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Land use/cover Change Detection Caused by Development using Satellite RS Data
The case study of Danau river watershed, West JAVA, Indonesia

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Abstract

In Java Island, the population density became one of the highest place (over 920/sqkm) in the world, and is still increasing. Indonesian Government has started an immigration project to avoid overflow of population, but rural environment has still been attacked by development of agriculture with increasing of population. It is necessary to conserve rural environment from such social causes.

CiDanau watershed was selected as study area and field survey to gather information was done in August 1999 and September 2000. We set three objectives for this study. They are 1) preparation of GIS (Geographic Information System) dataset, 2) selection of optimum method of land use change detection from 1972 to 1998 using 8 scenes of satellite remote sensing data (Landsat MSS/TM), and 3) detection of land use change. Digital elevation model (DEM) and watershed boundary were newly created using topographic map. By supervised classification (maximum likelihood classification method), land use maps were made from eight scenes of satellite images. The results of change detection analyses using NDVI differencing method showed decreasing of forest resources in the mountain, expansion of agricultural fields including annual and seasonal change in CiDanau watershed. It is expected that these technique, for example creation of land use map and detection of land use change using RS data with GIS, will provide valuable data to support a project of conservation in rural area.

1. Introduction

In Indonesia, the degradation of environment caused by agricultural and industrial development became apparent from 1960s. Indonesian government started the project aimed to develop agriculture in rural area since 1969. One of the reasons for starting this project was to support large population of the country (over 920 person/km^2 in Java Island). Recently there are a lot of serious problems originated from human activities, such as deforestation, water pollution and shortage, soil pollution and consumption of natural resources. To deal with such environmental changes and to develop optimum land allocation system to improve bio-production basis so as to enable sustainable production, it is necessary to develop and implement various kinds of techniques, such as proper data management and monitoring method.

To identify land use/land cover (LULC) change, a time-series of land use information is indispensable, but aerial photographs were not available for the study area. So we tried to make land use map and detect land use change using satellite remote sensing data with GIS. These techniques will support to conserve rural environment and to provide useful dataset to plan agricultural and forest management in the area.

2.Objectives

This study aimed to 1) make time series of land use maps from 1972 to 1998 using eight scenes of Landsat MSS/TM data and provide fundamental GIS dataset, 2) select an optimum method of land use change detection method, and 3) detect land use changed area for 7 periods, using CiDanau watershed, west Java as a case study.

3.Study area

In West Java, CiDanau (Danau River) watershed covers about 22,000ha. Its average annual temperature is about 27°C, and the climate has relatively clear rainy season and dry season. This area is located between latitude S6°07'40" - S6°12'22" and longitude E105°51'42" - E106°03'07" (Fig.1).

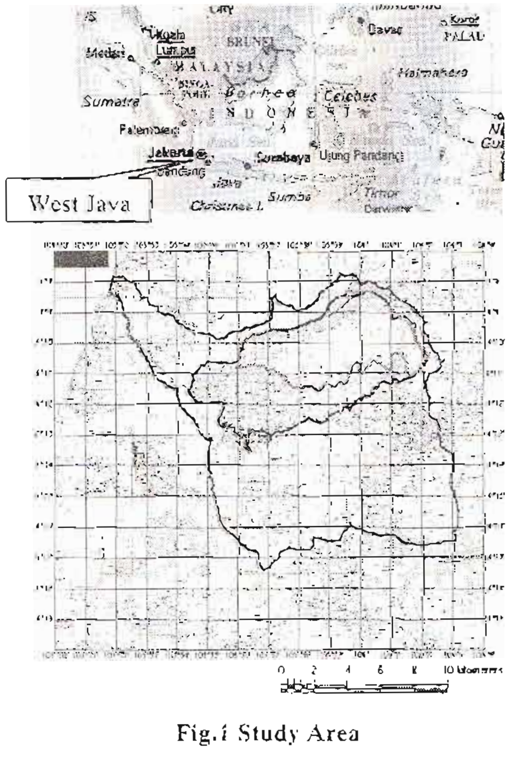

Fig.1 Study Area

CiDanau (22.2km) flows through the central flat area (about 7,000ha) surrounded by several mountains, which shows topographic feature of caldera. In 1921, national protected area (about 3,500ha) was established in order to conserve precious marshland vegetation and a swamp ecosystem. But instead of this regulation, large area was cultivated and changed into paddy, farmland or plantation. Rural environment of this area is receiving severe damage from agriculture.

