expansion of *Urbanization Promotion Area* (N) and deterioration of accessibility (H). On the other hand, it restrains diffusion of cars (I) and promotes a fall in farm-household ratio (C).

f) *Agricultural Promotion Area*

The expansionary policy of the *Agricultural Promotion Area* has few pervasive effects on other factors. Share of *Agricultural Land Zone* (-) decreases because the denominator (*Agricultural Promotion Area*) becomes bigger.

g) *Agricultural Land Zone*

A policy to expand the *Agricultural Land Zone* would bring about an increase of average farm size (G). This indicates that legal agricultural zoning is effective to somewhat improve the structure of agricultural enterprises.

h) *Urbanization Area*

The policy to expand the *Urbanization Promotion Area* would cause an increase in population density (A), an improvement in the accessibility to Osaka (H), and a fall in the farm-household ratio (C).

The above results of simulating the impacts of different policy measures conform with our empirical viewpoint. It is important to note that each policy measure has a variety of impacts on the other factors besides its direct effect.

4.4 Evaluation of land-use changes under different policy options

The projected values of the driving forces are input data for the land-use ratio function. Table 8 shows the land-use distribution obtained for each policy simulation estimated by the land-use ratio function. Differences in outcomes between the two options evaluated for each policy measure are also shown in the table. (for example (a+) - (a-)). Relative magnitudes of these differences are evaluated and shown with signs (++, +, (+), 0, (-), -, --). The impacts that each policy measure has on the land-use distribution are summarized in Table 8.

a) Population density

An accelerated increase of population density causes decrease of farmland and increase of both built-up area and other land use. On the other hand, a policy to limit population density would slow down the expansion of built-up areas, and would help to conserve farmland.

b) Average farm size

The policy to support an increase of average farm size is effective for expansion of farmland. This policy promotes decrease of forestry land, but does not give any strong impact to built-up area and other land use.

c) Accessibility

A policy to improve the accessibility to Osaka promotes an expansion of built-up area, and reductions of farmland and forestry land.

d) Number of cars

The car-diffusion policy causes an expansion of the built-up area and a reduction of forestry land. The effects of the car-diffusion policy are similar to those of the accessibility-improvement policy.

e) Land price

The land-price support policy conserves forestry land, and brings about the decrease of both farmland and built-up area. Similarly, the effects of a land-price regulation policy can be grasped when signs in Table 8 are reversed. A regulation policy of land price would cause expansion of farmland and built-up area, and a reduction of forestry land.

f) Agricultural Promotion Area

The policy to expand the *Agricultural Promotion Area* is effective for farmland conservation to some extent. But it may cause a modest decrease of forestry land.

g) Agricultural Land Zone

The policy to expand the *Agricultural Land Zone* promotes farmland conservation. This result is similar to the case of expanding the *Agricultural Promotion Area*. However, an important difference is that the expansion of the *Agricultural Land Zone* limits the expansion of built-up areas. This point is quite reasonable because the zoning of the *Agricultural Land Zone* is accompanied by strict regulations against farmland change. Furthermore it is also reasonable that the effects of this policy are similar to those of the policy to increase the average farm size.

h) Urbanization Area

The policy to enlarge the *Urbanization Promotion Area* causes an expansion of both the built-up areas and other land use, and a reduction of forestry land. While both policies, that increase population density and that of expanding the *Urbanization Promotion Area* policy, cause expansion of the built-up area and other land use, there is a noticeable difference in that the former policy results in a decrease of farmland whereas the latter causes a decrease of forestry land. In general, most farmland is suitable for conversion to built-up areas. Therefore, the change from farmland to built-up areas is a usual process. On the other hand, land designated as *Urbanization Promotion Area* must avoid excellent farmland. Therefore, forestry land is the major source of land for built-up areas in this case, which explains the difference in the outcome of the two policy alternatives.

In the discussion above, we have qualitatively examined the impacts of each policy measure on the land-use distribution, and we have shown that each policy measure causes distinctly different land-use changes. With the same procedure also more complex policy analysis is possible. When a target distribution of land-use is specified, such research output can contribute to establishing a local land-use policy which would be tailored to realizing the targeted land-use pattern.

Table 8. Comparison of land-use distribution by land-use policy options.

