A Model for Monitoring Urban Development and Disaster Prevention in the 10th National Plan of Thailand

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Abstract

The ultimate objective of this paper is to develop a model that can monitor urban development and disaster prevention. Working objectives are to classify urban forms of Thailand based on spatial patterns of urban land use in 2007, and find out factors that can explain the differences in urban land use changes in provincial level, between 2001 and 2006 of the 9th National Economic and Social Development Plan implementation. Methods for urban form classifications, spatial analyses and mapping the urban structure are GIS and statistical techniques. Urban structures include commercial, industrial, housing areas, networks and risk areas for disaster prevention such as flooding, landslide, and drought as well as shore erosion. Discriminant function is applied for classification analysis. The ratio of urban land use changes between 2001 and 2007 to urban land use in 2007 is applied for grouped variable while social, economic as well as resource and environmental variables are used for explanation variables.

Keywords : land use, urban form, urbanization, disaster prevention, discriminant function, cluster analysis

INTRODUCTION

In general, land use is a good reflection of human socio-economic activities and the capability of resource management in any operated areas. Human activities usually contribute to the development of city environment and urban structure changing. Previous research found that Pathum Thani province, north of Bangkok has been affected by the network expansion resulting in a rapid change from rural to urban environment in terms of spatial visualization and urbanization level. The rate of land development increased very far ahead of the social development without planning. This enforced local people to change their traditional style of living without preparation resulting in social and spatial organization problems [1]. If this change can be observed, it could help designing strategic planning and monitoring process. In addition, Thailand is now facing more natural disaster especially, flooding, shore erosion for example in Samut Prakan province. Urgent urban planning priorities within five years under urban policies in Thailand is the preparation in protection and mitigation plans for high-risk natural disaster areas, especially all river basin areas. The plan will include designated disaster risk zones, control permits and flood warning systems [2]. This paper focuses on an effort to investigate the patterns of spatial urban structure and urbanization level in 2007 across Thailand and statistical model development for predicting the potential urban growth of the province in order to use as a benchmark for monitoring the changes and as information for adjusting or driving the strategic urban development of the10th National Plan (2007-2011).

ULTIMATE OBJECTIVES

1. To explore the urban forms across Thailand
2. To develop a model that can monitor the urban growth of Thailand

WORKING OBJECTIVES

1. To classify provinces based on urban form, demographic profile and urbanization level.
2. To find out factors that can explain the difference between group of provinces that has positive ratio of urban land use change to urban land use in 2007 and the group that has negative one.

METHODOLOGY

1 Population of the study are 76 provinces in Thailand. In this study all population are applied.
2. Unit of analysis is province
3. Tools for analyses
   3.1 K-means cluster method and GIS are applied for exploring the urban form patterns.
   3.2 Discriminant analysis is applied for constructing monitoring model for classifying provinces based on urban land use change.
4. Variables and data sources
   4.1 Twenty four variables are used for K- means cluster analysis as shown in Table 1
   4.2 Fourteen variables are applied as independent variables or discriminating variables while ratio of urban land use change (%) is applied as grouped variable as shown in Table 2

Table 1 list of variables used for K-Mean cluster analysis [3]		
No.	**Variables**	**Description**
1	POLYGON_U1	Number of polygons of city, town and commercial land in 2007
2	POLYGON_U2	Number of polygons of village land in 2007
3	POLYGON_U3	Number of polygons of institutional land in 2007
4	POLYGON_U5	Number of polygons of industrial land in 2007
5	POLYGON_U6	Number of polygons of other land such as abandon area, golf course, etc. in 2007
6	U1_PER_U_%	Ratio of U1 polygon number per urban polygon number in 2006/2007 (%)
7	AVG_SPIDER _km	Average distances of U1 polygon to the Provincial Central Office in 2006/2007 (km)
8	U1_PER_U_L%	Ratio of U1 land area to urban land area in 2006/2007 (%)
9	U2_PER_HEA	Ratio of U2 land area to population of province in 2006
10	U3_PER_HEA	Ratio of U3 land area to population of province in 2006
11	U_AREA_07	Urban land area in square meters in 2006/2007
12	U1_AREA_07	City, town and commercial land area in square meters in 2006/2007
13	U2_AREA_07	Village land area in square meters in 2006/2007
14	U3_AREA_07	Institutional land area in 2006/2007
15	U4_AREA_07	Transportation, communication and utility land area in square meters in 2006-2007
16	U5_AREA_07	Industrial land area in square meters in 2006/2007
17	U6_AREA_07	Other land such as abandon area, golf course, cemetery etc, in square meters in 2006/2007
18	U405_AREA_	Road area in square meters in 2006/2007
19	TOTAL_POP_07	Total population of province in 2007
20	MALE_07	Total male of province in 2007
21	FEMALE_07	Total female of province in 2007
22	MUNI_POP_07	Municipal population of province in 2007
23	RURAL_POP_07	Rural population of province in 2007
24	URBANIZATI %	Ratio of municipal population to total population of province in 2007

Table 2: Variables used for Discriminant analysis [3]			
Variable type	**Variable name (X_1-X_n)**		**Description**
	For Analysis 1	**For Analysis 1a**	
Discriminating variables or independent variables	R_FOR_01	R_FOR_01	Ratio of forest land to provincial land in 2001 [5]
	R_UNU_01	R_UNU_01	Ratio of mixed land to provincial land in 2001 [5]
	SK_H_ARE	SK_H_ARE	Sinkhole risk area (fig.1-3) [4]
	SH_EROS	SH_EROS	Shore erosion (binary variable) yes=1, no=0 (fig.1-3) [4]
	FISHI01	FISHI01	GPP for fishing in 2001 [5]
	AGRI_GW	AGRI_GW	Growth of agricultural sector between 2001 and 2006 [5]
	POP_FLOOD0	POP_FLOOD0	Population affected from flood in 2004 (%) [5]
	R_AGR_01		Ratio of agricultural land to provincial areas in 2001 [5]
	SEA_TOUR		Number of natural places (sea) for touring in 2005 [8]
	ELECT01		GPP for electricity in 2001 [5]
	CONSTR01		GPP for construction in 2001 [5]
	POP_PHYSIC		Ratio population per physician in 2004 [5]
	AVG_SCORE_		Average education score in primary level (%) 2004 [5]
	POP_FLOOD_		Population affected from flood (numbers) 2004 [5]
	POP_INTERN		Population access to internet (%) 2005 [5]
	HH_PAR_IN_		Household participation in local group 2005 [5]
Grouped variable	**Group name**	**Description**	
	Group 1 (62)	Provinces that obtain the positive ratio of land use change (fig.1-2)	
	Group 0 (14)	Provinces that obtain the negative ratio of land use change (fig.1-2)	
The linear discriminantequation			**Description**
$D = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_pX_p$			D is discriminant score
			X is the value of discriminating variable
			B is the coefficient estimated from the data

