Regression Analysis on factors of land-use change in Japan

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1 Introduction

Most former land-use models were focused mainly on urban land uses and the areas covered by these models were relatively small regions. However from the viewpoint of global environmental issues, the land-use model must cover much larger regions than the urban models and must deal with wider ranges of land use categories including farmland, forestry land etc. besides the urban land uses. It has become important to elucidate driving forces of the land-use change for a larger area. The aim of this research is to identify the socioeconomic and physiographical factors prescribing the land-use changes in Japan for the global land-use model. Localities of these factors by regional types are also focused on in this analysis.

2 Frame of analysis

2.1 Data and Case study area

Unit of data is municipality. Regarding with land use and physiographical data, mesh or polygon is suitable as a unit of analysis. The largest reason why we adopted this administrative unit is that it is the smallest unit for which both physiographical and socioeconomic statistics are available.

Observation period of the land-use changes is 15 years from around 1975 to 1990. The reason is that precise land-use survey by Geographical Survey Institute was carried out in 1974 and 1989. Sources of the socioeconomic data were obtained from population census, agricultural census, establishment statistics etc. Survey years of the data are 1975 and 1990 to link the land-use data.

The case study area is the whole Japan. Eight land-use indicators are available for the whole Japan case. They are paddy field, upland field, orchard, forestry land, wasteland, urban land use (construction site), transportation site and the other land use. Table 1 shows mean values of the indicators and their correlation matrix for 1975. Because size of municipality is widely different each other, these average values disagree with real percentages of the land uses. According to the table, about a little less than 56 % of the total land area was forestry land, 28% was farmland including paddy field, upland field and orchard, and the remaining 16% was for urban land use and wasteland in 1975. The percentages of both paddy field and upland field have decreased between 15 years from 1975 to 1990, and the percentage of urban land-use area has increased, but drastic changes were not observed in general. In this background, legal regulations of land use were also strengthened after the end of the 1960's and the high economic growth had been converted to the moderate growth in the latter half of the 1970's.

Table 1. Average values for the land-use Indicators.

	Paddy field	Upland field	Orchard	Forestry land	Wasteland	Urban land use	Transportation	Other land use
Ave. % 1975	18.3%	7.3%	3.6%	56.3%	3.2%	8.1%	0.4%	2.8%
Ave. % 1990	17.4%	6.8%	3.8%	56.3%	3.3%	9.2%	0.5%	2.7%

Because the factors of the land-use changes are expected to depend on local mechanisms, we established

three other cases (the inland mountain areas, the inland urban areas and the Hokkaido area) besides the whole inland Japan. The factors of the land-use changes were extracted in each case. Comparative analysis of the driving forces was executed to make locality of the factors clear. The reason why the Hokkaido area was excluded from the case 1, 2 and 3 are because both physiographical and socioeconomic (and also historical) conditions in the Hokkaido area were quite different from those in the inland areas of Japan. Some peculiar samples and samples with any missing value were excluded from the analysis. Total number of the samples was about 3000 in the case 1.

Table 2. Area definitions of the four cases

No.	Case	Samples	Definition
1	The whole inland Japan		All municipalities except Hokkaido Island.
	case 1-f: farmland change	2976	
	case 1-u: urban land use change	2990	
2	The inland mountain areas		All inland municipalities except Hokkaido island whose percentage of forestry land is greater than 50 % and that of farmland is less than 20 % in 1975.
	case 2-f: farmland change	1157	
	case 2-u: urban land use change	1162	
3	The inland urban areas		All inland municipalities that have DID area in 1975 except Hokkaido Island.
	case 3-f: farmland change	854	
	case 3-u: urban land use change	858	
4	The Hokkaido area		All municipalities in Hokkaido Island.
	case 4-f: farmland change	204	
	case 4-u: urban land use change	204	

2.2 Frame of analysis

The previous study of the Kansai district in this LU/GEC project was the pilot study and the framework of the analysis was developed through this case study[1]. We adopted the same frame of analysis as the Kansai case. Figure 1 shows frame of the analysis. We applied a multiple regression model because techniques for variable selection are well developed. By the step-wise method, we choose statistically significant factors.