Policy options	Land-use distribution (%)				
	Farmland	Forestry land	Built-up areas	Others	Total
(a+) Population density is 1.1 times of 1990's	20.2%	61.5%	12.3%	6.0%	100.0%
(a-) Population density is 0.9 times of 1990's	23.4%	61.4%	10.4%	4.8%	100.0%
(a+) - (a-)	-3.2%	0.1%	1.9%	1.2%	0.0%
	- -	0	+	+	
(b+) Average farm size is 5.0 ha	30.9%	53.2%	10.7%	5.2%	100.0%
(b-) Average farm size is 0.5 ha	16.5%	64.3%	12.9%	6.3%	100.0%
(b+) - (b-)	14.4%	-11.1%	-2.2%	-1.1%	0.0%
	+ +	- -	(-)	0	
(c+) Accessibility to Osaka is 2 times of 1990's	19.0%	60.3%	14.6%	6.2%	100.0%
(c-) Accessibility to Osaka is same as 1990's	20.4%	61.6%	12.1%	5.9%	100.0%
(c+) - (c-)	-1.4%	-1.3%	2.5%	0.3%	0.0%
	-	-	+ +	0	
(d+) Number-of-car/person is 1.6 times of 1990's	22.4%	54.9%	17.3%	5.4%	100.0%
(d-) Number-of-car/person is same as 1990's	19.7%	62.7%	11.5%	6.1%	100.0%
(d+) - (d-)	2.7%	-7.8%	5.8%	-0.7%	0.0%
	(+)	- -	+ +	0	
(e+) Land price is 1.3 times of 1990's	19.1%	63.1%	11.8%	6.0%	100.0%
(e-) Land price is 0.7 times of 1990's	24.7%	56.3%	13.5%	5.6%	100.0%
(e+) - (e-)	-5.6%	6.8%	-1.7%	0.4%	0.0%
	- -	+ +	(-)	0	
(f+) Agri. Promotion Area is 1.2 times of 1990's	20.4%	61.0%	12.5%	6.1%	100.0%
(f-) Agri. Promotion Area is 0.8 times of 1990's	19.5%	62.8%	11.9%	5.8%	100.0%
(f+) - (f-)	0.9%	-1.8%	0.6%	0.3%	0.0%
	+	- -	+	0	
(g+) Agricultural Land Zone is 1.2 times of 1990's	20.6%	61.2%	12.2%	6.0%	100.0%
(g-) Agricultural Land Zone is 0.9 times of 1990's	18.1%	62.7%	12.9%	6.3%	100.0%
(g+) - (g-)	2.5%	-1.5%	-0.7%	-0.3%	0.0%
	+ +	-	-	0	
(h+) Urbanization zone is 1.2 times of 1990's	20.5%	60.9%	12.5%	6.1%	100.0%
(h-) Urbanization zone is 0.9 times of 1990's	20.6%	69.1%	6.8%	3.5%	100.0%
(h+) - (h-)	-0.1%	-8.2%	5.7%	2.6%	0.0%
	0	- -	+	+	

N.B.: Symbols (++, +, (+), 0, (-), -, --) in the table show direction and relative magnitude of land-use changes.

5. Spatial structure of land-use changes

In this section, land-use changes by municipalities are estimated. Instead of applying the KSIM method, the observed trends from 1975 to 1990 are linearly extrapolated into the future, to project the level of driving forces for 2050 by municipality. These values are input to the land-use distribution function, to estimate land-use changes for each municipality.

Figure 3-1, 3-2 and 3-3 show relative changes in the shares of farmland, built-up area and forestry land, respectively, in response to varying the price of land relative to 1990. Values of other driving forces for the year 2050 were estimated by trend extrapolation. Table 9 summarizes land-use changes in five sub-regions of the study area. Percentages of the built-up areas increase in all sub-regions when compared with the 1990's. It is worth noting that the changes of land-use are uneven among the sub-districts[15]. The signs of + and - indicate whether the land-price policy modifies the direction of change upward (+) or downward (-). We also find various local effects due to the tested land price policies. This indicates that projection by municipalities is important for establishing more concrete policy implications and conclusions.