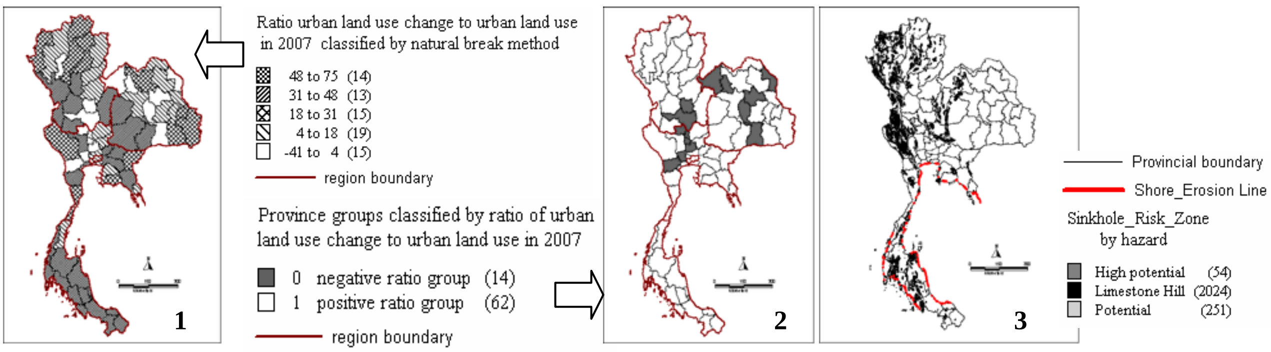


Fig .1 Distribution of spatial data used for analyses

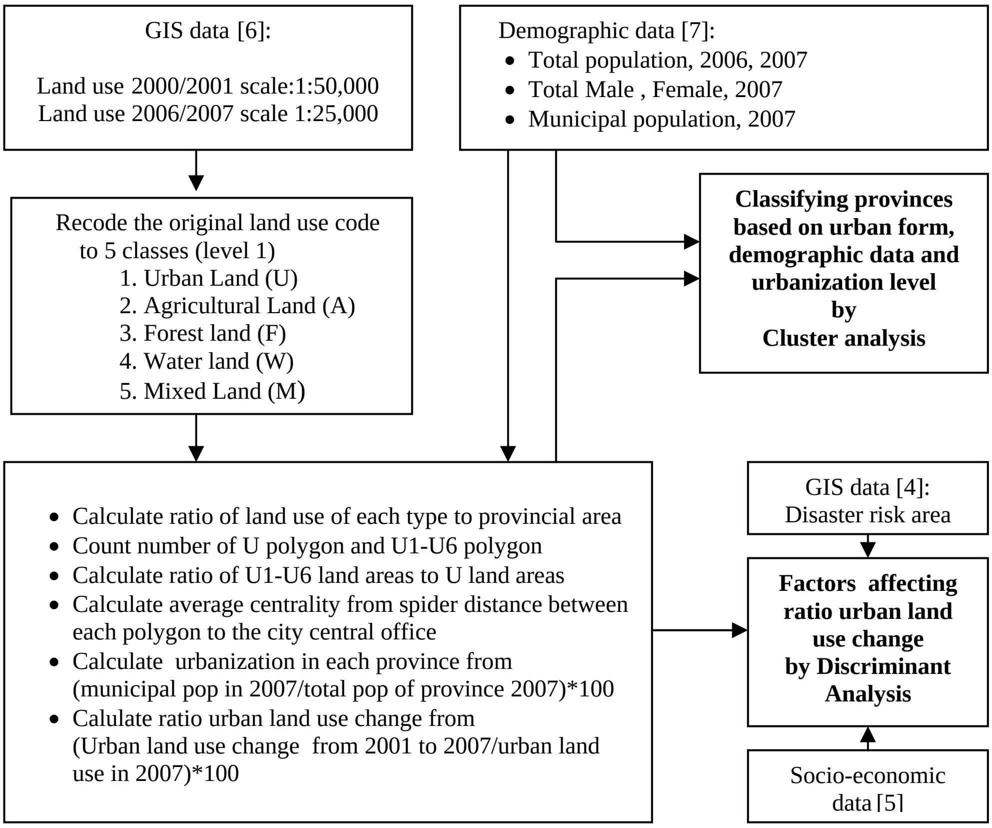


Fig 2 Flow chart of analysis

FINDINGS

1. Classification of provinces based on urban form, demographic data and urbanization

The main objective of this analysis is to observe the spatial patterns of urban land use structure, within 20 and 30 kilometers buffering around the point representing the provincial central office, whether they reflect cluster characteristics generated from cluster analysis.

In order to classifying the provinces of Thailand based on spatial form of urban land use in 2007, statistical data calculated from spatial form of urban land use in 2007, as well as demographic data and urbanization level total 24 variables were selected as shown in Table 1. K-means method was applied for clustering 76 provinces into three, four, five and six groups alternately. After comparing the classification results of four patterns, the six clusters pattern (fig. 4) was chosen to illustrate the spatial forms of urban land use. All variables were standardized before analysis.

