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Multi-temporal Analysis of Land Cover Changes in Nagasaki City Associated with Natural Disasters Using Satellite Remote Sensing

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ABSTRACT

Natural disasters are inevitable and it is almost impossible to fully prevent the damage that they cause. However, it is possible to reduce the potential risk by developing disaster early warning strategies and to help in rehabilitation and post disaster reduction. Remote sensing technology has proven its usefulness, not only for monitoring disastrous events, but also to provide accurate and timely information well before the occurrence of a disaster. The study of the temporal changes of spatial patterns is important to understand the underlying factors and the functional effects.

This paper addresses a multi-temporal analysis of land cover changes from 1986 to 2000 in Nagasaki City. Nagasaki City was studied using Thematic Mapper (TM) data acquired by Landsat-5. Particular attention is given to the selection of an appropriate method for land cover classification. A common and reputable unsupervised classification method, the Iterative Self-Organizing Data Analysis Technique (ISODATA) is used. The overall results of the study area show that the amounts of forestland and agricultural land are decreasing and in contrast the amounts of urban land and barren land are increasing. This trend is especially clear in detailed analysis of typically developed areas such as *Tagonoura*, *Koebaru* and *Kaminoshima*.

1. INTRODUCTION

Land cover change plays a vital role in regional, social and economic development and global environmental changes. It contributes significantly to Earth—atmosphere interactions. Biodiversity loss is a major factor in sustainable development and human response to global change, and is important in integrated modeling and assessment of environmental issues in general. Scientists, researchers and planners have paid much attention to the issues of land cover change over the past decade. A number of studies have been carried out using various methodologies and algorithms to derive land cover and change information from different sets of remotely sensed data.

Natural disasters are inevitable, and the Japanese Islands are prone to all type of natural disaster such as flood, drought, typhoon, earthquakes and forest fires. Disasters can be classified in several ways. Possible sub-divisions are: 1) Natural Disasters, 2) Human made disasters, and 3) Human induced disasters. Another sub-division is related to the main controlling factors leading to a disaster. These may be meteorological, geomorphological/geological, ecological, technological, global environmental and extra terrestrial. Some disasters strike within a short period with devastating outcomes; others have a slow onset period with equally or even more serious repercussions (The Japan Landslides Society, 1997).

Recent disasters include torrential downpours around Kumamoto and Nagasaki in 1972; disasters from Typhoon No. 17 in 1976; torrential downpours in Nagasaki in 1982; and disasters from Typhoon No. 19 in 1991 that hit Nagasaki Pref., and many others. Human causalities from these disasters amount to 543 deaths in the 1972 event, 298 deaths in the 1976 event, 493 deaths in the 1982 event and 66 deaths along with 777 persons wounded in 1991 event (Iseda, T., Ochiai, H. and Tanabashi, Y., 1982). Among them, the tragedy of 1992 was devastating. The disaster in Nagasaki in July 1982 had catastrophic effects. Hundreds of people died and many became homeless due to the disaster, which was followed by landslides. Thousands of billions yen of property were destroyed thus badly effecting the economy of the prefecture (**Table 1**).

The landslides occurred at various parts of the city during and after the disaster, mainly focused on the newly constructed areas. The intensity of landslides can be investigated at Nishi Yama Dai Township (Iseda *et al.*, 1982) (**Fig. 1**). The area is surrounded by mountains and after the disastrous event the occurrence of landslides around the New Township caused many deaths and extensive damage. In **Fig. 1**, points A and B indicate the locations where the collapses directly hit the front areas of public apartments. Small black circles show the locations where landslides occurred.

