ESRI International User Conference 2005
Paper No.1766

Real Time Landslide Disaster System in Yokohama, Japan

Keiko INAGAKI and Satoru SADOHARA

ABSTRUCT

In Japan, landslides must be measured where they often occur. Recent efforts to develop soft-measures are underway because hard-measures, like covering hillsides with concrete, create economical and environmental problems. This paper will demonstrate how municipal governments can use ArcGIS to manage landslides. Areas prone to landslides are identified using an ArcGIS and rainfall data. Also, a database system using an ArcGIS Server and ArcSDE was developed to combine spatial data with existing data about potential landslides. The steep slopes in Yokohama city are used as objects of this study. This method is applicable to all of Japan, because the same results of inspection apply to all local governments and various spatial data are made by them based on 'e-government' policy. This paper will also explain how to use existing inventory data on steep slopes, records of past landslides and rainfall data to manage landslides.

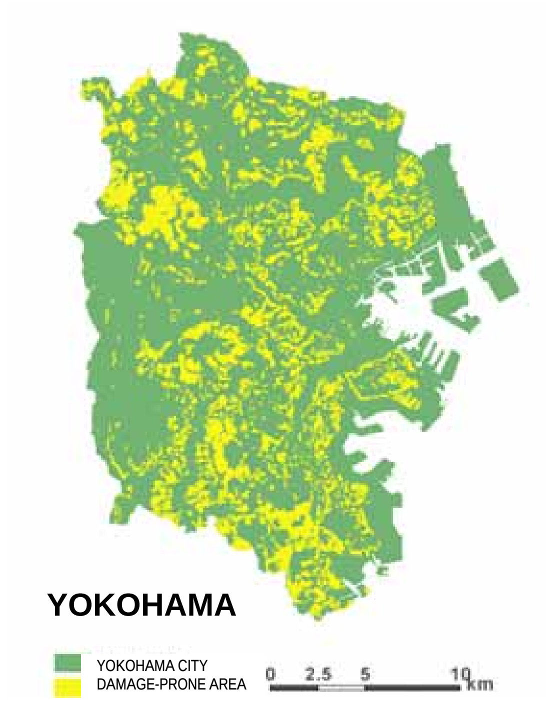
Objectives

Make use of inventories to assist municipal landslide management

1. **Link existing inventories with steep slope areas calculated by computer**
2. **Collect landslide data and analyze factors of collapse**
3. **Real time landslide prediction based on analysis and precipitation data**

INTRODUCTION

There were over 100 landslides per year in the past ten years, and about 200 landslide disasters in 2004 in Kanagawa Prefecture, Japan. This paper shows the contributory factors of landslide disasters utilizing inspection data and rainfall data. All prefectures have inspected slopes that are 10m and over in height and have an inclination of at least 30 degrees and over by 2001 in Japan. Kanagawa Prefecture inspected more than 7,000 steep slopes. On the other hand, the City of Yokohama in Kanagawa inspected 3,400 steep slopes. The slopes, 5m and over in height, were used in the study.



30 detailed factors such as geology, height, vegetation, surface thickness, leaking water, etc., were inspected by each local government (Fig.1). In this study, 10 important factors were quantified in order to multivariately analyze in the City of Yokohama. This method will be useful for all local governments in all of Japan, because it's based on the existing inspection records in Kanagawa Prefecture. The criterion variable is based on records of past landslides in this analysis. Samples for analysis are chosen on the same geology type.