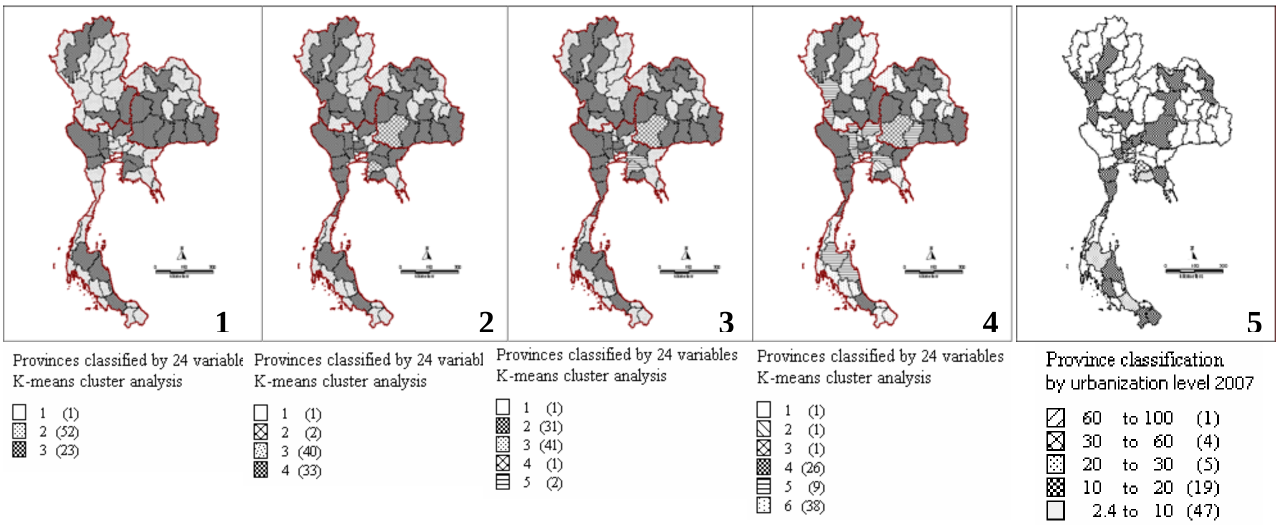


Fig.3 Patterns of province classifications based on 24 variables compared with urbanization

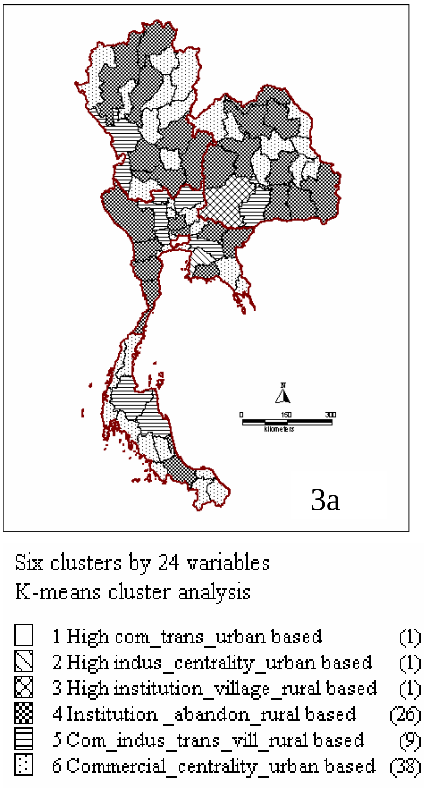


Table 3 Provinces by 6 clusters and regions

	Central region	North region	Northeast region	South region
1	Bangkok			
2	Chon Buri			
3	**Nakhon Ratchasima**			
4	Pathum Thani Rayong **Prachuap Khiri Khan** **Phetchaburi** **Phra Nakhon Sri Ayutthaya** Ratchaburi Sra Kaeo Kanchanaburi Prachin Buri	**Lampang** **Nakhon Sawan** Chiang Mai Phitsanulok Chiang Rai Phetchabun Kamphaeng Phet	**Khon Kaen** **Udon Thani** Ubon Ratchathani Nong Khai Sakhon Nakhon Si Sa Ket Chaiyaphum Surin Roi Et	Songkhla
5	**Nakhon Pathom** Chacheongsao Suphan Buri Chai Nat Lop Buri	Tak	Buri Ram	Surat Thani **Nakhon Sri Thammarat**
6	Nonthaburi Samut Prakarn Samut Sakhon **Saraburi** **Samut Songkhram** **Chanthaburi** Sing Buri Nakhon Nayok Trat Ang Thong	Phichit Uttaradit Sukhothai Uthai Thani Nan Phayao Phrae Lamphun Mae Hong Son	**Nakhon Phanom** **Mukdahan** Amnat charoen Maha Sarakham Nong Bua Lam Phu Yasothon Kalasin Loei	Phuket **Yala** **Trang** **Narathiwat** Chumphon Ranong Satun Phatthalung Phang-nga Pattani Krabi
	Bold characters have urbanization level in 2007 between 10-20%			

Table 4 Final Cluster Centers

Variables	Cluster No. (number of cluster members)					
	1(1)	**2 (1)**	**3 (1)**	**4 (26)**	**5 (9)**	**6(38)**
POLYGON_U1	**5.26009**	1.15383	.28846	-.15467	***1.04825***	-.31882
POLYGON_U2	-.18131	.56582	**2.25402**	.17927	***1.73501***	-.60302
POLYGON_U3	-.02702	-.03027	**4.20648**	***.56734***	.47989	-.61103
POLYGON_U5	.41804	**3.88354**	2.89415	.09347	***1.01473***	-.49365
POLYGON_U6	-.07495	3.03190	**6.18189**	***.22656***	-.21558	-.34445
U1_PER_U_%	**4.25053**	.10042	-.64487	-.35745	-.13491	***.17900***
AVG_SPIDER_km	-.34683	**-1.10373**	1.68474	.31897	.15476	***-.26106***
U1_PER_U_L%	**4.76270**	.00544	-.34550	-.21779	-.44745	***.13860***
U2_PER_HEA	-1.57784	-.07915	-.07437	.26356	***.76375***	-.31566
U3_PER_HEA	-1.06237	**.94480**	.79650	***.62205***	-.06349	-.42844
U_AREA_50_	2.84833	1.84143	**3.84653**	.52975	***.68312***	-.74889
U1_AREA_50	**7.47074**	.78553	1.08860	***.10327***	-.09877	-.29319
U2_AREA_50	1.35659	.85961	**3.54266**	.56776	***.84297***	-.73967
U3_AREA_50	.31119	1.55697	**4.05467**	***.68700***	.01531	-.62954
U4_AREA_50	**2.93847**	1.47561	.20681	-.21661	***1.81266***	-.40271
U5_AREA_50	.24288	**4.81965**	2.31535	.13447	***.29067***	-.35500
U6_AREA_50	.39062	4.92833	**4.95232**	***.10227***	-.15493	-.30358
U405_AREA_	**2.15327**	1.85091	.16301	-.22825	***1.94566***	-.41430
TOTAL_POP_50	**6.71491**	.55513	2.36817	***.27688***	.07616	-.46112
MALE_50	**6.59481**	.56285	2.43196	***.29014***	.08141	-.47016
FEMALE_50	**6.82268**	.54755	2.30705	***.26431***	.07121	-.45238
MUNI_POP_50	**8.48066**	.54042	.17644	***-.09565***	-.12988	-.14583
RURAL_POP_50	-1.59651	.11948	**3.84153**	***.63112***	.33569	-.57355
URBANIZATI%	**6.24370**	2.11713	-.07465	-.14103	-.25024	***-.06230***

Comparison of classification results

First analysis :Three clusters pattern (Fig. 3-1)

Cluster 1 includes only one member that is Bangkok, presenting the highest number of U1 polygon and land areas, ratio of U1 polygon to total U polygon, ratio U1 land areas to U land areas, total U4 and U405 land areas as well as highest urbanization and demographic profile except rural population. The second group, the largest members accounting for 52 provinces, obtains the least cluster centers for all variables. The third group, comprising 23 provinces, is very strong in number of U2, U3 and U5 polygons that represent village, institutional and industrial land, respectively. However, this group also obtains highest number of U6 polygons. This supports high total U, U3,U5 and U6 land areas.