4.Data and Software

1) Topographic map and GIS dataset

Topographic maps (1:25,000, 8-sheets) were digitized and contour vector data were created using GIS. DEM (Digital Elevation Model) data were generated from this contour data, via TIN (Triangulated irregular network) creation. CiDanau watershed boundary was also defined from this data. The area of CiDanau watershed is referred to in various figures, from 25,097ha(KTI) to 22,620ha. But with our analysis we can define the area as 22,196ha, based on topographic map.

Danau River and village boundaries were also digitized and added into vector layers using topographic maps. Although there has been several definition and modification of "Cagar Alam (strictly protected area)" boundary in the center of the study site, only one reliable map was available from Wetland International of Indonesia. This map was digitized and used as Cagar Alam layer. The area of Cagar Alam was 3,686ha.

2) Satellite remotely sensed data

From 1972 to 1998, 8 scenes of Satellite data (Landsat MSS/TM) were georeferenced to Lat/Lon projection, using more than 30 GCPs (Ground control points) selected with topographic map. Maximum error of geometric correction was less than one pixel size. Details of Satellite data are shown in Table.1.

Table.1 Satellite data

Sensor	resolution	Path/Row	date
LandsatMSS	80m	131/64	1972/10/1
		132/64	1977/5/30
		123/64	1983/6/19
LandsatTM	30m	123/64	1991/10/23
		123/64	1994/8/28
		123/64	1995/5/27
		123/64	1997/7/19
		123/64	1998/5/19

All of cloud and shadow area was removed using mask data. Noise reduction and destriping were applied to 1972 (MSS) and 1997/98(TM) data. Finally, all of data were resampled into common cell size, 80m*80m for Landsat MSS and 30m*30m for Landsat TM.

3) Ground-truth data

Field observations were done in August 1999 and in September 2000 to identify land use/cover. More than 450 points of landmark data (latitude/longitude) were recorded using GPS receiver (Magellan GPS 315^{TM}), and digital photographs were taken at the same time. We also conducted simple questionnaire survey to several farmers in the following villages: Batukuwung, Citasuk, Gumeureup, Babakan and Bugel. The questions were about trend of population growth, plan of cultivation, water usage, rural life and natural resources utilization and so on. These ground truth data were very important to identify detail land use as references for RS data analysis.

4) Population and Precipitation data

Population data of two villages, Padarincang and Cinangka (Fig.2) inside CiDanau watershed, and precipitation data near the watershed, Mandalawangi, Ciomas, Padarincang, and Cinangka, were also used as ancillary data. From this precipitation data, we can identify rainy season is from November to April, and drying season is from May to September (Fig.3).

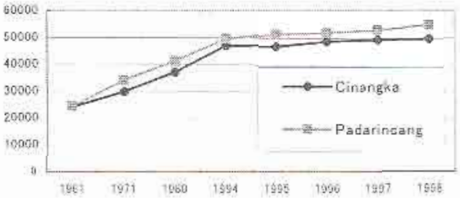

Fig.2 Population data

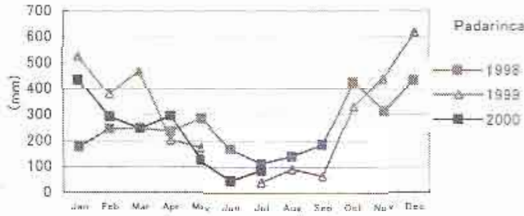

Fig.3 Precipitation data

GIS/RS software used for all of the analyses in this study was TNTmips (Ver. 5.9 - 6.3) manufactured by MicroImages, USA.

5. Creation of Land use maps using Satellite images

5.1 Method

Maximum likelihood (MLH) method is one of the most popular methods of supervised classification to make land use/cover map using Satellite RS data. Analyst should decide classification categories from reference data such as topographic map, DEM data and ground-truth data. In this study, a classification result created by Fuzzy C Means method (FCM, a kind of unsupervised classification methods) was also used during deciding and selecting training areas. The primary FCM classification results with 30 classes were combined into 7-classes: forest-1 (swamp forest), forest-2 (lighten forest), Forest-3 (densely forest), abandoned (similar to grass), grass (including crop field), water surface and wetland (most of them are paddy filed), bare land (including paddy field and cultivated field and villages).