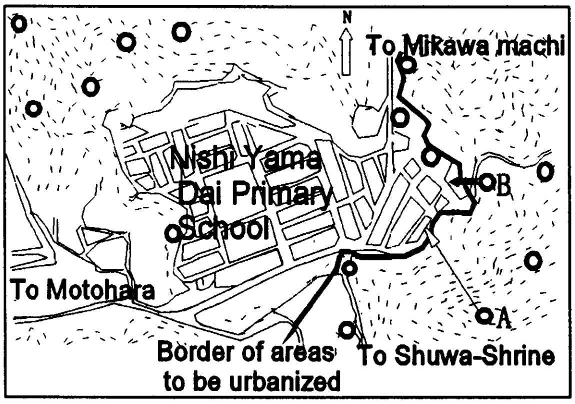
Land cover changes in Nagasaki City have been significant over the past few decades. The development of new townships in recent years i.e. Sakura no Sato, Yume ga Oka and Minato Zaka

KEY WORDS: Remote sensing, Land cover, Landslide, Natural disaster, Nagasaki

Table 1. Catastrophic Losses of the Disaster in Nagasaki in July 1982 (Iseda et al., 1982)

				Unit	Number	Amount of money (¥1000)
Human Beings	Dead		1	Persons	294	
	Lost		2	Persons	5	
	Heavily injured		3	Persons	16	
	Slightly injured		4	Persons	789	
	Total		5	Persons	1,104	
Houses	Residential	Fully damaged	6	House	584	
				Family	605	
				Person	1,843	6,523,371
		Half damaged	7	House	954	
				Family	1,031	
				Persons	3,234	4,764,825
		Slightly damaged	8	House	1,111	
				Family	1,157	
				Persons	4,146	995,678
		Houses flooded above floor level	9	House	17,909	
				Family	19,495	
				Persons	58,957	22,943,642
		Houses flooded below floor level	10	House	19,197	
				Family	20,360	
				Persons	66,297	2,604,551
	Commercia	Public	11		95	1,220,481
		Others	12		3,021	4,061,127
	Total		13			43,113,675
Agricultural land	Paddy field	Buried in runoff	14	ha	860.09	7,909,323
		Submerged in water	15	ha	1,333.13	159,802
	Dry Field	Buried in runoff	16	ha	431.85	3,779,864
		Submerged in water	17	ha	37.03	33,512
	Facility for agriculture		18	Location	18,687	55,585,791
	Agricultural product		19	ha	4,789.16	3,153,607
	Animal Husbandry		20	Animal	72,632	82,646
	Faccility for forestry		21	Animal	835	13,171,950

				Unit	Number	Amount of money (¥1000)
	Forestry products		22		-	383,331
	Total		23			84,259,826
Fishery	Fishing boats		24	Ship	48	18,500
	General boats		25	Ship	46	48,405
	Fishing ports		26	Port	41	913,500
	Fishing products & others		27		-	1,619,054
	Total		28			2,599,459
Civil structure	Roads		29	Location	4,969	16,820,392
	Bridges		30	Location	116	2,806,986
	Rivers		31	Location	4,190	35,711,206
	Coasts		32	Location	9	76,488
	Debris slide production works		33	Location	7	16,884
	Ports		34	Location	25	216,000
	Total		35			55,647,956
Commercial	Communication facilities		36	Number	851	221,800
	Rail roads		37	Number	31	142,530
	Industrial damages		38	Number	9,440	95,969,915
	Total		39			96,334,245
Health	Hospitals		40	Number	228	3,445,532
	Water works		41	Location	577	1,965,701
	Cleaning facilities		42	Location	6	65,127
	Total		43			5,476,360
Education	School	Public	44	Number	85	1,367,013
		Private	45	Number	45	465,600
	Others		46	Number	2	316,528
	Total		47			2,149,141
Others	Landslide		48	Location	4,306	6,130,065
	Jisuberi		49	Location	151	2,014,130
	Others		50		-	17,588,504
	Total		51			25,732,699
Grand Total			52			315,313,361



O Landslides that caused no casualties
A, B Landslides that caused casualties and damages

Fig. 1 Landslides at Nishi Yama Dai area, Nagasaki in the 1982 Disaster (Iseda et al., 1982)