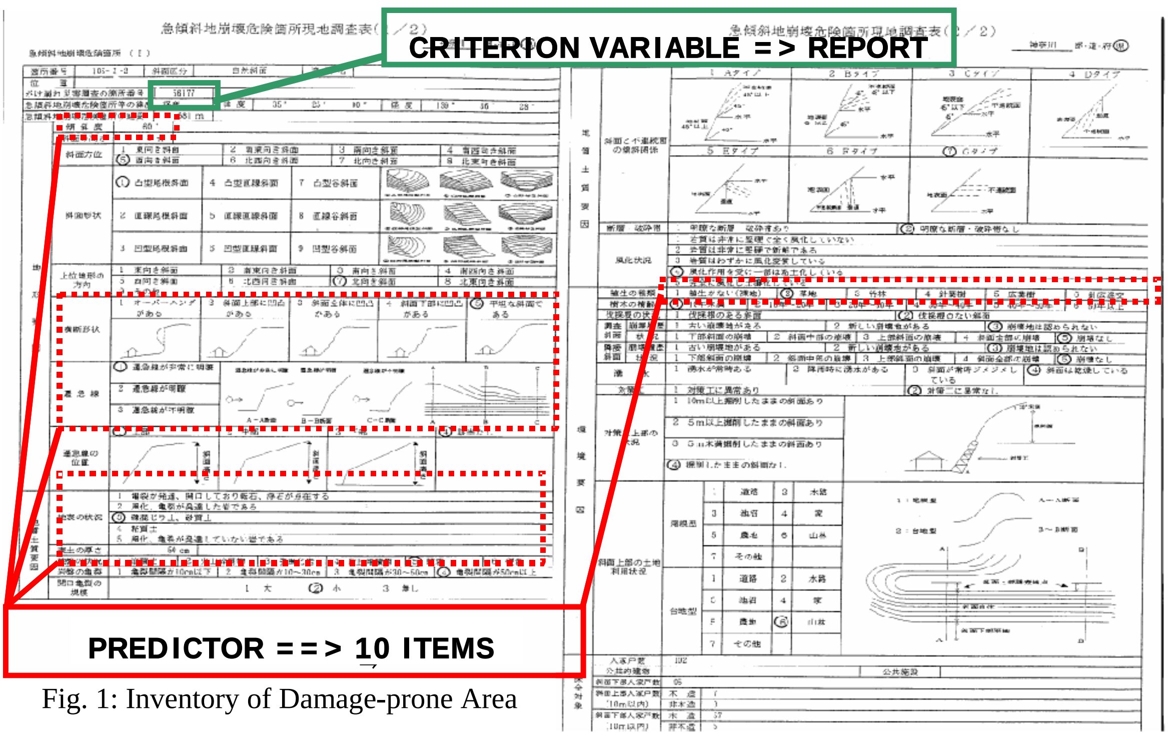


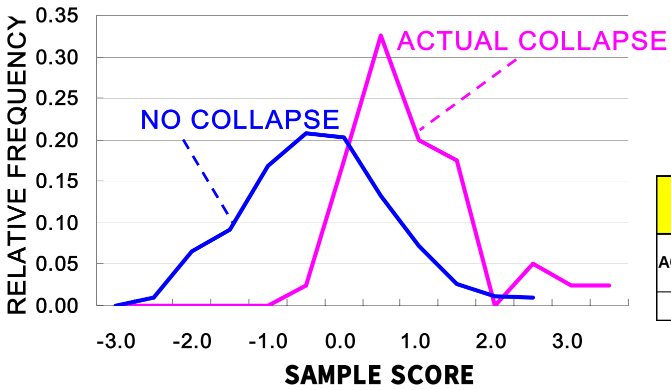
Fig. 1: Inventory of Damage-prone Area

Evaluating the Primary Cause, using Steep Slope Inventories and Multivariate Analysis; Quantification Theory Type II

Table1 is the results of quantification theory type II for slopes in the Yokohama area. The number of samples is 454. Each value means the contribution-ratio for the collapse. A higher value contributes to collapse strongly, while a lower value has less of a contribution. ”CROSS SECTION”, “CONSTRUCTION WORK” and “VEGITATION & AGE OF TREE” are strong factors for the collapse. Moreover, the sum of values can be used to evaluate the possibility of slope failure based on the past collapse record. Fig.2 shows that most steep slopes that have a value higher than around 0.467 have actually collapsed in the past. As a result, the potential of collapse can be estimated to be 75.3% accurate.