Two sets of training area data were selected using reference data described above. Among these two sets of training area, one was used for MLH classification: the other was used for evaluation of classification. After classification of MLH by 7-classes, by 3*3 filtering was conducted to all of the results images to avoid some small "salt and pepper" pixels.

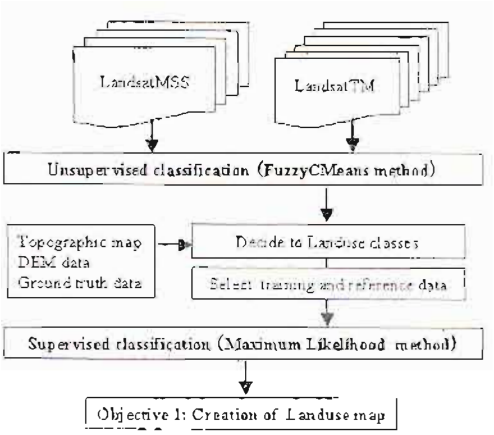

Fig. 4 Flow of making landuse map

5.2 Results and Discussion

Overall accuracy of classification were above 90% except for 1983 data (88%). Better accuracy was obtained when 3*3 filtering was conducted than original classification results. Table 2 shows number of pixels of each land use classes from 1972 to 1998. Ratio of forest classes (including swamp forest) is not so changing during this period (Fig.5). After 1994, forest area is slightly decreasing, but kept about 50% of study area for 26 years constantly. Bare land and water surface area are often changing into each other. It is mainly due to seasonal change of paddy field. Paddy field can be divided into 3 types of growing stage: water surface stage, vegetation stage and bare land stage. These three stages correspond to just after planting, growing and after harvesting. It is difficult to detect pure pixels of paddy field using by a few satellite images, due to mixture of these stages in one pixel.

Fig.6, 7 shows land use map of 1977 using Landsat MSS and 1997 using Landsat TM, showing 20 years interval. To compare land use each other, we tried to set same land use classes and same pixel size in spite of different sensors of Landsat MSS and TM. It shows that the area of western swamp forest were changed from bare land or water surface classes (Fig.6) to grass class (Fig.7). This grass area's border was almost identical to the boundary of protected area. Most of bare land and water surface area can be thought as paddy field, but it was impossible to separate villages, roads and abandoned fields in this study only from satellite RS data. If there were detail information of this area (for example, aerial photographs), land use conditions will more clearly be identified.

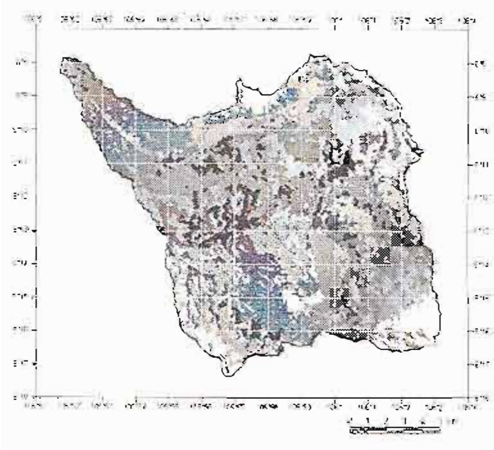

Fig 6 Land use map of 1977 using Landsat MSS

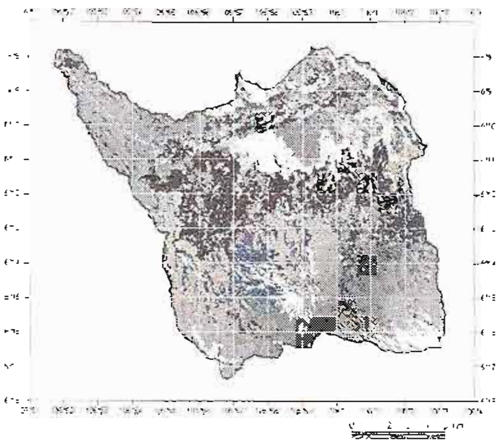

Fig 7 Land use map of 1997 using Landsat TM

6. Land use change detection analyses

6.1 Method

6.1.1 Optimum method of change detection

Four types of landuse change detection method were tested, two Image differencing methods using 1) NDVI (Normalized Difference Vegetation Index) and 2) PDM (Pattern Decomposition Method), 3) CVA (Change Vector Analysis) and 4) Post classification method by maximum likelihood method. These methods were judged from three viewpoints, "accuracy" "utility" and "simplicity" for analyses. First, change detection was done to decide an optimum method using 1994 and 1995 (5th period). These two images are acquired in a very short interval of 9 months that the any significant land use change have taken place. Also these two scenes have good atmospheric condition with small clouds. After selection an optimum method, we tried to detect land use change of 7 periods for 26 years in CiDanau watershed.