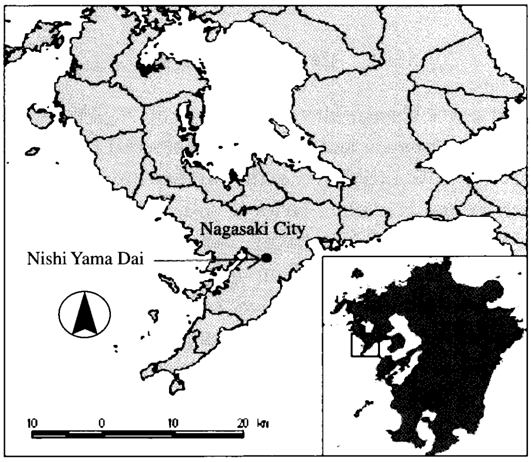


Fig. 2 Location of the study area (Nagasaki City, Japan)

etc. has accelerated the chance of landslides occurring in those areas. Landslides generally occur along gently to moderately sloping ground. Such areas tend to include residential and agricultural use. Because of these conditions, measures must be taken to protect the slopes from future landslides and failures.

Now we can access information gathering and organizing technologies such as remote sensing and geographic information systems (GIS), which have proven their usefulness in disaster management and monitoring. The use of remote sensing data, such as satellite imageries and aerial photos allow us to map the variability of terrain properties, such as vegetation, water and geology, both spatially and temporally. Remote sensing also allows monitoring the event during the time of occurrence while the forces are still in progress. After the cessation of the disaster event, remote sensing can help to prevent the occurrence of such disasters again in future.

2. STUDY AREA AND USED DATA

Nagasaki, with the exception of Okinawa, is the westernmost prefecture of Japan and has a land area and population of 241.2km^2

Table 2. Land Cover Classification Scheme

Class	Description
1	Water
2	Forestland
3	Rangeland
4	Urban land
5	Agricultural land
6	Barren land

and 426,500 (The World Gazetteer, 2002). Only 10% of the land area is "flatland" and 58% of the total area is comprised of forests. Nagasaki City was selected for analyzing land cover variation (**Fig. 2**). As other cities, this city includes land cover types of forest, grassland, urban and built-up land, agricultural land, wetland, etc. In the last few decades, due to natural disasters and urbanization, the land cover in this area has changed significantly.

Landsat TM digital data of May 12, 1986, May 12, 1992, and May 2, 2000 were employed in this study. Criteria to the selection of the multi-temporal Landsat data set involved assessment of cloud cover percentage, time of acquisition, and sensor type so that to optimize the land cover change detection scope. Aerial photographs of Nagasaki taken in December 1982 were used mainly to verify the accuracy of the land cover classification (Nagasaki Shinbun Sha, 1985).

3. METHODOLOGY

3.1 Data Acquisition and Image Preprocessing

Seven banded remotely sensed data were acquired by TM on Landsat 5, having 5,965 lines and 6,920 pixels. The data used in this study were extracted as a sub-scene from the original dataset. For the purpose of temporal land cover change detection, remotely sensed data were obtained in the same month, i.e. May of 1986, 1992 and 2000.

With constraints such as spatial, spectral, temporal and radiometric resolution, relatively simple remote sensing devices cannot record adequately the complexity of the Earth's land and water surfaces. Consequently, error creeps into the data acquisition process and can degrade the quality of the remotely sensed data collected. Therefore, it is necessary to preprocess the remotely sensed data before the actual analysis. Radiometric and geometric errors are the most common types of errors encountered in remotely sensed imagery. The commercial data provider has removed the radiometric and systematic errors of Landsat/TM data, while the unsystematic geometric distortion remains in the image.

The geometric errors were corrected using ground control points (GCP). Nearest-neighbor re-sampling method was used to correct the data geometrically. A correlation threshold is used to accept or discard points. The correlation range was within limits i.e. 1 pixel size. The x and y corrections were below 0.5 pixel.