Table 1: Results of Quantification Theory Type II

ITEM	CATEGORY	WEIGHTED COEFFICIEN	RANGE
SLOPE	1 - 40°	-0.43	0.97
	2 40°- 60°	-0.05	
	3 60°-	0.54	
HIGHT OF SLOPE	1 - 50cm	-0.10	0.15
	2 50cm -	0.05	
LANDUSE OF HILLTOP	1 ROAD, HOUSES	0.23	0.44
	2 OTHERS	-0.21	
KINICKLINE	1 CLEAR	0.11	0.38
	2 NOT CLEAR	-0.27	
OPEN CRACKS	1 EXIST	0.65	0.90
	2 NONE	-0.25	
VEGITATION AGE OF TREE	1 FIELD	0.27	1.28
	2 BUMBOO	-0.44	
	3 OTHERS (- 40 years)	0.44	
	4 OTHERS (40 years-)	-0.84	
LANKING WATER	1 EXIST	-0.02	0.02
	2 OTHERS	0.00	
CROSS SECTION	1 OVERHUNG	1.49	1.90
	2 UNEVEN	0.33	
	3 FLAT	-0.42	
CONSTRUCTION	1 FINISHED	-0.37	1.05
	2 UNFINISHED	0.68	



75.30%		DISTINCTION RESULTS		TOTAL
		COLLAPSE	NO COLLAPSE	
ACTUAL	COLLAPSE	32	8	40
	NO COLLAPSE	104	310	414
TOTAL		136	318	454

Fig.2: Frequency Distribution of Distinction Result

Evaluating the Primary Cause, using the Report of Landslides and Rainfall data

It is important to clear the relationship between rainfall and soil quality to prevent landslide disasters during heavy rainfall. The Soil Water Index shows the level of soil moisture in each 5km grid (Fig.3). The index is calculated based on the Tank Model by using rainfall on the radar screen in all parts of the country and the order of the index in the grid has been recently used for warning against landslide disasters. On the other side, some local governments fix each standard of Critical Lines (CL), Evacuation Lines (EL), and Warning Lines (WL) by using rain gauges. In this study, the Soil Water Index, effective rainfall, T=1.5 and T=72 are used. Effective rainfall as an antecedent precipitation index, Rt is calculated by

$$R_t = r_t + (\alpha_1 \cdot r_{t-1} + \alpha_2 \cdot r_{t-2} + \cdots + \alpha_x \cdot r_{t-x}) = \sum_{n=1}^{x} \alpha_n \cdot r_{t-n}$$
$$\alpha_n = 0.5^{n/T} = (0.5^{1/T})^n \qquad (1)$$

Precipitation data will be taken at 99 fire stations in Yokohama and past data was taken at 34 stations of various governments (Table2). Fig.5 shows the correlation between sample scores based on results of Quantification Theory Type II and the maximum ratio of Soil Water Index at each collapse in the last 10 years for considering the specific characteristics of each region in Yokohama. High score areas prone to landslides that have a high potential of collapse with little rain are shown in Fig.4. Moreover it is also found that slopes collapsed in order of sample score when typhoon No.0422 hit Japan in this study.