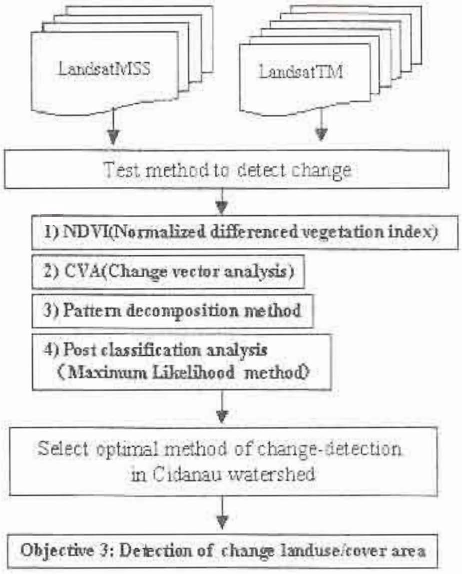

Fig.8 Flow of change detection analysis

1) NDVI (Normalized Difference Vegetation Index)

NDVI is the most commonly used index of vegetation amount, which is calculated by the following formula, using near infrared (NIR) and visible (VIS) portions of satellite data. NDVI has good correlation with biomass. Change detection is done by subtraction of two different date's NDVI data.

$$NDVI = \frac{NIR-VIS}{NIR+VIS}$$

2) Change Vector Analysis (CVA)

Image differencing uses only single value (spectral reflection or any kind of index image), while CVA can be defined as expansion of image differencing to multi-band or multi-dimensional space. Image differencing in multi-dimensional space produces difference vector from first to second data. This vector, describing the direction and magnitude of change, is referred to as change vector. Change detection is done by thresholding the magnitude of change vector, and the type of change is detected by the direction of change vector.

Originally, change detection analysis used principal components to calculate vector. Because first principal component (PC1) image usually explained as "Brightness" and second principal component (PC2) as "Greenness" are obtained when satellite RS image including vegetation used, so that change of vegetation is easily detected. In this study, principal component analysis (PCA) was also applied to satellite image and PC1 and PC2 image were used as Brightness and Greenness. The change vector was calculated in the B-G space to indicate the land cover changes.

"Magnitude" and "angle" of change vector between first and second date were calculated for each period. In the B-G space, the IVth quadrant with positive brightness value and negative greenness value stand for vegetation decrease. CVA is expected to catch smaller change than NDVI because NDVI uses only two bands but CVA uses all bands integrated by PCA.

2) Pattern Decomposition method

Pattern decomposition method was made to separate basic spectral characters of soil, water and vegetation using multi-dimensional satellite image using spectral un-mixing method. Vegetation change is well analyzed by this method in Japan. We decided basic spectral pattern (water, vegetation and soil) by sampling Landsat TM data. In this study, we used only decomposition image of vegetation component to compare with NDVI and CVA.

6.1.2 Threshold

All of outputs should be divided into "increase" "decrease "and "unchanged" according to each pixel value. In this study, threshold was used to divide values. Although decision of threshold value is the key of threshold, there is no significant method. Standard deviation from mean is usually selected as threshold value decision. In this study, standard deviation approach was employed. We tested from 0.25SD to 2SD with every 0.25SD interval (Table 3), and found 1.5SD to be most suitable.