3.2 Classification Analysis

In this study, the satellite images were classified using a common and popular unsupervised, Iterative Self-Organizing Data Analysis Technique (ISODATA) classification algorithm. The ISODATA clustering method uses spectral distance as in the sequential method, however it iteratively classifies the pixels, redefines the criteria for each class, and classifies again, so that the spectral distance patterns in the data gradually emerge. ISODATA is iterative in that it repeatedly performs an entire classification and recalculates statistics. Self-Organizing refers to the way in which it locates clusters with minimum user input. The ISODATA method uses minimum spectral distance to assign a cluster for each candidate pixel (Digital Image Processing, 1996).

To perform ISODATA clustering, the following parameters were specified:

- N – the maximum number of clusters to be considered. Since each cluster is the basis for a class, this number becomes the maximum number of classes to be formed (10 in this study).
- T – the convergence threshold, which is the maximum percentage of pixels whose class values are allowed to be unchanged between iterations (95% in this study).
- M – the maximum number of iterations to be performed (24 in this study).

Certain classification schemes that can readily incorporate land use and/or land cover data obtained by the interpretation of remotely sensed data have been developed (Introductory Digital Image Processing, 1996). The classification scheme shown in **Table 2** was applied in this study.

3.3 Accuracy Assessment

The most common and typical method to assess classification accuracy "Error Matrix" (sometimes called a confusion matrix or contingency table) was used to assess the accuracy assessment for this study. Error matrix compares, on a category-by-category basis, the relationship between known referenced data and the corresponding results of an automated classification. Such matrices are square, with the number of rows and columns equal to the number of categories whose classification accuracy is being assessed (Introductory Digital Image Processing, 1996).

In this study, satellite classified image of the year 1986 and aerial photographs of Nagasaki City taken in December 1982, published by Nagasaki Shinbun Sha were compared to assess the accuracy. These aerial photographs were the latest authenticated available source of information for the study area. Further knowledge of the study area was obtained through field surveys. These investigations provided better detail as to what type of land cover is actually present, especially at the locations of distinctive land cover change. For computing the accuracy assessment 250 reference pixels were used. The overall accuracy calculated was 82%.

4. RESULTS

4.1 Land Cover Change in whole Nagasaki City

The results of ISODATA classification of Nagasaki City are presented in **Fig. 4-6**. The calculated areas of each land cover are shown in **Table 3** and **Fig. 3**.

The overall results of the area indicate that the amounts of forestland and agricultural land are decreasing and in contrast the amounts of urban land and barren land are increasing. The amount of urban land has been increasing from 1986 until 2000; on the other hand, the amount of barren land has been decreasing from 1986 until 1992 and then started increasing from 1992 until 2000.

Table 3. Land Cover Change in Nagasaki City Estimated by ISODATA Classification

Area in km²	1986/5/12	1992/5/12	2000/5/2	Overall Change
Water	4	3.4	3.5	-0.5
Forest land	123.7	117.5	106.3	-17.4
Range land	28.1	28.2	29.2	1.1
Urban land	33.3	49	58.9	25.6
Agricultural land	42.6	38.8	35.7	-6.9
Barren land	9.5	4.3	7.6	-1.9

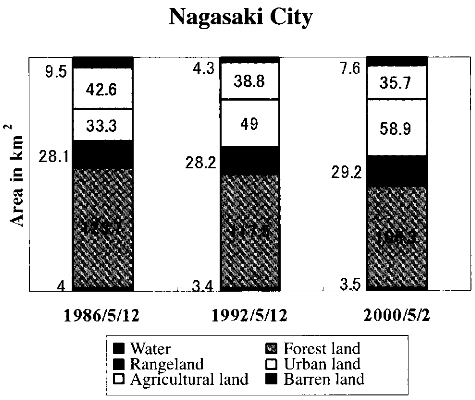


Fig. 3 Land Cover Change in Nagasaki City

Both the forestland and agricultural land within the study area show an inclination towards decrease. The change of decrease in the forestland and agricultural land since year 1986 until year 2000 comes up to 17.4km² and 6.9km², respectively. Whereas, the overall change of urban land from 1986 to 2000 was calculated as 25.6km².