Second analysis : Four clusters pattern (Fig.3-2)
The third group under the first analysis becomes the fourth group in this analysis with members increasing to 33 provinces. There are 12 provinces added to the group while two of them in previous cluster namely Chon Buri and Nakhon Ratchasima are moved to form the second group. The new group members added are Lampang, Tak, Kamphaeng Phet, Pathum Thani, Phra Nakhon Sri Ayutthaya, Rayong, Srakaeo, Prachin Buri, Nong khai, Sakhon Nakhon, Pechaburi and Prachuab khiri khan.

Third analysis : Five clusters pattern (Fig.3-3)
The fourth group in previous analysis is assigned as the second group in this one comprising 31 members since the two provinces, Chacheongsao and Sra Kaeo provinces from previous cluster are separated to other cluster.

Fourth analysis : Six clusters (Fig.3-4)
When six clusters are specified for analysis, three cases namely Bangkok, Chon Buri and Nakhon Ratchasima provinces are formed separately in three clusters showing significant differences in cluster centers and spatial structure of urban land use within the buffer zones of 20 and 30 kilometers around the provincial central office. As shown in table 1 and figure 3, Bangkok, the capital and primate city, has highest urbanization level and largest city and commercial land (U1) both in terms of number of polygons and land areas while Chon Buri, the eastern seaboard city, obtains the highest number of U5 polygons and largest industrial land use areas. Nakhon Rachasima, the entrance of the northeast region, has another unique urban spatial form, comprising high density both of polygons and land areas of U2, U3 and U6 which representing village, institutional and other land such as abandoned area, recreation area, golf course, cemetery, refugee camp. In addition, the figure in table 2 shows that the accessibility to the provincial central office from each urban polygon by average is very low since the average spider lines between each polygon to the city central point is the longest distance comparing to other cluster. Urbanization level of Bangkok is 100% because of 100% municipality and Chon Buri is 41.77%.while Nakhon Rachasima is only 10.84%.

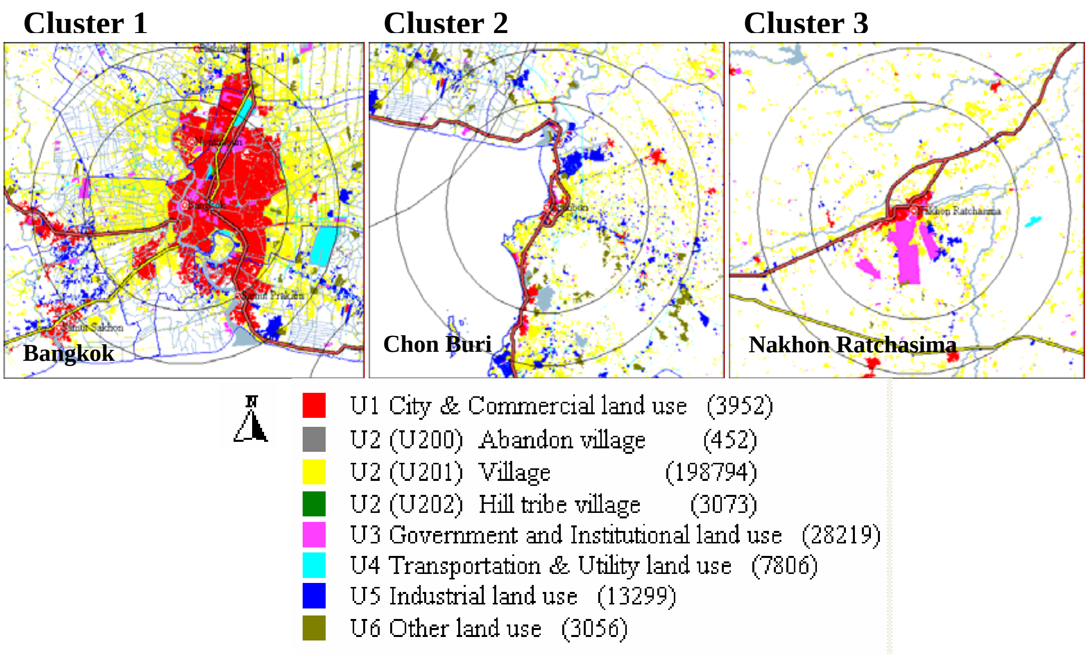


Fig. 4 Spatial urban form of cluster 1-3

Another three clusters are cluster 4, 5 and 6 obtaining members accounting for 26, 9 and 38 provinces respectively. The second group in the third analysis becomes the fourth group in this analysis remaining members for 26 provinces since 6 provinces namely Tak, Nakhon Pathom, Buriram, Lop Buri, Supan Buri, Surat Thani and Nakhon Sri Thammarat, are removed to the fifth group while Sra kaeo is added. Comparing among these three clusters, variables contribute to urban characteristics of cluster 4 are high number of U6 polygon and large areas of city and commercial land (U1), institutional land (U3) as well as other land (U6); moreover, demographic profile is also high especially the rural population. Urbanization level in 2007 of this group varies from 2.6 to 34.49 resulting as 9.9 by average. The provinces contributing to the group, high city and commercial land areas are Chiangmai, Phitsanulok, from the north region and Khon Kaen, Ubon Ratchathani, from the northeast. The provinces contributing to the group, the substantial institutional land, considering within the defined buffers, are Rayong, Prachuap Khiri Khan, Kanchanaburi, Prachin Buri, Lampang, Chiangmai, Phetchabun, Sakhon Nakhon, Khon Kaen, Surin and Roi Et. The cities sharing major industrial land to the group are Pathum Thani, Rayong, Phra Nakhon Sri Ayutthaya, Kanchanaburi, Lampang. The numbers on the right top of the city land use images and on the country map 5a as shown in figure 5 represent the provincial urbanization level ranking from the highest (1) to the lowest (26). It is noted that the big cities like Chiangmai, Khon Kaen, Ubon Ratchathani have quite low urbanization level as 9.74%, 11.15% and 7.98% respectively. (table 3,4 and figure 5)