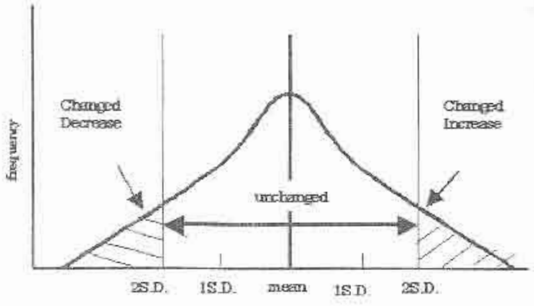

Fig.9 Histogram of image and threshold using Standard Deviation

6.1.3 Comparison of change detection analyses

Table 4 show results of change detection between 1994 and 1995 using 1.50SD as a threshold. Layers of vegetation change area are overlaid with land use map of each date. We defined inaccuracy of change detection by "change to forest classes from other classes", because this change is impossible to occur only in one year. From comparison of change matrix (Table 4) of 4 methods, it was judged that result of NDVI had relatively better accuracy. Also this method is easier to do than other methods. Finally, NDVI differencing method was selected for change detection of all of periods using 1.50SD in this study (Table 5).

6.2 Result and Discussions

There were a number of changes in bare land and water surface classes inside the lowland area, which seemed like seasonal change of paddy field. In the protected area, the area of swamp forest did not changed so much, but distribution of grass and abandoned area changed much from 1970's to 1990's. From the land use map of 1970's, we can see illegal cultivation of paddy field already started before 1970's inside of western of protected area. But after 1991, these areas were changed to grass and abandoned area. This fact supposes to have strong relation to the policy of the Indonesian Government to start immigration projects in this protected area from 1988. Despite of the policy, population of CiDanau watershed is still increasing until now.

From table 6, it was identified that in 1st, 4th and 7th period "decreased" area was larger than "increased" area, and ratio of changed area for 7 periods were from 23.57% (1972 - 1977) to 8.67% (1994 - 1995) using 1.50SD as a threshold. Land use/cover change usually includes two kinds of change, seasonal change and annual change. It was so difficult to separate them in these Landsat images. But it was able to identity land use distribution in Capture 5, and the trend of change was also identified to a certain extent. For example, change detection image in period 5 (1994 – 1995) (Fig.10,11) shows that most of "decrease" change were concentrated in western lower area and "increase" area were widely spread to lower land and lower mountains. It was found that the most of major changes occurred in paddy field (bare – water surface) were in lower land. Second case was deforestation in slope of mountains for 26 years.

7.Conclusion

From land use classification map created by this study, it was found that large paddy fields already existed in western and southern part of the protected area in 1972. But swamp forest in the protected area did not change so much in term of area, which is about 1,500ha. Most of changes in the protected area were from paddy to abandoned or grass classes. In the lowland area, bare land and water surface classes, which thought to be paddy fields, occupied 60% to 87% of the area. In the mountain area, we could find paddy fields and small clear felling patches spreading up to 500m in elevation. In 1970's, large agricultural field existed in western part of the protected area, but changed to abandoned field in 1990's, which suggests strong relation to immigration project by the Government started from 1988.

In this study, it was not so difficult to detect clearing area in forests, but it was quite hard to identify distribution and area of paddy field accurately using only Landsat satellite data. It was mainly due to mixture of different growing stages of rice. Cropping timing and frequency strongly depend on personal, social or natural conditions. Accurate detection of paddy field distribution might be the main subject in this study field. Change area of forest and agricultural field fluctuated and did not show steady trend, so that it was not able to find any apparent trend of land use change in CiDanau watershed. From this study, it was identified that there were no significant land use changes caused by logging or development of agricultural field during the study period from 1972 to 1998. This is because most usable area for agricultural field with flat terrain was already cultivated before 1970s. But the population of CiDanau watershed has been still increasing, and it is anticipated that there will be a danger of agricultural area expansion into remained forest area.

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Table 2 Result of classification (common size =30m*30m)

	MSS72	MSS77	MSS83	TM91	TM94	TM95	TM97	TM98
Forest1	31901	9584	11572	15027	11282	25604	17923	16906
Forest2	28198	44339	81332	89162	111076	67152	84936	66795
Forest3	44877	61663	23492	19399	21900	41529	32924	41537
Bare	35575	40580	66932	47702	38630	56627	32172	42307
Abandoned	25648	50950	32861	22253	7606	13954	16242	12428
Water	13529	16733	5913	19416	27864	18895	35821	19130
Grass	20553	4723	8645	14422	7177	7392	8659	7176
Total	200281	228572	230747	227381	225535	231153	228677	206279