4.2 Detailed View in the Typical Areas

Three different sites, within the study area are chosen to show the typical change in land cover. The locations are shown in **Fig. 7**. **Fig. 8-10** show the land cover classification images of these distinctive areas within the research site. The land cover change, in terms of percentage, is presented in **Figs. 11**, **12** and **13**.

5. DISCUSSION

The results obtained through analyzing the satellite data were verified through the ground truth method. The ground truth method was also used to verify the accuracy of the results obtained by satellite data. In order to obtain the ground truth, three typical sites within the research area were visited. The results showed that all three sites have the same tendency of constructing new towns. The new towns namely, "Sakura no Sato", "Yume ga Oka" and "Minato Zaka" were being constructed in Tagonoura, Koebaru and Kaminoshima areas respectively (**Figs. 8-10**). These new towns have been constructed within the last 15 years.

The construction of new towns has significantly changed the land cover of those areas. Due to Sakura no Sato new town in Tagonoura area, the land cover has drastically altered between

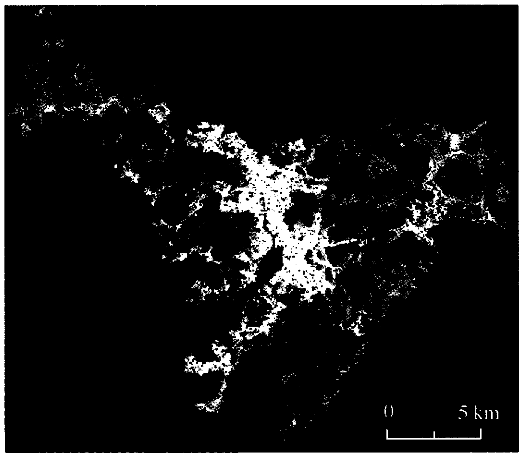


Fig. 4 Result of Land Cover Classification, 1986/5/12

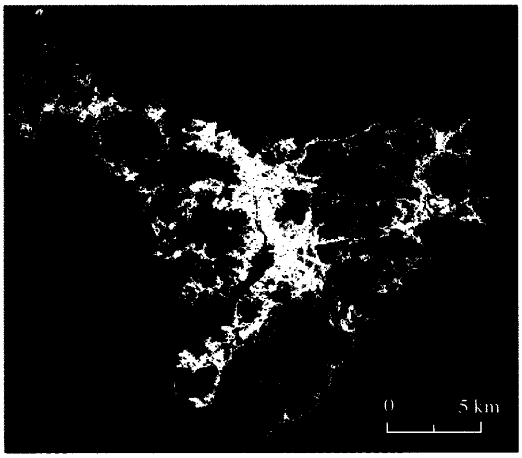


Fig. 5 Result of Land Cover Classification, 1992/5/12

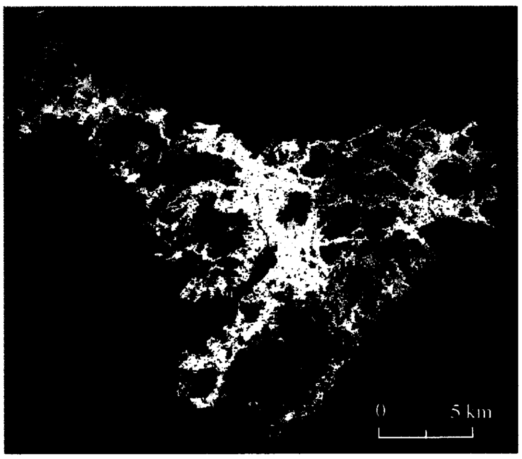


Fig. 6 Result of Land Cover Classification, 2000/5/2

Color	Class
	Water
	Forest land
	Range land
	Urban land
	Agricultural land
	Barren land