(1) Target indicators

Naturally an outcome from the analysis is depend on what kind of change indicators we chose. Therefore the indicators representing the land-use change must be carefully selected. Based on some preliminary analysis, we adopted “change in percentage of each land-use category” as the target indicator for the analysis. The indicator is calculated by the following equation.

$$LCi = L1i - L2i.$$

LCi; the land use change indicator of the category type i, L1i; the percentage in the i-type land use at the beginning of the period, L2i; the percentage in type-i land use at the end of the period. It is expected that a combination of the extracted factors depend on the length of duration, but the duration is compulsively fixed because only two time points of the land-use data are available.

Among 8 categories of the land use, we focused on farmland and urban land use mainly because we could not prepare enough explanatory indicators for the other land uses. But it is the most important to analyze driving forces of these two land-use changes.

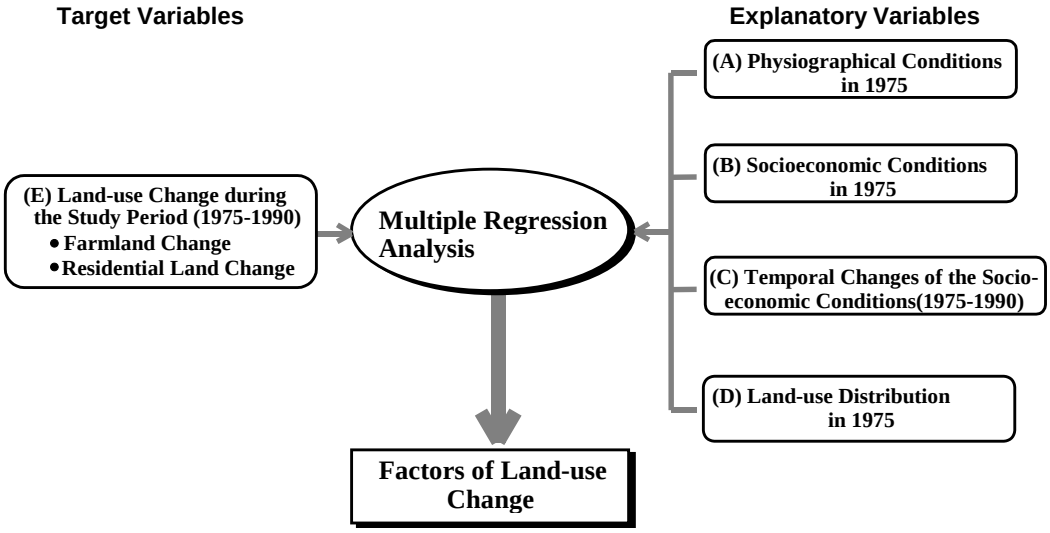

Fig. 1. Framework of analysis for land-use change.

(2) Explanatory indicators

Factors prescribing the land use divided into several groups such as physiographical conditions, socioeconomic conditions, transportation conditions, policy and legal conditions and social infrastructure technological innovation and economic trends. Table 3 shows the list of the indicators and their variable names. We adopted indicators of slope, elevation and topography for the physiographical conditions (A), and population and household indicators, work-force indicators and some indicators on economic activities for the socioeconomic conditions (B). Not only initial conditions but also temporal changes of the conditions must have had certain impacts to the land-use change. So we added temporal changes of the socioeconomic indicators (C). Indicator values of the temporal changes were calculated in the same way as the target indicators. Land use distribution at the beginning of the period would be also important factors. But they may conceal the contributions of the other important factors because land use itself has a kind of consequence of various human activities. Only the percentage of the same land-use as the target indicator (D) was adopted in this analysis. We were able to use only two indicators (CAR75_P and S_CAR_P) related to the transportation conditions and no indicator in the political conditions, because of unavailability of the data.