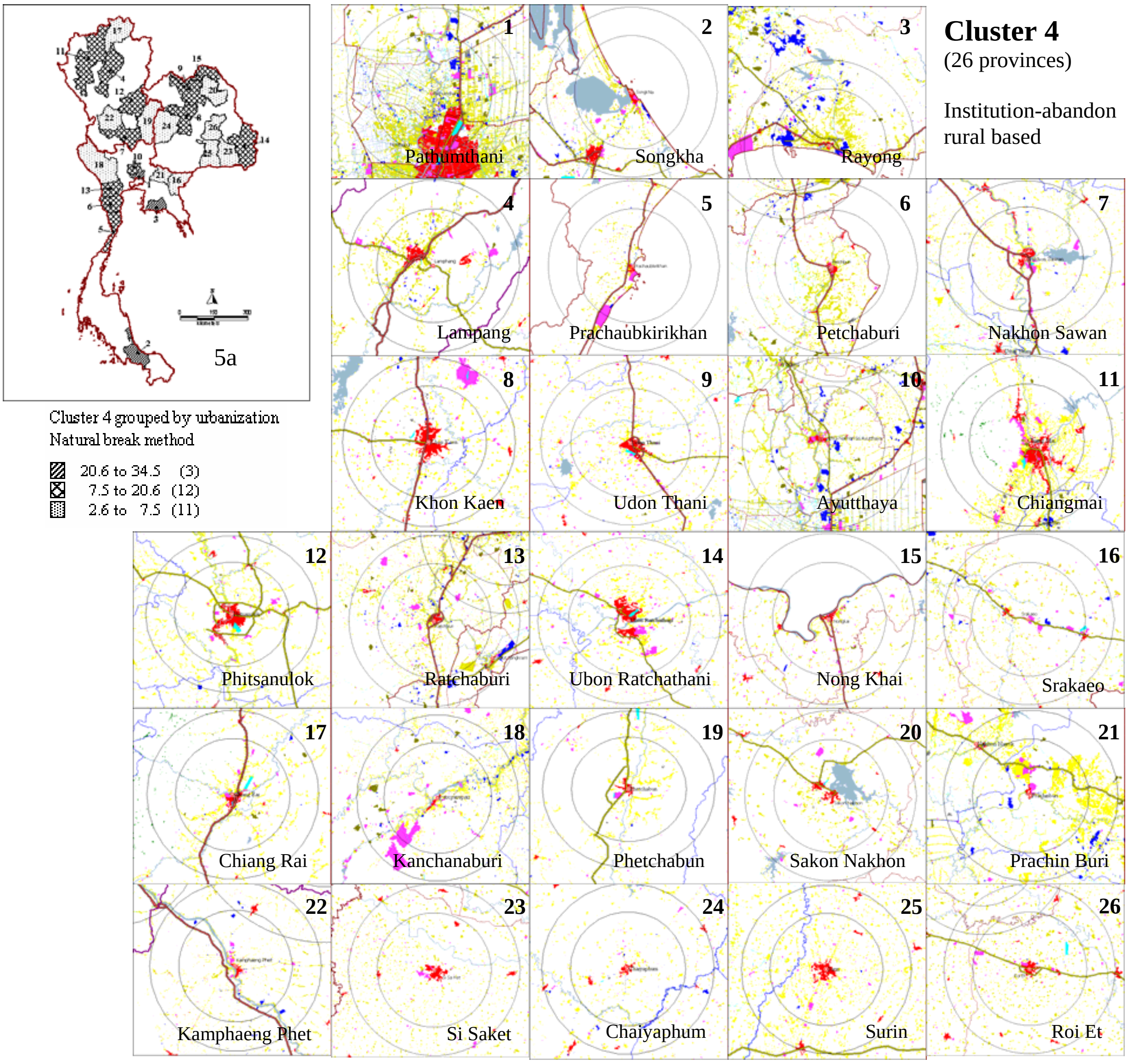
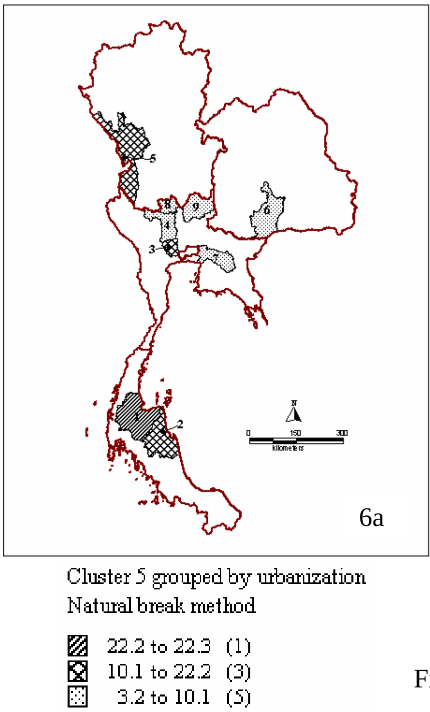


Fig. 5 Spatial urban forms of cluster 4

Cluster 5 consists of 9 provinces, showing high number of U1,U2 and U5 polygons, large land areas of village, transportation, communication and utility as well as industry but low demographic profile. The numbers on the right top of the city land use images and on the country map 6a as shown in figure 6 represent the provincial urbanization level ranking from the highest (1) to the lowest (9) Cluster urbanization level by average is 8.36%, ranging from 3.2% to 22.3% (table 3,4 and figure 6).

Cluster 6 is the biggest cluster comprising 38 provinces. Cluster urbanization has wide range varying from 2.47% to 53.48% resulting as 11.01% by average higher than cluster 4 and cluster 5. The cluster characteristics are high ratio of U1 polygons to urban polygons (U) as well as high ratio of U1 land area to urban land area. Four provinces such as Nonthaburi, Samut Prakarn, Smut Sakhon in central region and Phuket in southern region, contribute high urbanization level to the group as 53.48%, 44.03%, 26.17% and 29.18% respectively (table 3,4 and figure 7). As shown in table 2, average spider value is the shortest among all clusters excluding cluster 2. This implies high centrality of city and commercial land use (U1) to the provincial central office.