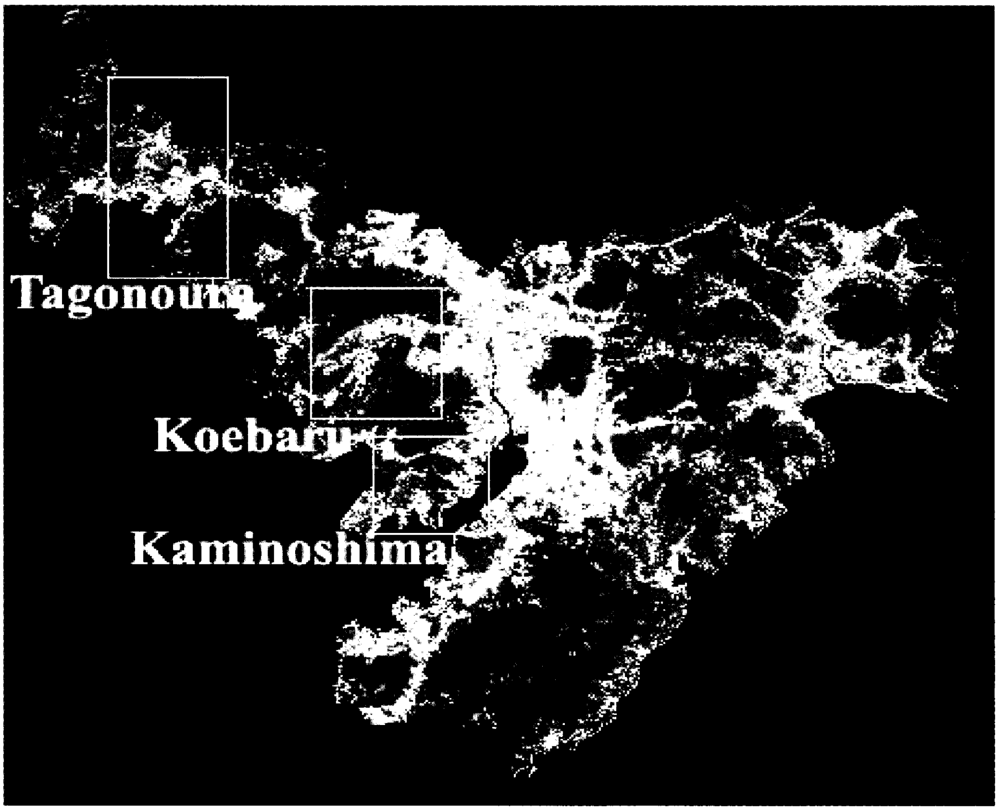


Fig. 7 Location of three selected areas

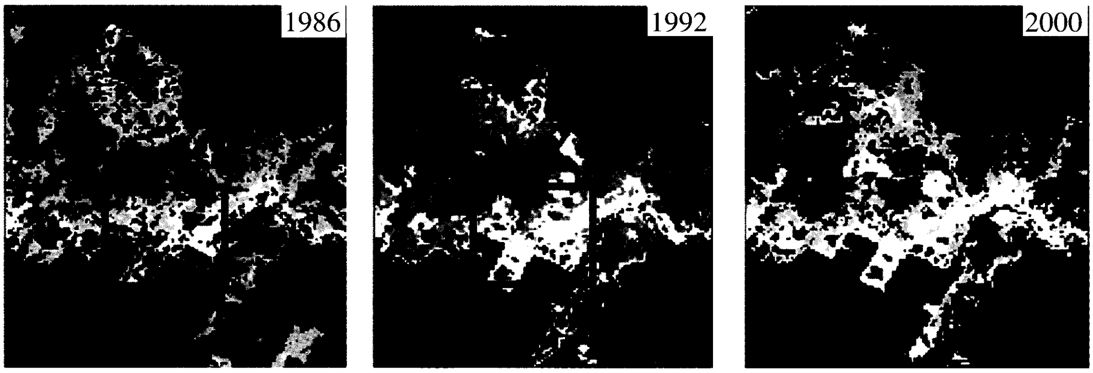


Fig. 8 Land Cover Classification Images of Tagonoura in 1986, 1992 and 2000

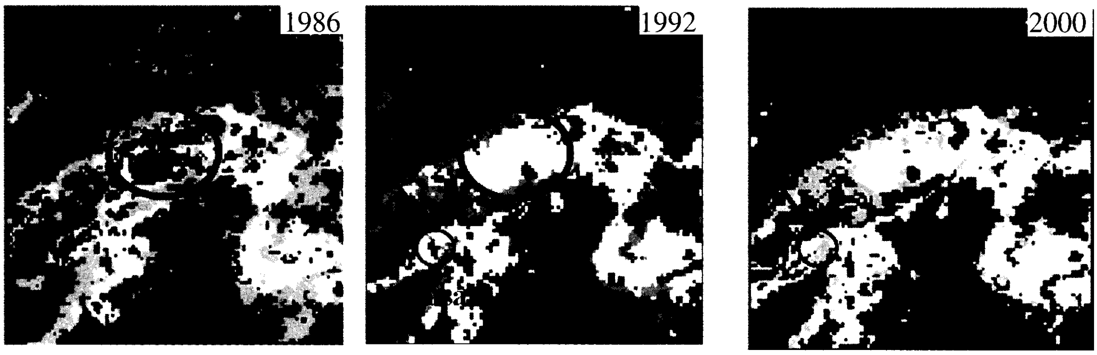