3 Factors of farmland change

3.1 Case 1-f: the whole inland Japan

We executed the regression analysis in which the target variable was the indicator of farmland change. The whole Japan except Hokkaido was the object of this analysis (case 1). Extraordinary samples and the indicators that caused multicollinearity were excluded. The probability of F value for the step-wise method was 0.05 in case of variable inclusion and 0.10 in case of exclusion. The final multiple correlation coefficient was 0.623, and the adjusted coefficient of determination was 0.382. 27 indicators were extracted as the explanatory variables. We divided these explanatory indicators into 6 groups. The indicator groups of B and C are respectively subdivided into the agricultural factors and the other socioeconomic factors.

Numerical values for the following indicators show standardized regression coefficients.

Table 3. List of indicators and variable names.

Indicator	Variable name	Indicator	Variable name
Section A : Physiographical conditions		**Section C : Temporal changes****	
% of 0-3 degree slope area	SLOPE1	Change in total population	S_TPOP
% of 3-8 degree slope area	SLOPE2	Change in population density	S_POPDEN
% of 8-15 degree slope area	SLOPE3	Change in % of population - 14 years old	S_POP_14
% of 15 degree and over slope area	SLOPE4	Change in % of population 15 – 64 years old	S_POP_64
% of 0-100m elevation area	ELEV1	Change in % of population 65 – years old	S_POP_65
% of 100 – 200 m elevation area	ELEV2	Change in DID* population ratio	S_DIDPOP
% of 200 –400 m elevation area	ELEV3	Change in daytime population ratio	S_DAYPOP
% of 400 m and over elevation area	ELEV4	Change in farm-household ratio	S_FARMP
% of mountain and volcano area	MOUNTAIN	Change in % of full-time farm household	S_FULL_F
% of hill, plateau & tableland area	HILLPLA	Change in % of part-time farm household (type2)	S_PART_F
% of lowland area	LOWLAND	Change in % of workers in primary industry	S_PRIMER
		Change in % of workers in secondary industry	S_SECOND
Section B : Socioeconomic conditions		Change in % of workers in tertiary industry	S_TERTIA
		Change in gross farm product per unit farmland	S_AGR_FL
Total population	TPOP75	Change in average farm size	S_FSIZE
Population density	POPDEN75	Change in # of agricultural workers per farmland	S_AGW_FL
% of population – 14 years old	POP75_14	Change in gross farm product per agr. worker	S_AGR_AW
% of population 15 - 64 years old	POP75_64	Change in # of business firms per 100 people	S_ENTP_P
% of population 65- years old	POP75_65	Change in industrial product per 100 people	S_PROD_P
DID* population ratio	DIDPOP75	Change in # of shops per 100 people	S_SHOP_P
Daytime population ratio	DAYPOP75	Change in retail sale per 100 people	S_SALE_P
Farm-household ratio	FARMP75	Change in # of cars per 100 people	S_CAR_P
% of full-time farm household	FULL_F75	Change in % of DID* area	S_DID_A
% of part-time farm household (type 2)	PART_F75		
% of workers in primary industry	PRIMAR75	**Section D : Land-use indicators**	
% of workers in secondary industry	SECOND75		
% of workers in tertiary industry	TERTIA75	% of farmland	FARM75
Gross farm product per unit farmland	AGR75_FL	% of forestry land	FOREST75
Average farm size	FSIZE75	% of residential land	URBAN75
# of agricultural workers per farmland	AGW75_FL	% of land for public use and others	OTHERS75
Gross farm product per agri. worker	AGR75_AW		
# of business firms per 100 people	ENTP75_P	**Section E : Land-use change****	
Industrial product per 100 people	PROD75_P		
# of shops per 100 people	SHOP75_P	Change in % of farmland	S_FARM
Retail sale per 100 people	SALE75_P	Change in % of forestry land	S_FOREST
# of cars per 100 people	CAR75_P	Change in % of residential land	S_URBAN
% of DID* area	DID75_A	Change in % of land for public use and others	S_OTHERS

* DID means “Densely Inhabited District” that satisfies the following conditions. (1) The area must be consolidated. (2) The population density of the area is more than 4,000 people / km^2 (3). Total population of the area is more than 5,000 people.

** The duration of the temporal changes is from 1975 to 1990.

(1) A Physiographical conditions

One indicator was selected in the physiographical conditions. The steep slope was a factor of farmland decrease. The reason why only one physiographical indictor was selected is thought that the indicator of farmland area might replace other indicators of the physiographical conditions.