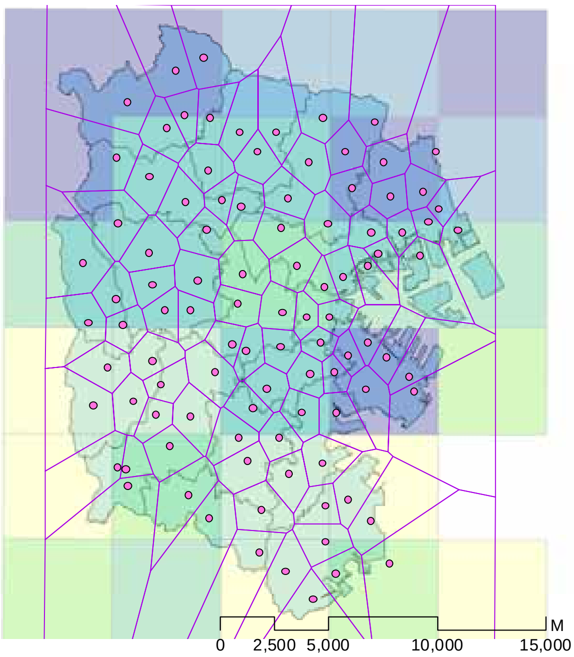


Fig.3: Grids of Soil Water Index and 99 Fire stations in Yokohama

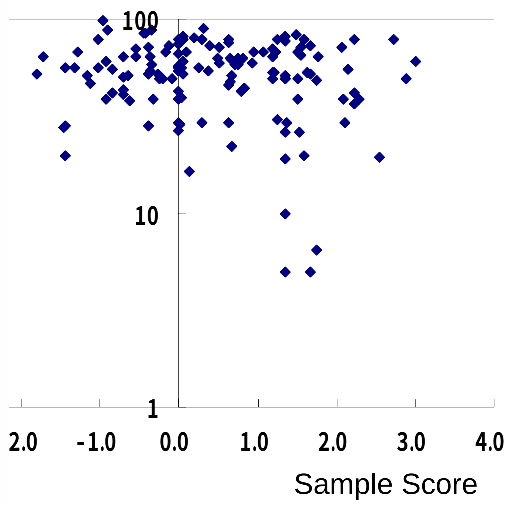


Fig.4: Correlation between Sample Score and Ratio of Soil Water Index to Max in last 10 years in each collapse point (1998-2003)

Critical line (CL) is drawn based on the precipitations when each landslide happened with consideration of the scale of the landslides (Fig.5). Fig.6 shows CL and Precipitations at Oct. 2004 when landslides were caused by typhoon No.0422 in Yokohama. High score areas prone to landslides that have a high potential of collapse with rain near by CL are shown in Fig.7. There is a relationship between the SCORE and RAIN on landslide disasters.

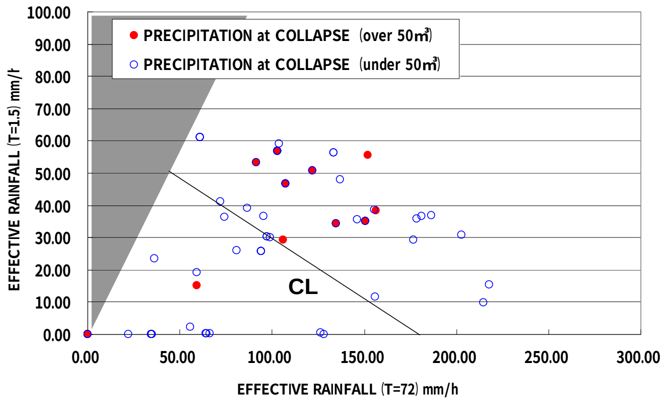


Fig.5: Critical Line in Yokohama City (1998-2003)