Fig. 9 Land Cover Classification Images of Koebaru in 1986, 1992 and 2000

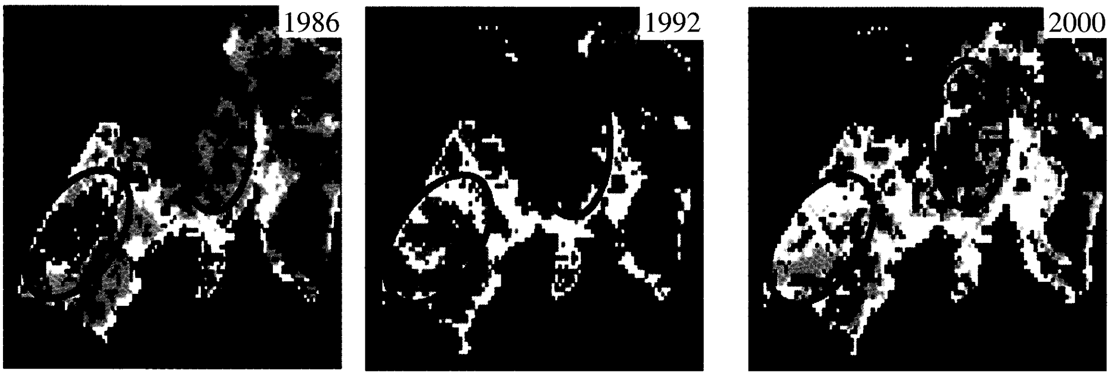


Fig. 10 Land Cover Classification Images of Kaminoshima in 1986, 1992 and 2000

Color	Class	Color	Class	Color	Class
	Water		Range land		Agricultural land
	Forest land		Urban land		Barren land