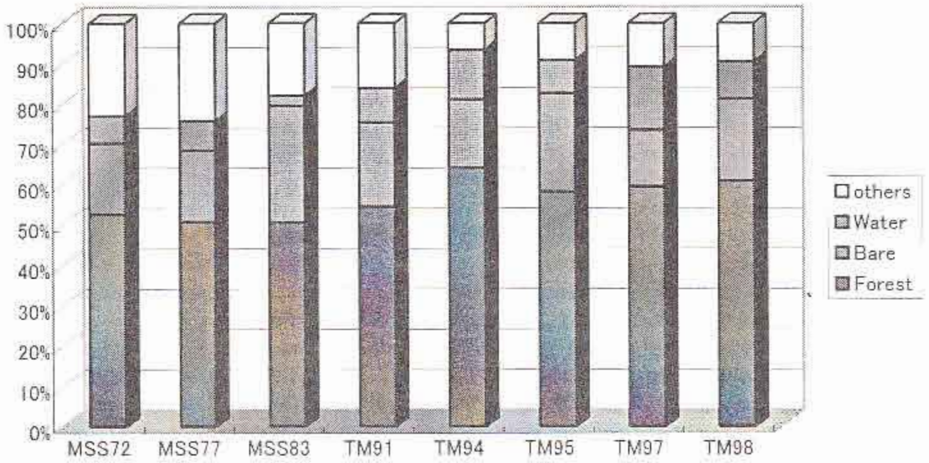


Fig.5 Ratio of land use classes between 1972 and 1998
(Others class was included grass and abandoned class)

Table. 3 Select optimal threshold and method of change detection analysis

CVA_05

Numitems: 256
minvalue: 0
maxvalue: 60
datalast: 255
mean: 7.691766
stddev: 6.409388
Total Cells 222422

	Threshold	Change Cells	Ratio of Area
0.25*SD	9.29	58612	26
0.50*SD	10.90	49950	22
0.75*SD	12.50	37757	17
1.00*SD	14.10	28927	13
1.25*SD	15.70	25501	11
1.50*SD	17.31	19841	9
1.75*SD	18.91	17328	8
2.00*SD	20.51	13146	6

NDVI_05

NumItems: 256
minvalue: -75
maxvalue: 70
datalast: 127
mean: 3.319937
stddev: 11.072387
Total Cells 222494

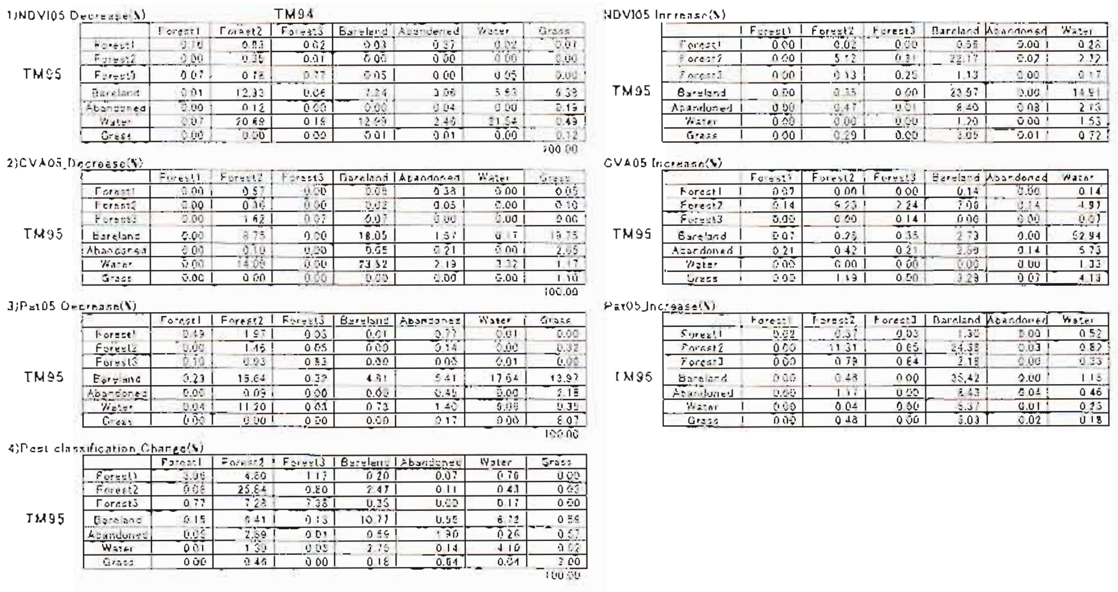
	Upper Range	Lower Range	Change Cells	Ratio of Area
0.25*SD	6.09	0.55	157985	71
0.50*SD	8.86	-2.22	112303	51
0.75*SD	11.62	-4.98	79245	36
1.00*SD	14.39	-7.75	52192	23
1.25*SD	17.16	-10.52	35086	16
1.50*SD	19.93	-13.29	26234	12
1.75*SD	22.70	-16.06	18621	8
2.00*SD	25.46	-18.82	13922	6