Slope		
SLOPE3	Percentage of 8-15 degree slope area	-0.06

(2) B1 Initial conditions of the agricultural factors

As the initial conditions of the agricultural factors, the following four factors were extracted. The areas where part-time farming had advanced, the following decrease of farmland was more remarkable. It is considered that the initial level of part-time farming would show the existing level of agriculture labor force. Average farm size was a factor of farmland decrease and intensive use of farmland was a factor of preservation. This suggests that decrease of farmland was larger in open field agricultural zones than intensive agricultural zones. High initial share of full-time farm households can be interpreted that opportunities of non-agricultural jobs were not well developed at the beginning of the period. It is suggested that the effect of urbanization would be remarkable in such areas.

1) Level of the agricultural labor force (-)		
PART_F75	Percentage of part-time farm household (type 2)	-0.28
2) Intensive agriculture (+)		
AGR75_FL	Gross farm product per unit farmland	+0.13
3) Open field agriculture (-)		
FSIZE75	Average farm size	-0.19
4) Share of full-time farm household (-)		
FULL_F75	Percentage of full-time farm household	-0.11

(3) B2 Initial conditions of the other socioeconomic factors

We could identify three factors. Initial level of "rurbanization" (= 1.0 - farm household ratio) was a remarkable factor of farmland decrease. Percentage of DID area, percentage of DID population and number of business firms per population were also factors of farmland decrease. These four indicators might stand for initial potentiality of urbanization. On the other hand, initial number of retail shops per population contributed to farmland preservation. The rural areas in Japan had experienced drastic depopulation before 1975 (during the period of the high economic growth) but most retail shops in such rural areas had survived. Therefore the initial ratio of the shops to the total population had been high in 1975. This indicator might show a kind of inverse potentiality of urbanization. Initial level of aging was a factor of farmland decrease, too. Rate of the aged population in rural areas means aging of farm population. Therefore where the rate of aging had been advanced before 1975, the following decrease of farmland would have been remarkable. It was expected that the total population size would be a factor of farmland decrease but the sign of the regression coefficient was contrary to our expectation.

1) Potentiality of urbanization (--)		
FARMP75	Farm-household ratio	+**0.52**
DIDPOP75	DID population ratio	-0.14
DID75_A	Percentage of DID area	-0.12
ENTP75_P	Number of business firms per 100 people	-0.05
SHOP75_P	Number of shops per 100 people	+0.11
2) Initial level of aging (-)		
POP75_65	Percentage of population 65- years old	-0.15
3) Unreasonable factor (+)		
TPOP75	Total population	+0.07

(4) C1 Temporal change of the agricultural conditions

The following five factors were extracted. The outflow of agriculture labor force and the intensification of farmland use were selected as factors of farmland decrease. The improvement of agricultural labor

productivity and the enlargement of average farm size were factors of farmland preservation. The enlargement of the farm size could be achieved through small farms giving up farming and the remaining farms absorbing their farmland. So it means that farmland was preserved in good condition in the areas where such a structural change of agriculture could have been carried out smoothly. The increase of full-time farm households was a factor of farmland decrease. It is inferred that the increase of full-time farmer would have occurred by increase of old retired persons from another jobs. Therefore this indicator means aging of the agriculture labor force.

	1) Outflow of agricultural labor force (-)	
S_PRIMAR	Change in percentage of workers in primary ind.	+0.29
	2) Intensification of farmland use (-)	
S_AGR_FL	Change in gross farm product per unit farmland.	-0.27
S_AGW_FL	Change in number of agri. workers per farmland.	-0.05
	3) Increase of agricultural labor productivity (+)	
S_AGR_AW	Change in gross farm product per agri. worker	+0.19
	4) Enlargement of farm size (++)	
S_FSIZE	Change in average farm size	+**0.30**
	5) Increase of full-time farm households (-)	
S_FULL_F	Change in percentage of full-time farm household	-0.06

(5) C2 Temporal change of the other socioeconomic conditions

The increase of DID area and DID population indicated enlargement of DID area. The advancement of “rurbanization”, the increase of daytime population ratio, the increase of per capita retail sale and the increase of total population all indicated the advancement of urbanization. They acted as a factor of farmland decrease that spurred farmland conversion to urban land uses. The advancement of aging was also a factor of farmland decrease. Though population density should have been the indicator of urbanization, but the sign of the regression coefficient was positive. We cannot reasonably explain this .