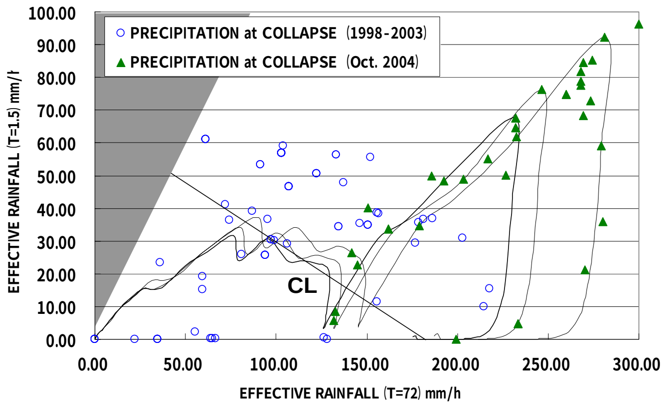


Fig.6: Critical Line in Yokohama City and Precipitations at Oct. 2004 Landslides

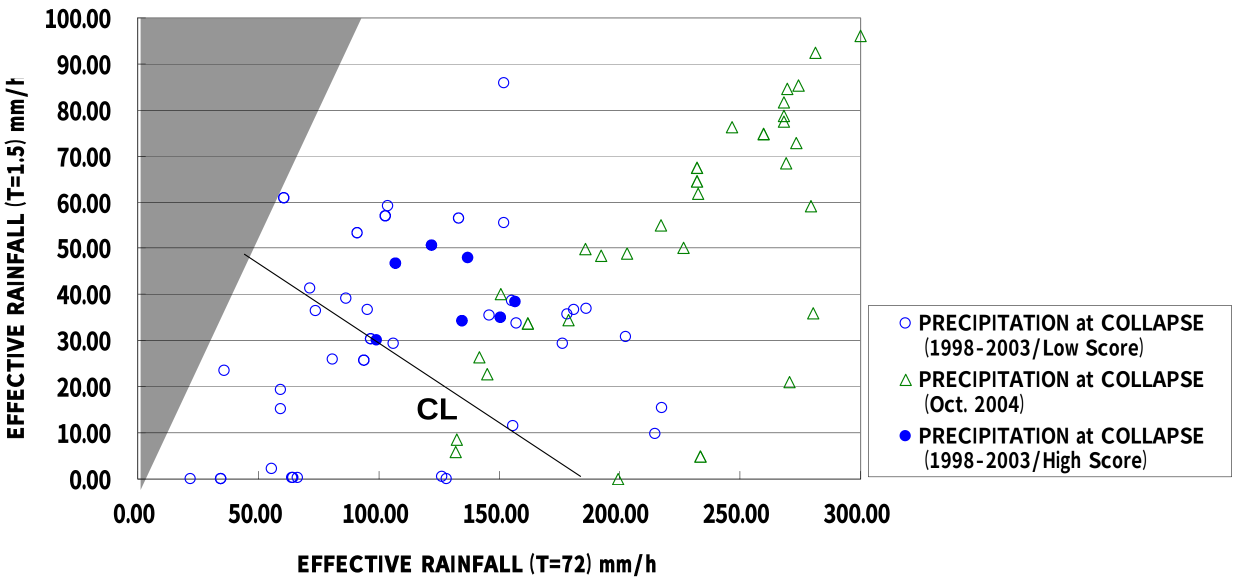


Fig.7: Correlation between Sample Score and Precipitations at Collapse (1998-2004)

Functions of Real Time Landslide Disaster System

Real Time Landslide Disaster System has 3 components, (1) Management of slopes by officers, (2) Analysis of landslides with slopes and landslides information and (3) Prediction of areas prone to landslide with results of analysis and real time precipitation data (Fig.8). A database was developed using ArcGIS Server and ArcSDE. Information on slopes, landslide reports and rainfall data are integrated on this system. Slopes in Yokohama are managed by Kanagawa Prefecture and Yokohama City who add this data to the database. The database can integrate rainfall data recorded by Japan Meteorological Agency, Office of River, Fire Stations, Office of Drainage, etc. This system will be useful for officers to manage slopes during daily work and emergency response.