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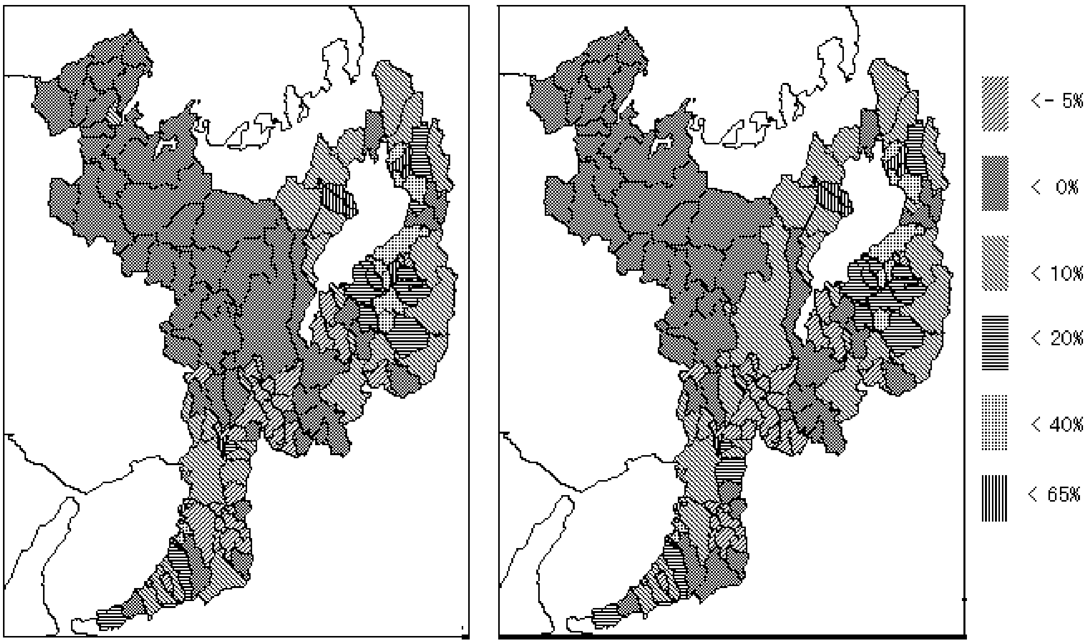
[15] However there are some inconsistencies in the spatial structure of land-use change. For example, farmland increases in Osaka, but that does not seem to be realistic. We think that simple trend extrapolation produces unrealistic projections for some driving forces.

Table 9. 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	↘	↘	↗	↘	↘
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.

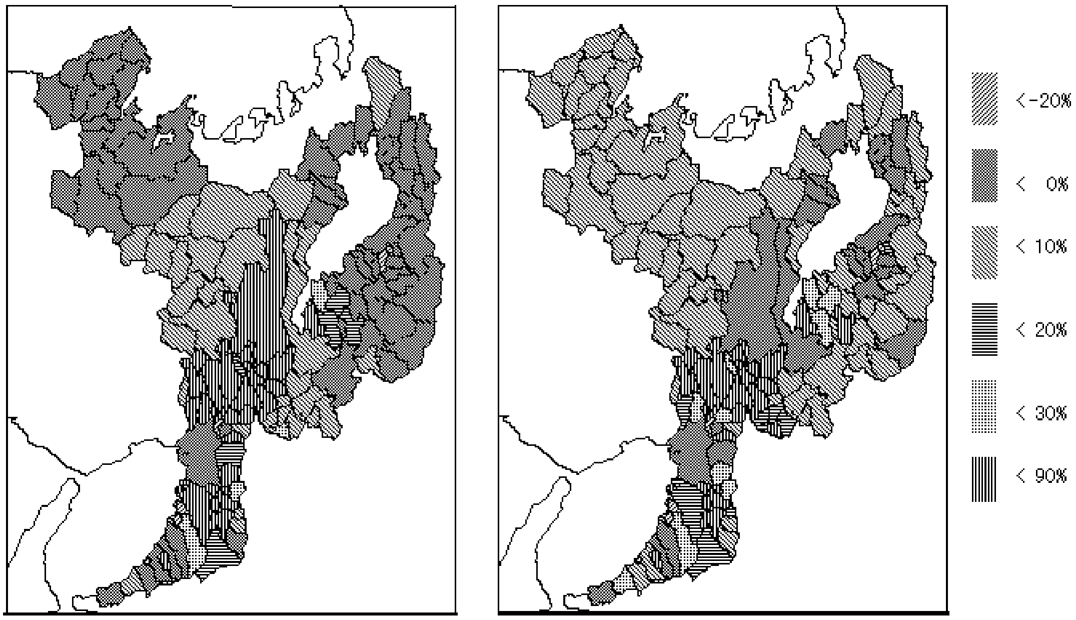


Land prices in 2050 are fixed at **80 %** of those in 1990. Land prices in 2050 are fixed at **120 %** of those in 1990.