	1) Enlargement of DID area and advancement of urbanization (-)	
S_DID_A	Change in percentage of DID area	-0.14
S_FARMP	Change in farm-household ratio	+0.27
S_TPOP	Change in total population	-0.06
S_DAYPOP	Change in ratio of daytime population	-0.04
S_SALE_P	Change in retail sale per 100 people	-0.06
	2) Advancement of aging (-)	
S_POP_14	Change in percentage of population - 14 years old	+0.04
S_POP_65	Change in percentage of population 65 - years old	-0.09
	3) Unreasonable factor (+)	
S_POPDEN	Change in population density	+0.13

(6) D Land-use distribution

The initial share of farmland distribution was a factor of farmland decrease. This is a common factor among all cases for farmland change.

	Initial share of farmland area (--)	
FARM75	Percentage of farmland	-0.27

3.2 Case 2-f: the inland mountain areas

Table 4 summarized the results of all cases. Characteristics of the farmland change factors in the inland mountain areas (case 2-f) are as follows.

1) Multiple correlation coefficient was 0.695, and the adjusted coefficient of determination was 0.473. The number of indicator selected was 21.
2) In the initial conditions of the agricultural factors (B1), the existing level of agricultural labor force was

extracted as a factor of farmland preservation. In the mountain areas, depopulation had been remarkable before 1975, but it also had caused outflow of the agriculture labor force. This result shows that in the areas where the outflow of agriculture labor force had not been so severe, farmland decrease in the following period was comparatively gentle.

Table 4. Summary of the regression analysis for farmland change.

	Case 1-f Whole inland	Case 2-f Inland mountain	Case 3-f Inland urban	Case 4-f Hokkaido area
(A) Physiographical conditions				
1) Slope	✓ (1)	✓ (1)		✓✓ (2)
2) Elevation		✓ (1)		
3) Topography		✓ (1)		✓✓ (2)
(B1) Initial conditions of agricultural factors				
1) Level of the agricultural labor force	+ (1)	+ (2)		++ (1)
2) Intensive agriculture	+ (1)		+ (1)	+ (1)
3) Open field agriculture (ave. farm size)	- (1)	- (1)		-- (1)
4) Share of full-time farm household	- (1)			
5) Labor productivity of agriculture		- (1)	- (1)	
(B2) Initial conditions of the other socioeconomic factors				
1) Potentiality of urbanization	-- (5)	-- (4)	-- (2)	- (1)
2) Initial level of aging	- (1)	- (1)		
3) Total population (unreasonable)	+ (1)		+ (1)	
(C1) Temporal change of agricultural factors				
1) Outflow of agricultural labor force	- (1)	-- (1)	- (1)	
2) Intensification of farmland use	- (2)	-- (2)	-- (1)	
3) Increase of agricultural labor productivity	+ (1)	++ (1)	+ (1)	+ (1)
4) Enlargement of farm size	++ (1)	+ (1)	++ (1)	++ (1)
5) Increase of full-time farm households	- (1)	- (1)		
6) Increase of part-time farm huseholds (unreasonable)			+ (1)	+ (1)
(C2) Temporal change of the other socioeconomic conditions				
1) Enlargement of DID area and advancement of urbanization	- (5)	-- (1)	-- (4)	- (1)
2) Advancement of aging	- (2)	- (1)	- (1)	
3) Population density (unreasonable)	+ (1)		+ (1)	
(D) Land-use distribution				
Share of farmland area	- (1)	- (1)	- (1)	-- (1)

N. B.: The figures in parentheses show number of the indicators selected by the step-wise method of the regression analysis.
Instead of the signs, the "✓" mark is used for the physiographical conditions. Double sign such as "++", "--" and "✓✓" means that the factor includes at least one indicator of which the values of standardized regression coefficient is more than 0.3.