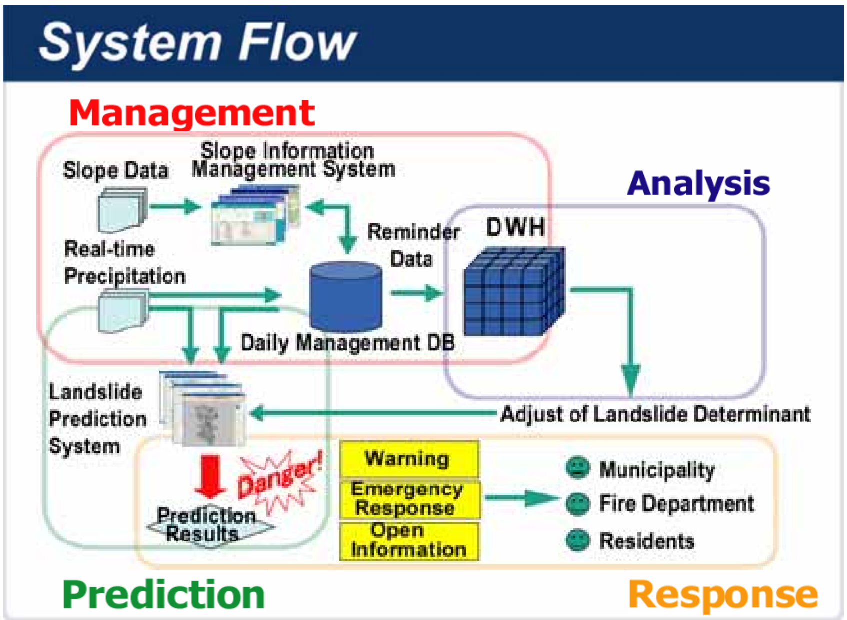


Fig.8: System Flow

Table 2: Precipitation Data in Yokohama

		NUM OF OBSERVATORY IN YOKOHAMA	ACCESS	INTERVAL	OBSERVER	AREA
RAINFALL	METEOROLOGICAL OBSERVATORY	2	WEB	1HR	JAPAN	
	OFFICE OF RIVER	4	WEB	1HR	JAPAN	40km²
	OFFICE OF RIVER	6	WEB	1HR	PREF.	
	FIRE STATION	99	△	15MIN	CITY	4km²
	OFFICE OF DRAINAGE	22	×	1HR	CITY	18km²
RADAR	PRECIPITATION ANALYSIS	2.5km-mesh	ONLINE	30MIN	JAPAN	
	PRECIPITATION ANALYSIS AND FORCAST	1km-mesh	ONLINE	10MIN	JAPAN	
	OFFICE OF DRAINAGE		WEB	5MIN	CITY	

Fig.9 shows the flow for predicting areas prone to landslides using slope information, landslide reports and precipitation data based on above analysis for Real Time Landslide Disaster System. The steep slope areas are colored according to their risk level of when it rains over the Critical Line on the application using ArcGIS (Fig.10). This system will assist officers in patrolling areas of high risk and in making an evacuation plan for residents when it rains heavily.