Figure 3-1. Influence of land-price policy on farmland change.

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

Figure 3-2. Influence of land-price policy on forestry-land change.



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

Figure 3-3. Influence of land-price policy on built-up area change.

6. Summary

i. Based on the past temporal stability of the relationships between land-use distribution and various explanatory factors, a land-use distribution function was estimated for the Kansai study area. The function contains a well-balanced combination of socio-economic driving forces, policy factors, and natural conditions. The specification used is a multinomial logit model. The estimated model parameters were considered plausible and the goodness of fit of the model was excellent.

ii. For the study area an experimental driving force prediction model was developed by applying the KSIM method. This model was applied to provide future values of explanatory variables used in the land-use distribution function. The coefficients of the cross-impact matrix for the driving force prediction model were specified by expert judgment. The trajectories of the projected variables were judged to be rather plausible.

iii. The driving force prediction model was used to study the impacts of eight different land-use related policies (2 scenarios for each) on the trajectories of several driving forces. It was ascertained that each policy measure would bring about various pervasive effects on the other driving forces through the application of the matrix cross-impact process. In general, the control of population density, altered accessibility to Osaka, control of land price, and policies that change the designated *Urbanization Area* have a wide range of different effects, whereas impacts from agricultural policies, such as control of average farm size, or designation of *Agricultural Promotion Area* and *Agricultural Land Zone*, are mainly limited to the agricultural sector.

iv. The land-use distribution for year 2050 was estimated by evaluating the land-use ratio function with the projected values of the driving forces. We thus examined what kind of land-use changes were to be expected when certain policy measures were executed. The analysis clearly revealed the specific characteristics of each policy measure. Thus, with the help of a few relatively simple procedures, we were able to develop a land-use change model that reflects the local conditions of the region, and that could be effectively used for local land-use policy.

v. Future research tasks are as follows:

- The applicability of the proposed model structure depends on the temporal stability of the estimated land-use ratio function. However, it is to be expected that its structure will change in the longer term. The chosen target year was 2050, but 2020 might be a more reasonable limit for projections.

- The parameters of the driving forces prediction model were as yet not sufficiently tested. A more accurate identification of these model parameters is a future task.

- To capture the spatial structure of land-use change is an inevitable task for more concrete and useful policy analysis. However, to obtain land-use distribution at municipality level, the driving forces prediction model must be parameterized for each municipality. In this paper, we tested a simple trend extrapolation method. Estimation of more elaborate functions for projecting driving forces by municipality needs further study.

References

Hoshino, S. (1996): Statistical Analysis of Land-use Change and Driving Forces in the Kansai District, Japan, IIASA Working Paper WP-96-120, Laxenburg.

Ishitani, H. and Ishikawa, M. (1992): "Social System Engineering", chapter 3 Quasi-quantitative modeling, 33-65, Asakura Shoten, Tokyo (in Japanese).

Japan Map Center (1992): "User's Guide of National Land Numerical Information", Revised version, Japan Map Center, Tokyo (in Japanese).

Kitamura, T., Kagatsume, M., Hoshino, S., Morita, H., Mizuno, K., Konagaya, K. (1996): pp.1-49 in Ootsubo, K. (Ed.) Long term forecast of land use / cover change in Asia and the Pacific Region (1). National Institute for Environment Study, Japan (in Japanese).

Kitamura, T., Kagatsume, M., Hoshino, S., Morita, H. (1997): A Theoretical Consideration on the Land-use Change Model for the Japan Case Study Area, IIASA Interim Report, IR-97-064, Laxenburg.

National Land Agency (1992): "Outline of National Land Information System", 1-50, Printing Bureau, Ministry of Finance, Japan, Tokyo.

Oota, K. (1984): Theoretical development of disaggregate model, Textbook for the 15th lecture course on "Doboku-keikakugaku", 9-24, Doboku-Gakkai (in Japanese).

Sawaragi, Y. and Kawamura, K. (1981): "Participatory Systems Approach", Chapter 6, KSIM method and its applications, 181-203, Nikka-giken, Tokyo (in Japanese).