Pattern Decomposition_05_Chl (Vegetation)

minvalue: -2.535994
maxvalue: 2.308903
datainit: -2.535994
datalast: 2.308903
mean: 0.395642
stddev: 0.423748
Total Cells 222494

	Upper Range	Lower Range	Change Cells	Ratio of Area
0.25*SD	0.49455	0.28971	171657	77
0.50*SD	0.60752	0.18327	125273	56
0.75*SD	0.71345	0.07793	77904	35
1.00*SD	0.81939	-0.02811	60469	27
1.25*SD	0.92533	-0.13404	41103	18
1.50*SD	1.03126	-0.23998	27386	12
1.75*SD	1.13720	-0.34592	17819	8
2.00*SD	1.24314	-0.45185	11654	5

Table 4 NDVI threshold value for all period 1972-1998



1)NDVI05 Decrease(%) TM94

		Forest1	Forest2	Forest3	Bareland	Abandoned	Water	Grass
TM95	Forest1	0.10	0.83	0.02	0.03	0.37	0.02	0.01
	Forest2	0.00	0.35	0.01	0.00	0.00	0.00	0.00
	Forest3	0.07	0.12	0.77	0.05	0.00	0.05	0.00
	Bareland	0.01	12.33	0.06	7.24	3.06	5.53	4.39
	Abandoned	0.00	0.12	0.00	0.00	0.04	0.00	0.19
	Water	0.07	20.69	0.19	12.99	2.46	21.54	0.49
	Grass	0.00	0.00	0.00	0.01	0.01	0.00	0.12

100.00

NDVI05 Increase(%)

		Forest1	Forest2	Forest3	Bareland	Abandoned	Water
TM95	Forest1	0.00	0.02	0.00	0.55	0.00	0.26
	Forest2	0.00	5.12	0.31	22.17	0.07	2.32
	Forest3	0.00	0.13	0.25	1.13	0.00	0.17
	Bareland	0.00	0.35	0.00	23.57	0.06	14.91
	Abandoned	0.00	0.47	0.01	8.40	0.03	2.13
	Water	0.00	0.00	0.00	1.20	0.00	1.53
	Grass	0.00	0.29	0.00	3.05	0.01	0.72

2)CVA05_Decrease(%)

		Forest1	Forest2	Forest3	Bareland	Abandoned	Water	Grass
TM95	Forest1	0.00	0.57	0.00	0.05	0.38	0.00	0.05
	Forest2	0.00	0.06	0.00	0.02	0.05	0.00	0.10
	Forest3	0.00	1.62	0.07	0.07	0.00	0.00	0.00
	Bareland	0.00	8.75	0.00	18.05	1.57	0.17	15.75
	Abandoned	0.00	0.10	0.00	0.65	0.21	0.00	2.65
	Water	0.00	14.09	0.00	23.32	2.19	3.32	1.17
	Grass	0.00	0.00	0.00	0.00	0.00	0.00	1.10

100.00

CVA05 Increase(%)

		Forest1	Forest2	Forest3	Bareland	Abandoned	Water
TM95	Forest1	0.07	0.00	0.00	0.14	0.00	0.14
	Forest2	0.14	9.23	2.24	7.06	0.14	4.97
	Forest3	0.00	0.00	0.14	0.06	0.00	0.07
	Bareland	0.07	0.25	0.35	2.73	0.00	52.94
	Abandoned	0.21	0.42	0.21	2.59	0.14	5.73
	Water	0.00	0.00	0.00	0.00	0.00	1.33
	Grass	0.00	1.49	0.50	3.29	0.07	4.13

3)Pat05 Decrease(%)