3) The initial level of agricultural labor productivity was a factor of farmland decrease (B1). This indicator was selected in the cases of the inland mountain areas (case 2-f) and the inland urban areas (case 3-f). If there had been severe competition in local labor market between agricultural sector and non-agricultural

sector before 1975, the initial level of agricultural labor productivity could not but have become high. We can easily understand that the decrease of farmland during the following period would have become remarkable in such labor-competitive areas.

4) Outflow of the agriculture labor force was an important factor of farmland decrease particularly in the mountain areas (C1). This factor is closely related to the above factor.
5) Improvement of the agricultural labor productivity was also a strong factor of farmland preservation (C1). It suggested that attainment of high labor productivity of agriculture that could compete with the non-agricultural sectors would be an important factor of farmland preservation. Where the improvement of the agricultural labor productivity was not enough, the labor force would have flowed out into the other sectors, and decrease of farmland was promoted.
6) The level of aging was extracted in the mountain areas (B2). It is interesting that this indicator was not extracted in the urban areas (case 3-f). This fact coincided with our empirical knowledge that the aging would bring a negative effect to farmland preservation more remarkably in the mountain areas than in the urban areas.
7) Indicator regarding to the enlargement of DID area and the advancement of urbanization was hardly selected except the rurbanization indicator (B2). Actually, pressure of built-up areas and strength of city functions must have been weak in the mountain areas consisting of small-sized cities and towns.
8) The initial share of farmland area was a factor of farmland decrease (D).

3.3 Case 3-f: the inland urban areas

1) Multiple correlation coefficient was 0.689, and the adjusted coefficient of determination was 0.463. The number of the indicators selected was 17.
2) Any indicator in the physiographical conditions (A) was not selected at all. It is reasonable that importance of the physiographical conditions was relatively small in the urban areas.
3) Only a few indicators in initial conditions of the agricultural factors (B1) were selected. Urbanization had fairly advanced before 1975 in the urban areas. So the initial levels of part-time farming and the agriculture labor force did not remain as a factor of farmland change.
4) The combination of temporal change factors of the agricultural conditions (B2) well resembled in that for the case of whole inland Japan (case 1-f). The intensification of farmland use and the outflow of agriculture labor force were factors of farmland decrease, whereas the improvement of agricultural labor productivity and the enlargement of farm size were factors of farmland preservation.
5) On the other hand, contributions of the indicators related to the initial potentiality of urbanization and their temporal changes were large (B2 and C2). It might be said that the urbanization process would have been a dominant factor of farmland decrease in the urban areas.
6) Intensification of part-time farming was selected as a positive factor but it seems to be unreasonable.

3.4 Case 4-f: the Hokkaido area

1) Multiple correlation coefficient was 0.791, and the adjusted coefficient of determination was 0.598. The number of the indicators selected was 13.
2) Four indicators were selected in the physiographical conditions (A), and their absolute values of the standardized regression coefficients are remarkably large. The physiographical conditions played a very

significant role on farmland change in the Hokkaido area. Farmland was preserved in good condition in both the flat areas and the steep slope area. And decrease of farmland was remarkable in both the mountainous areas and the low land areas.

3) The initial farm size (B1) was a strong factor of farmland decrease and the enlargement of farm size (C1) was a very strong factor of farmland preservation. Internationalization of food trade and retreats of price support policy during the period have damaged the farm management in the Hokkaido area where open-field agriculture was dominant. These indicators suggested that the large farmers have been making great efforts to enlarge their farm size to seek for a better scale economy.

4) The indicators on urbanization (B2 and C2) were hardly selected except the initial level of DID area and its temporal change. Potentiality of urbanization was not an influential factor at least in Hokkaido.

4 Analysis of factor of urban land use change

4.1 Case 1-u: the whole inland Japan

We also made clear the factors of urban land-use change in the same way as the analysis of farmland change. The object of the case 1-u was the whole inland Japan. 8 indicators associated only with farmland were excluded from the explanatory variables. Because of the multicollinearity, the initial share of urban land use was also excluded. After all, multiple correlation coefficient was 0.652, and the adjusted coefficient of determination was 0.422. 15 indicators were extracted.