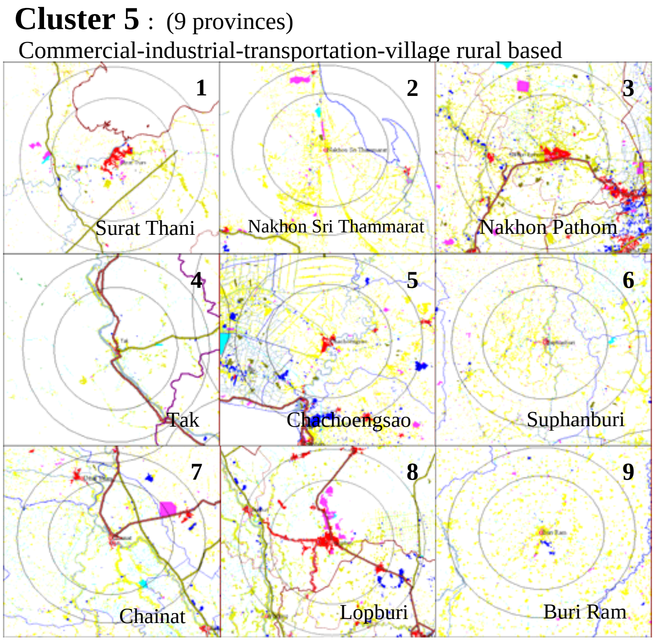


Fig.6 Spatial urban forms within buffers of 20 and 30 kms. around the provincial central office.

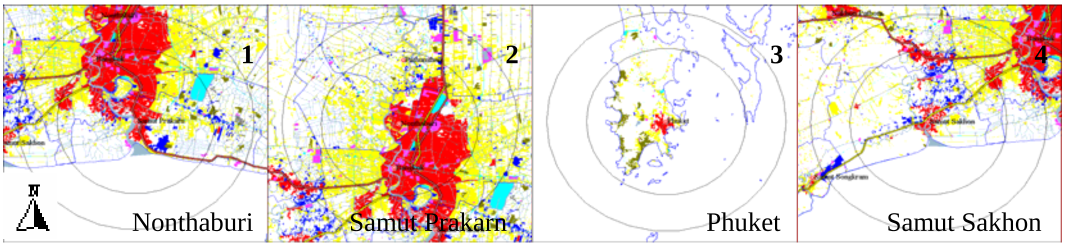


Fig. 7 Urban structure within 20 and 30 kms. buffers of four cities in cluster 6

The earlier explanation illustrates how K-means cluster analysis identify relatively homogeneous groups of provinces based on urban form measured by spatial arrangement of land use in terms of polygon distribution and land areas; demographic profile defined by total population in 2007; municipality and rural population as well as urbanization level. As shown in table 5 there is low association between urbanization and number of city and commercial polygons (U1) since correlation coefficient is 0.523 at 0.01 significant level (2-tailed). Number of urban polygons (U) have strong relationship with number of village polygons (U2) and moderate association with industrial polygons (U5) accounting for .991 and .705 at 0.01 significant level (2-tailed) respectively. Provincial urbanization in Thailand are characterized by commercial based and industrial based patterns. In order to follow up urban land development in the 10th national plan between 2007and 2011, the changes of urban land use in terms of the ratio changes between 2001 and 2007 to urban land use in 2007.

Table 5 Pearson Correlation (2 tails sig.)

	URBANIZATI%	POLYGON_U2	POLYGON_U3	POLYGON_U5
POLYGON_U1	**.523(.000)**	.344(.002)	.073(.532)	.292(.011)
POLYGON_U3	-.084(.471)	**.644(.000)**	1	.429(.000)
POLYGON_U5	.264(.021)	**.657(.000)**	.429(.000)	1
POLYGON_U6	.078(.505)	.324(.004)	**.525(.000)**	**.518(.000)**
POLYGON_U	-.045(.699)	**.991(.000)**	**.699(.000)**	**.705(.000)**

2. Factors that can explain the difference between group of provinces that has positive ratio and that has negative ratio of urban land use changes