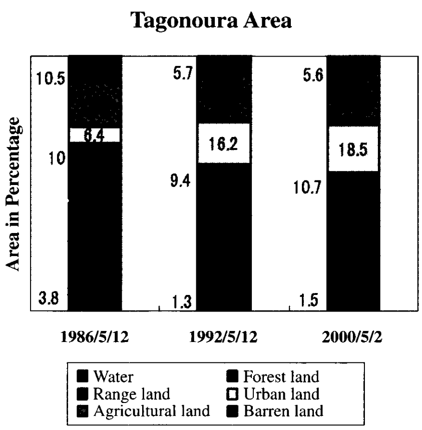


Fig. 11 Land Cover Change of Tagonoura Area

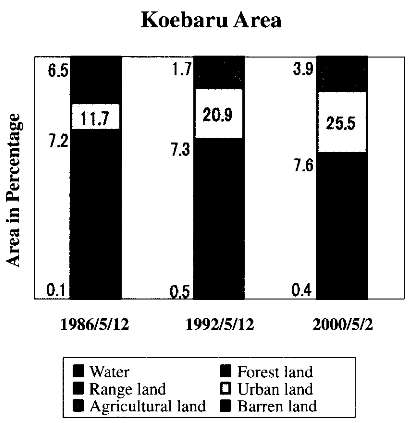


Fig. 12 Land Cover Change of Koebaru Area

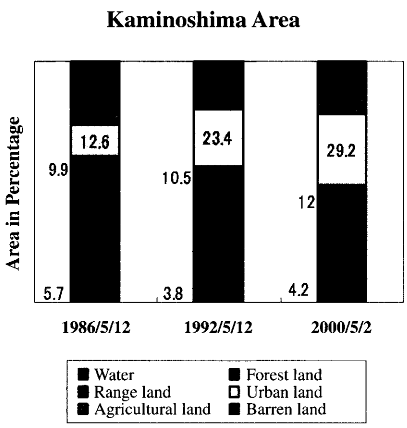


Fig. 13 Land Cover Change of Kaminoshima Area

1986 and 1992. *A* and *A'* in **Fig. 8** shows the land cover change caused by the new township of Sakura no Sato. Yume ga Oka new town has significantly altered the land cover between 1986 and 1992. While noticing *B* and *B'* in **Fig. 9**, it is apparent how Yume ga Oka new town affected the land cover of the Koebaru area. A new park named, "Nagasaki Sogo Koen" was constructed in 1998 in the Koebaru area, which helped to convert the barren land into agricultural land (*C* and *C'* in **Fig. 9**). In the Kaminoshima area, Phase 1 and 2 of Minato Zaka new town are largely accountable for the land cover change. *D*, *D'*, and *D"* in **Fig. 10** show the step by step conversion of land cover due to Phase 1 of Minato Zaka new town. Whereas *E*, *E'*, and *E"* in **Fig. 10** illustrate how Phase 2 of Minato Zaka new town altered the land cover of the Kaminoshima area.

Vegetation cover is an important factor influencing the occurrence and movement of rainfall-triggered landslides, and changes to vegetation cover often result in modified landslide behavior. Landslides occur when pore-water pressures in the regolith decrease frictional resistance below that required to keep the saturated and heavier regolith in place. When tree roots are absent, resistance of the regolith is further reduced, increasing the probability of landslides.

As mountains cover these areas, there is a likelihood of landslides. Due to forest and agricultural land, the water bearing capacity of soil was significantly high in those areas. But with the decrease of both forest and agricultural land, the water bearing capacity of soil also decreased. This results in increased danger of landslides in those areas, which may cause casualties and also damage to the infrastructure.

6. CONCLUSION

Land cover is one of the boundary conditions that directly or indirectly influence natural disasters. For this reason, the impacts of land cover changes are of primary concern. In this study, the effects of land cover changes in Nagasaki were evaluated using satellite remote sensing data. There is a reduction of forest and agricultural land mainly due to the construction of new townships within the study area. In the last fourteen years, the forest and agricultural land was reduced by 123.7km^2 and 42.6km^2 in 1986 as compare with 106.3km^2 and 35.7km^2 in 2000, respectively. In contrast, urban land increased from 33.3km^2 in 1986 to 58.9km^2 in 2000. The dynamic changes are also clearly visible in three typical sites within the study area.

The current study demonstrates the role of man made land cover changes in increasing natural disasters risks. It is possible to reduce the potential risks and damage of natural disasters by planning and controlling the development of new townships in the study area. If not, the radical land cover changes within the study area may impact directly on the activities of human beings and also it may accelerate the damage caused by natural disasters.

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