(1) A Physiographical conditions

Five indicators on the physiographical conditions remained as the explanatory variables. The excluded indicator of urban land use might be replaced by these physiographical conditions.

	1) Slope	
SLOPE1	Percentage of 0-3 degree slope area	+0.20
SLOPE2	Percentage of 3-8 degree slope area	+0.05
	2) Elevation	
ELEV1	Percentage of 0-100m elevation area	+0.06
	3) Topography	
MOUNTAIN	Percentage of mountain and volcano area	-0.06
LOWLAND	Percentage of lowland area	-0.12

(2) B Initial conditions of socioeconomic factors

The initial level of rurbanization, the initial share of DID area, the initial number of business firms per population were enlargement factors of urban land use. It is considered these indicators represented potentiality of urbanization. On the other hand the initial number of shops per population was the factor that restrained enlargement of urban land use. The same interpretation as mentioned in the case 1-f must apply to this case. And the initial level of aging acted as a factor enlarging urban land use.

	1) Potentiality of urbanization (+)	
FARMP75	Farm-household ratio	-0.18
DID75_A	Percentage of DID area	+**0.33**
ENTP75_P	Number of business firms per 100 people	+0.03
SHOP75_P	Number of shops per 100 people	-0.13
	2) Initial level of aging (+)	
POP75_65	Percentage of population 65- years old	+0.06

(3) C Temporal change of socioeconomic conditions

The temporal change of DID area, the temporal change of daytime population and the temporal change of

total population stood for the enlargement of built-up area and advancement of urbanization. These factors were enlarging urban land use. And increase of full-time farm households was a negative factor of urban land use.

1) Enlargement of DID area and advancement of urbanization (+)		
S_TPOP	Change in total population	+0.11
S_DID_A	Change in percentage of DID area	+0.09
S_DAYPOP	Change in daytime population ratio	+0.11
2) Increase of full-time farm households		
S_FULL_F	Change in percentage of full-time farm household	-0.04

4.2 Case 2-u: the inland mountain areas

Table 5 summarized the results of all cases for urban land-use change. Characteristics of the factors in the inland mountain areas (case 2-u) are as follows.

Table 5. Summary of the regression analysis for urban land-use change.

	Case 1-u Whole inland	Case 2-u Inland mountain	Case 3-u Inland urban	Case 4-u Hokkaido area
(A) Physiographical conditions				
1) Slope	✓ (2)			✓ (1)
2) Elevation	✓ (1)	✓ (1)		✓ (1)
3) Topography	✓ (2)		✓ (1)	✓ (1)
(B) Initial conditions of the socio-economic factors				
1) Potentiality of urbanization	++ (4)	+ (4)	++ (3)	+ (2)
2) Initial level of aging	+ (1)			- (1)
3) Initial level of economic activities (economically depressed area)		- (2)		- (1)
4) Initial level of vehicle diffusion		- (1)		
(C) Temporal change of the socio-economic conditions				
1) Enlargement of DID area and advancement of urbanization	+ (3)	+ (3)	+ (3)	+ (1)
2) Increase of full-time farm households	- (1)		- (1)	
3) Enhancement of economic activities (depression of economic activities)		- (2)		
(D) Land-use distribution				
Share of area	(-)	+ (1)	(-)	++ (1)

N. B.: The figures in parentheses show number of the indicators selected by the step-wise method of the regression analysis.
Instead of the signs, the "✓" mark is used for the physiographical conditions. Double sign such as "++", "--" and "✓✓" means that the factor includes at least one indicator of which the values of standardized regression coefficient is more than 0.3.

1) Multiple correlation coefficient was 0.720, and the adjusted coefficient of determination was 0.512. The number of indicator selected was 14.
2) The initial share of urban land use (D) was a factor encouraging expansion of urban land use. In the mountain areas (and also in the Hokkaido area, which is mentioned later), the existing mass of urban land use brought about further enlargement of urban land use. In case of both the whole inland and urban areas, we excluded this indicator because of high multicollinearity, but the sign of the coefficient was negative in the both cases when we included this indicator into the explanatory variables. Between the inland mountain areas and the inland urban areas, there might be a large difference in mechanism of

urban growth.