		Forest1	Forest2	Forest3	Bareland	Abandoned	Water	Grass
TM95	Forest1	0.49	1.97	0.03	0.01	0.77	0.01	0.00
	Forest2	0.00	1.45	0.05	0.00	0.14	0.00	0.32
	Forest3	0.10	0.93	0.83	0.00	0.05	0.01	0.02
	Bareland	0.23	15.64	0.32	4.81	5.41	17.64	13.97
	Abandoned	0.00	0.09	0.00	0.60	0.45	0.00	2.15
	Water	0.04	11.20	0.03	0.73	1.40	0.08	0.35
	Grass	0.00	0.00	0.00	0.00	0.17	0.00	8.07

100.00

Pat05_Increase(%)

		Forest1	Forest2	Forest3	Bareland	Abandoned	Water
TM95	Forest1	0.02	0.37	0.03	1.30	0.00	0.52
	Forest2	0.00	11.31	0.65	24.38	0.03	0.82
	Forest3	0.00	0.79	0.64	2.18	0.00	0.33
	Bareland	0.00	0.48	0.00	35.42	0.00	1.15
	Abandoned	0.00	1.17	0.00	8.43	0.04	0.46
	Water	0.00	0.04	0.00	5.37	0.01	0.23
	Grass	0.00	0.48	0.00	3.03	0.02	0.18

4)Post classification Change(%)

		Forest1	Forest2	Forest3	Bareland	Abandoned	Water	Grass
TM95	Forest1	3.06	4.80	1.17	0.20	0.07	0.76	0.00
	Forest2	0.06	25.64	0.80	2.47	0.11	0.43	0.63
	Forest3	0.77	7.28	7.38	0.35	0.00	0.17	0.00
	Bareland	0.15	6.41	0.13	10.77	0.55	6.72	0.59
	Abandoned	0.05	2.59	0.01	0.59	1.90	0.26	0.57
	Water	0.01	1.30	0.05	2.75	0.14	4.10	0.02
	Grass	0.00	0.46	0.00	0.18	0.64	0.04	2.00

100.00

Table 5 Threshold value for NDVI differencing image

NDVI threshold	Period01	Period02	Period03	Period04	Period05	Period06	Period07
mean:	17.40677	-1.86023	-23.3939	10 13383	3.27988	5.427003	19.14555
stddev:	13.89676	12.34033	10.9473	9.18199	11.54842	10.97739	14 73832
Above 1.50*SD	38.2519	16.6503	-6 9730	23.9068	20.6025	21.8931	41 2530
Below 1.50*SD	-3 4383	-20 3707	-39.8149	-3.63915	-14 0427	-11.0391	-2.96193

Table 6 Result of changing area

NDVI changedetection	Period01	Period02	Period03	Period04	Period05	Period06	Period07
Increasing (ha)	164 74	284 43	115.15	72 63	81 74	85 41	61.31
Decreansing (ha)	231 37	93 31	64.93	113 83	91 80	87.73	117.75
Unchange	1217 51	1802 98	1829.35	1697 59	1818.85	1842.57	1555.37
Total area	1680.24	1989 59	1959.20	1925 25	2002.45	2018.03	1790.87
Ratio of changing	23 57	18 99	9.19	9 69	8.67	8.58	10.00

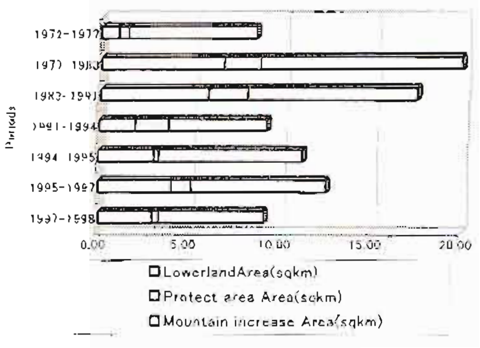


Fig. 10 Increase area of NDVI value

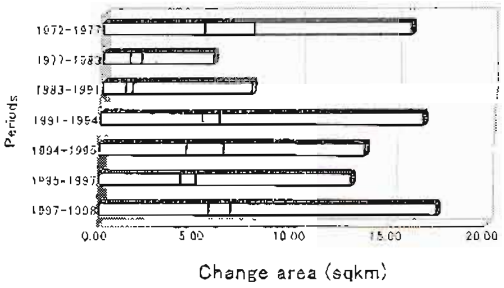


Fig. 11 Decrease area of NDVI value