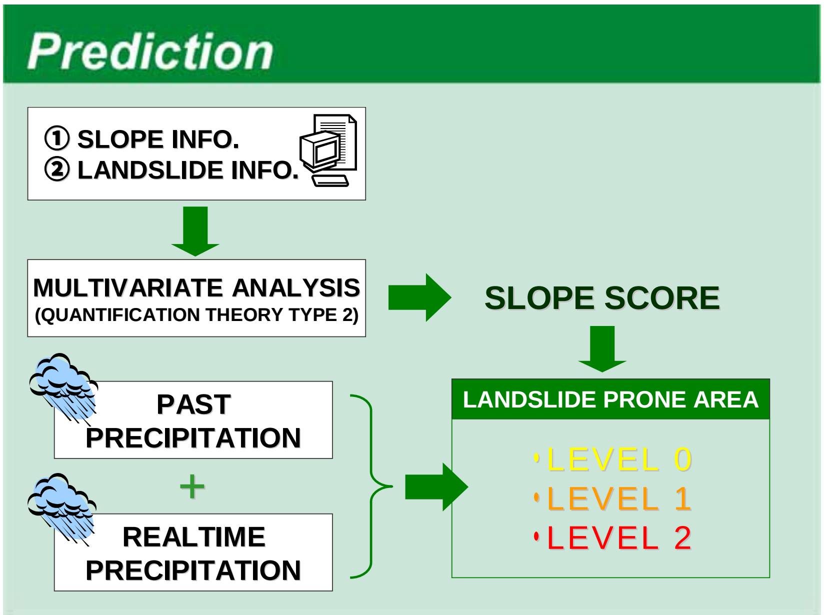


Fig.9: Prediction Flow Chart

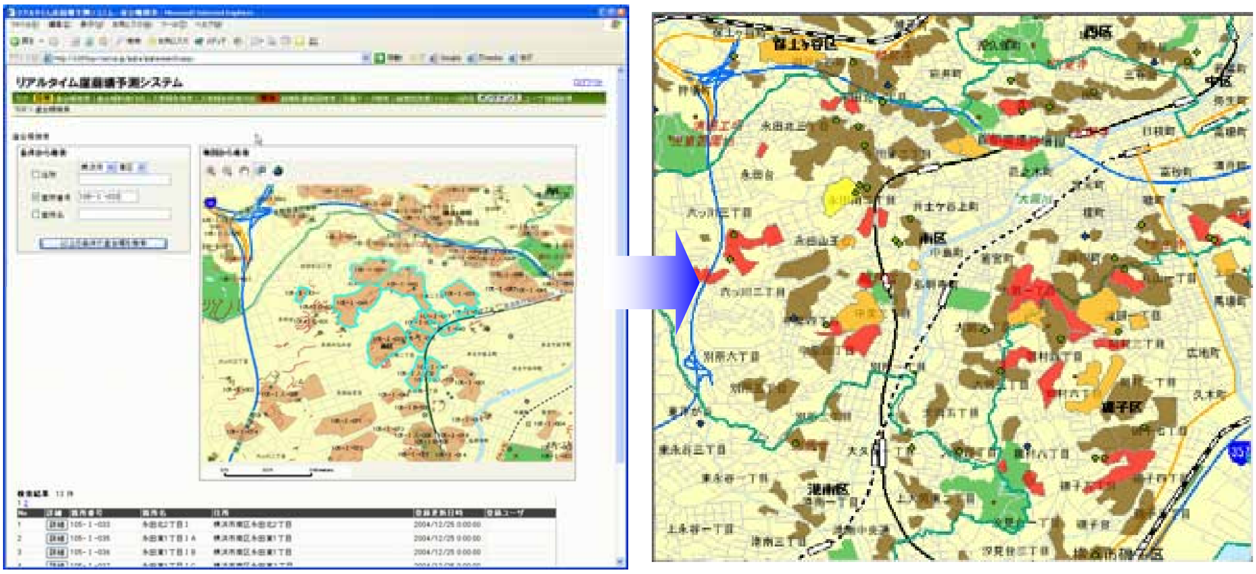


Fig.10: Application for Prediction of Landslide

CONCLUSION

This paper demonstrated how municipal governments can use ArcGIS to manage landslides. Areas prone to landslides are identified using ArcGIS and rainfall data. Also, a database system using ArcGIS Server and ArcSDE was developed to combine spatial data with existing data about potential landslides. In particular this paper showed how to predict areas prone to damage using spatial data, existing data and real time precipitation data. This method is used in all of Japan because the same results of inspection apply to all local governments. This paper also explained how to use existing inventory data on steep slopes, records of past landslides and precipitation data to manage landslides. There will be a system demonstration at an office in Yokohama City and officers will use this system on the job to improve user interface.

ACKNOWLEDGEMENT

Special thanks to: Ms. OKUMURA Mako, Ms. IRIBE Yoshimi, Mr. IMAMASU Keisuke, Mr. Li Long Ji, Ms. Rizka Oktora Ibrahim, Mr. WANG Jin, Ms. WANG Dongzhi, Mr. Fang JI, Mr. HIGUCHI and Dr. YOSHIDA Satoshi, Yokohama National Univeristy.

This work is contribution to the 2004 Research and Development of Construction Technologies by the MLIT (The Ministry of Land, Infrastructure and Transport), JAPAN.

REFERENCE

1. Akiyuki KAWASAKI, Satoshi YOSHIDA, Satoru SADOHARA "Statistical Researchies of the Factors Affecting Slope Failure in YOKOHAMA." J. Architect. Plann., AIJ, No.569, Jul., 2003: 125-130.
2. Akiyuki KAWASAKI, Kazuki HATTORI, Go URAKAWA, Tetsuya NAKAJIMA, Satoru SADOHARA. "The Utilization of GIS for the Measure against Slope Failure Disaster." Theory and Applications of GIS, 2001, Vol.9, No.2, 2001: 25-32.
3. Kenji Okada. "Soil Water Index", Sokkojiho (測候時報), 69.5, 2002: 67-100.
4. Yasuo ISHIHARA, Shigeki KOBATAKE "Runoff Model for Flood Forecasting", Bulletin of the Disaster Preventation Research Institute, Kyoto University, Vol.29, 1979: 27-43.

Author Information

Keiko INAGAKI
Research Associate of Yokohama National University, Japan
Tel: +81-45-339-4248 / fax; +81-45-338-1016
E-mail: keiko@arc.ynu.ac.jp