3) The initial ratio of daytime population and the initial number of business firms indicated the initial level of economic vigor (B). The increase of daytime population ratio and the enlargement of employees in the secondary industry were representing the enhancement of the economic vigor (C). Signs of the coefficients for these four indicators were all negative. The reason is inferred as follows. Phenomena to move their houses from inconvenient districts to a center of the same or neighboring municipalities in order to improve their living conditions could be observed here and there in the mountain areas. Such intra-transfers without any change of their occupations were often observed to the economically depressed municipalities in the remote places. The above result precisely tells us the actual behaviors of such urban land-use demand in the mountain areas.
4) The initial level of vehicle diffusion (B) was a relatively weak factor restraining increase of urban land use. In the area where ownership rate of vehicle had been high at the beginning of the period, the following increase of urban land use was relatively small.

4.3 Case 3-u: the inland urban areas

1) Multiple correlation coefficient was 0.623, and the adjusted coefficient of determination was 0.383. The number of indicator selected was 8.
2) The combination of the selected indicators was along the same lines as well that in case of the whole inland Japan.

4.4 Case 4-u: the Hokkaido area

1) Multiple correlation coefficient was 0.811, and the adjusted coefficient f determination was 0.639. The number of indicator selected was 9. Fitness was the best in all the cases
2) In case of the Hokkaido area, indicators of the initial conditions (A, B and D) were dominant. Among the 9 indicators, 8 indicators were those of initial conditions.
3) Same as the mountain areas (case 2-u), the initial share of urban land-use area was a factor enlarging the area of urban land use. It means that the existing muss of urban land have encouraged further expansion.
4) The coefficient for initial share of daytime population was negative (B). It is considered the reason would be the same as that of the mountain areas.

5 Conclusion

1) As we having expected, the initial potentiality of urbanization and the advancement of urbanization during the period were extracted as major factors of farmland and urban land use. These factors suggest that the competition with urban land and farmland is the most significant mechanism of land-use change that should be considered in the land-use model.
2) In the urban areas where urbanization adjustment areas were designated, the existing urban land restrained enlargement of urban land, whereas in the mountain areas and the Hokkaido area where such regally controlled districts were not so rigidly designated, the existing urban land promoted further enlargement of urban land adversely. We could not consider the regal regulation that controlled the land-use competition in this analysis but the above fact tells us the importance of further research on the effect of such regulation.

3) From the agricultural aspect, it is important for farmland preservation to keep the agriculture labor force in the agriculture sector. However job opportunities of non-agricultural sectors increase as the urbanization advances. Agricultural labor force flows out into the non-agricultural sectors if agriculture labor productivity is not improved, then farmland must decrease. But, under the limited labor force, the area of farmland also would decrease if the farmers intensify the farmland use in order to increase the labor productivity.
4) On the other hand, in the place where labor productivity can be made through enlargement of farm size, the farmland is preserved in good condition. Therefore, it is most important to build in the mechanism of long-term transaction of the agriculture labor force and the mechanism of structural change of agriculture into the land-use model.
5) The factor of aging was identified in both farmland change and urban land-use change. This factor is closely related to the economic activities and long-term transaction of agricultural labor force.
6) Some interesting factors were also detected. In the mountain areas, the depression of economic activities was extracted as a factor enlarging urban land use. This might be a counter action by the people living in the inconvenient districts to improve their life environments. And diffusion of vehicle was extracted as the factor that restrained enlargement of urban land use.
7) We made clear the factors in each case and could identify some interesting factors that reflect the regional characteristics. But any remarkable discrepancy was not found among the three cases of the inland. It suggests the possibility to summarize the inland area as one case. The Hokkaido area should be treated as an independent case because of the unique characteristics.

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[1] S. Hoshino (1996): Statistical Analysis of Land-use Change and Driving Forces in Kansai District, Japan. WP-96-120, IIASA, 1 – 40. S. Hoshino (1998): Driving Forces of Land-use Change in Japan, K. Ootsubo ed. “Final Report of Land Use for Global Environmental Conservation (LU/GEC)”, NIES, 101-112.