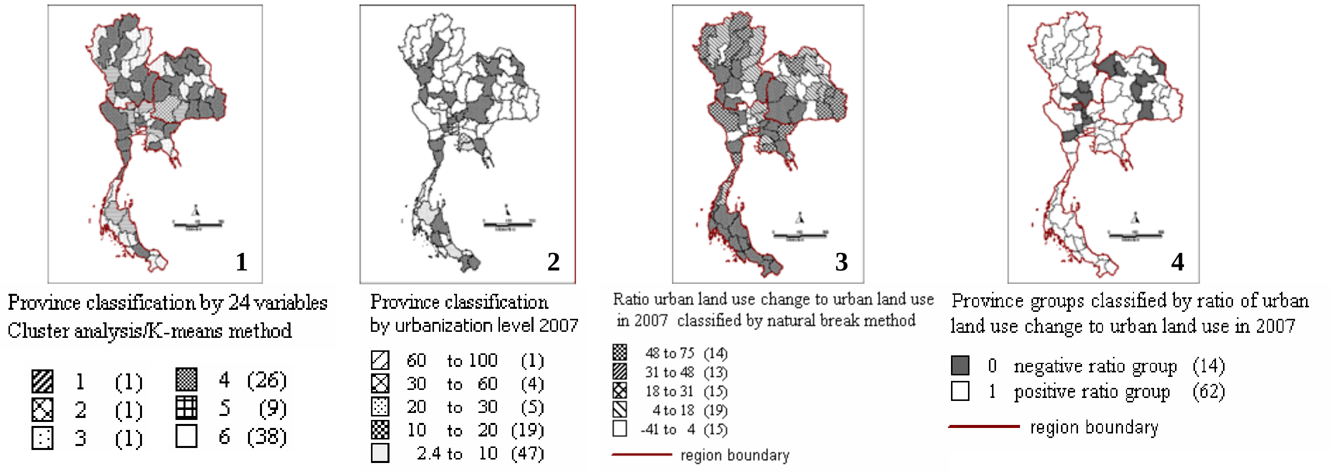


Fig 8 Province classification comparison

Fig. 8-1 illustrates the pattern of provinces classified by multivariate such as urban form, demographic profile and urbanization level. Fig. 8-2 and fig.8-3 show the patterns of provinces classified by univariates that are urbanization level and ratio of urban land use changes between 2001 and 2007 to urban land use in 2007, respectively. As shown in fig.8-3, five classes can be grouped into two major groups (fig.8-4), one is the group obtaining negative value of the ratio while another is the group gaining positive value of the ratio. The negative ratio value here means there was a decrease in urban land use in 2007 or urban land uses in 2001 were changed to other land use type in 2007. In contrast, the positive ratio value means there was an increase in urban land use in 2007 or some of urban land uses in 2007, were previously other type of land use. Since these ratio values have been calculated from urban land use changes (urban land use in 2007 minus urban land use in 2001) divided by urban land use in 2007, then multiplying by 100 to make the percentage number, the ratio values provide more meaning than increased or decreased concept. It also implies how rapid changes happen to the group. For example, there are 5 classes in fig.8-3, the first class has 14 provinces, having ratio values ranging from 48 to 75%, this means that 48 to 75% of urban land uses in 2007 are the changes just happening during the past five years (2002-2006). Ten of fourteen provinces of this group have urbanization level less than 10% while the fourth class having 19 provinces and ratio values ranging from 4 to 18 %. Five of the group members have urbanization levels more than 30% because these provinces became urban before the past five years.

If variables that discriminate the two groups have been identified, we can use these variables classifying the provinces in the next national plan. Discriminant analysis will be used to determine whether the variables listed in Table 2 distinguish between provinces that have positive urban land use changes and those that have negative ones. The followings are the two results of Discriminant analyses applying 2 groups classified by the ratio of land use changes as shown in fig.8-4 as a grouped variable while 16 and 7 variables were applied as discriminating variables for analysis 1 and analysis 1a respectively.

Interpretation of analysis 1

Table 6 shows significance tests for the equality of group means for each variable. Since the observed significance level of nine variables are less than 0.10, the hypothesis that all group means are equal is rejected. The group means of the ratio of agricultural land use as well as ratio of forest land to the province areas in 2001 (R_AGR_01, R_FOR_01), are different at .01 significance level. The group means of the ratio of mixed land to the provincial areas in 2001, shore erosion and average agricultural growth per year (calculating from 2001 to 2006) are different at .05 significant level while that of the rest four variables such as sinkhole risk areas, GPP for fishing in 2001, percentage of population affected from flood in 1004, number of natural sea for touring, are different at.10 significance level. The canonical correlation of .654 in table 7 is a measure of degree of association between the discriminant scores and the groups being equivalent to eta. Thus the eta^2 is .428 (.654^2) representing the proportion of the total variance in the discriminant scores contributing to differences between the groups while Wilks' lambda of .572 in table 8 is the proportion of the total variance in the discriminant scores not explained by the differences between groups. In order to assess the contribution of variable to the discriminant function is to examine the correlations between the values of the function and the values of the variables as shown in Table 10. The table indicates that the variable R_AGR_01 has the highest correlation (-.449) with the discriminant function. The negative sign indicates that the small function values are associated with the high ratio of agricultural land to the provincial land in 2001. The R_FOR_01 has the second largest correlation in absolute value. Discriminant function coefficients as shown in Table 9 may be used as indicators of the

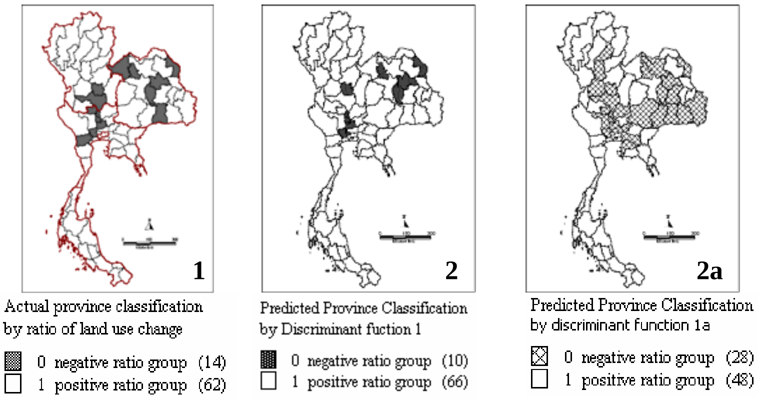


Fig. 9 Actual and predicted classification

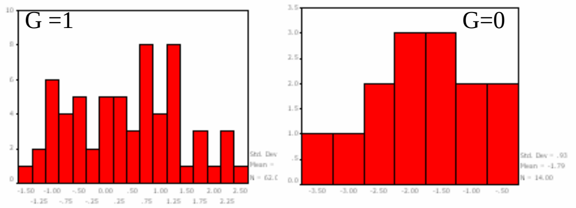


Fig. 10 Canonical Discriminant Function 1

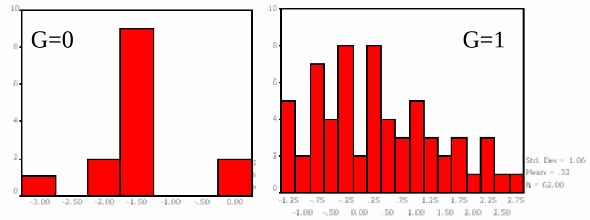


Fig. 11 Canonical Discriminant Function 1a

Table 6
Tests of Equality of Group Means

Variables	F	Sig.
1. R_AGR_01	11.159	.001
2. R_FOR_01	9.632	.003
3. R_UNU_01	5.875	.018
4. SK_H_ARE	3.189	.078
5. SH_EROS	5.150	.026
6. FISHI01	2.808	.098
7. AGRI_GW	5.685	.020
8. POP_FLOOD0	2.845	.096
9. SEA_TOUR	3.839	.054
10.ELECT01	.469	.495
11.CONSTR01	.550	.461
12.POP_PHYSIC	2.696	.105
13.AVG_SCORE_	1.198	.277
14.POP_FLOOD_	2.218	.141
15.POP_INTERN	1.766	.188
16.HH_PAR_IN_	1.714	.194

Table 9
Canonical discriminant function Coefficients

	standardized	**unstandardized**
	Function 1	Function 1
R_AGR_01	3.318	17.745
R_FOR_01	4.244	19.178
R_UNU_01	1.032	40.561
SK_H_ARE	-.297	.000
SH_EROS	-.228	-.558
FISHI01	.074	1.775
AGRI_GW	.271	.070
POP_FLOOD0	-.684	-.135
SEA_TOUR	.076	.013
ELECT01	.284	2.961
CONSTR01	.169	1.745
POP_PHYSIC	-.143	.000
AVG_SCORE_	.077	.029
POP_FLOOD_	.267	.000
POP_INTERN	.771	.183
HH_PAR_IN_	-.421	-.035
(constant)		-16.665

Table 10 Structure Matrix

	Function
	1
R_AGR_01	-.449
R_FOR_01	.418
R_UNU_01	.326
AGRI_GW	.321
SH_EROS	.305
SEA_TOUR	.264
SK_H_ARE	.240
POP_FLOOD0	-.227
FISHI01	.225
POP_PHYSIC	-.221
POP_FLOOD_	-.200
POP_INTERN	.179
HH_PAR_IN_	-.176
AVG_SCORE_	.147
CONSTR01	.100
ELECT01	.092

Table 7 Eigenvalues

Func tion	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.747(a)	100.0	100.0	.654

Table 8 Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.572	36.812	16	.002

Table 6a
Tests of Equality of Group Means

	F	Sig.
R_UNU_01	5.875	.018
SK_H_ARE	3.189	.078
FISHI01	2.808	.098
POP_FLOOD0	2.845	.096
AGRI_GW	5.685	.020
R_FOR_01	9.632	.003
SH_EROS	5.150	.026

Table 9a
Canonical discriminant function Coefficients

	standardized	**unstandardized**
	Function 1a	Function 1a
R_FOR_01	.848	3.830
R_UNU_01	.626	24.615
POP_FLOOD0	-.425	-.084
AGRI_GW	.275	.071
FISHI01	.251	6.030
SK_H_ARE	-.115	.000
SH_EROS	.026	.063
(constant)		-1.809

Table 10a Structure Matrix

	Function
	1a
R_FOR_01	.536
R_UNU_01	.418
AGRI_GW	.411
SH_EROS	.392
SK_H_ARE	.308
POP_FLOOD0	.291
FISHI01	.289

Table 7a Eigenvalues

Func tion	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	.454 (a)	100.0	100.0	.559

Table 8a Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.688	26.375	7	.000

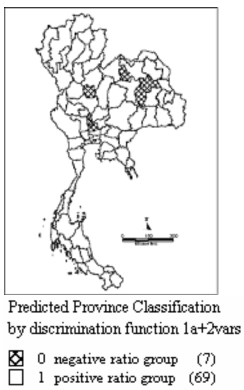


Fig. 12 Predicted classification by adding R AGR 01 and SH EROS to function 1a

Table 11 Functions at Group Centroids

CHG_URBG	Function 1
0	-1.794
1	.405

Table 11a Functions at Group Centroids

CHG_URBG	Function 1a
0	-1.399
1	.316

Relative importance of variables. Variable R_FOR_01 has the largest coefficients (4.244) and seems to contribute more to the overall discriminant function, since coefficients are the multipliers of variables. It can be noticed that R_AGR_01 is negatively correlated with the discriminant function (table 10) but has positive standardized coefficient the same as R_FOR_01 (table 9). This occurs because R_AGR_01 and R_FOR_01 are high negatively correlated (-.916) at .01 significance level (2-tailed). Thus the contributions of AGR_01 and R_FOR_01 are shared and the individual coefficient is not meaningful. Based on the coefficients in Table 9, discriminant score for each case can be calculated by multiplying the unstandardized coefficients by the values of the variables, summing these products, and adding the constant. Then discriminant scores can be plotted to examine their distributions, and see how much the two groups overlap. Fig.10 shows score histograms for each group separately. The group centroid, describing the average score for a group, for group 0 is -1.794 where as the average value for group 1 is .405. This means that the province obtaining minus score tends to belong to group 0 while that obtaining positive score tends to belong to group 1. When comparing the actual group membership and predicted membership by the discriminant function, the overall percentage of the cases classified correctly is 92.1% (70 out of 76) as shown in fig.9-2a.

Interpretation of analysis 1a

In this analysis, only variables that have different group means and no association with each other, are chosen to be the discriminating variables as shown in table 2 and table 6a. Canonical correlation (eta) reduces to be .559 as shown in table 7a and eta^2 is .3125. This means that the new linear discriminant function can represent 31.25% of the total variances in discriminant scores which is less than the previous analysis. The variable R_FOR_01 tends to be the important discriminating variable in this function since its coefficient is the highest (Table 9a). The second and the third are R_UNU_01 and POP_FLOOD01. The correctness in classifying the case is 76.3% (58 out of 76) The disaster risk variables included in this linear function are SK_H_ARE (sinkhole area) and SH_EROS (shore erosion) have low values of coefficients, while POP_FLOOD01 shows much higher coefficient values. It is noted that the standardized coefficients of SK_H_ARE and POP_FLOOD01 have negative coefficients. This means that these two variables measured in interval level, tend to reduce the discriminant scores while SH_EROS, a binary variable, having positive sign tends to add the value of discriminant scores. If we would like to predict which province will have negative ratio of urban land use changes from 2007 to 2011 to urban land use in 2011, we can replace the variable value collected in 2001 by that in 2007 as follows : Province scores = -1.809 +3.830 (R_FOR_07)+24.615 (R_UNU_07)–.084 (POP_FLOOD)+.071(AGRI_GW from 2007 to 2011)+6.030(FISHI07)+.063(SH_EROS). If the province has negative scores, this tend to be classified into group 0 while positive scores tend to belong to group 1.

If the variables R_AGR_01 and SEA_TOUR which have high associations with R_FOR_01 and SH_EROS respectively, are added to the linear function, this will result in the same values of canonical correlation and the group centroids. However, it increases the grouped cases correctly classified from 76.3% to 90.8% (69 out of 76) as shown in fig 12.

CONCLUSION

Three key indicators included in this paper for monitoring urban growth are spatial urban forms, urbanization level, land use changes and disaster risk areas. Urban forms in Thailand can be grouped into six patterns as follows: 1) High commercial-transportation urban based (1 province), 2) high industry-centrality urban based (1 province), 3) High institution-village rural based (1 province), 4) Institution-abandon rural based (26 provinces), 5) Commercial-industrial transportation-village rural based (9 provinces) and 6) Commercial-centrality urban based (38 provinces). Factors that can explain the difference between two groups of provinces, the group that has negative ratio of urban land use changes and another that has positive ratio of urban land use changes, are 1) Ratio of forest land to provincial land, 2) Ratio of unused or mixed land to provincial land, 3) Sinkhole risk areas, 4) Shore erosion, 5) GPP for fishing, 6) Agricultural growth and 7) Population affected by flood (%). These variables can form a linear discriminant function and can explain 31.25 % of total variation of the discriminant scores. The correctness in classifying the cases by this function is 76.3 %.

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