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SPATIAL DISTRIBUTION PATTERN OF RAPID SHALLOW LANDSLIDES IN AMAKUSA ISLAND

RAEUMLICHE VERBREITUNGSMUSTER DER SEICHTEN RUTSCHUNGEN IN DER AMAKUSA INSEL, JAPAN

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ABSTRACT

Spatial distribution pattern of 1144 rapid shallow landslides, which occurred in a study area of 97.8 km^2, Amakusa Island, 1972 by a rainfall of 437 mm in 2 days, is analyzed using aero-photographes and maps. Basic geology is of late Mesozoic to Tertiary sedimentary rocks. Fractal dimension of landslides by the box counting method gives values from 0.81 to 1.16, which mean the linear pattern due to the parallel distribution of strata. Because of more than 35 % of the total events occurred along belts of geologic border, and normal fault. On the boundary between black schist and limestone, and the fault in lithoidite area, densities are 51.8 and 52.9 per 1 km^2, relatively. Morishita's Id shows the uniform pattern in high density area of landslides and the concentrated one in low density. These values suggest the high potential zone of rapid shallow landslides, where adequate forest managements are requested to reduce the potentiality of landslide's occurrence.

ZUSAMMENFASSUNG

1972 ereigneten sich anlässlich eines 2-Tages-Niederschlags von 437 mm in einem 98 km2 grossen Untersuchungsgebiet auf der AMASKUSA-Insel (Japan) 1144 flachgründige Rutschungen. Deren räumlichen Verteilungsmuster wurden anhand von Luftbildern und Karten analysiert. Kartenmaterial analysiert. Das Grundgestein besteht aus spaetmesozoischen bis tertiaeren Sedimentgesteinen. Die fraktale Dimension der

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Rutschungen, bestimmt mit der "Boxcounting-Methode" ergibt Werte zwischen 0.81 und 1.16. Dies bedeutet ein lineares Muster infolge der parallelen Lagerung der Schichten. Mehr als 35 % aller Ereignisse treten entlang von geologischen Grenzen und normalen Verwerfungen auf. An der Grenze zwischen reinem Schiefer und Kalkfels und an anderen Verwerfungen betraegt die relative Dichte 51.8 bis 52.9 pro km^2. "Morishita's Id" zeigt uniforme Verteilungsmuster in Gebieten mit hoher Rutschungsdichte und konzentrierte Muster in Gebieten mit geringer Dichte. Die Werte weisen auf eine Zone mit einem hohen Potential fuer schnelle, flache Rutschungen. Eine angepasste Waldbewirtschaftung koennte das Auftreten von Rutschungen moeglicherweise reduzieren.

INTRODUCTION

Fractal dimension and Morishita's Id are the significant indicators to express geomorphological pattern in different scale and spatial dispersion of thing, respectively (Takayasu 1986, and Morishita 1956). Fractal analysis was applied for distribution of rapid shallow landslides (Omura 1995). But there was few study related with Id. As a basic study for hazard mapping of rapid shallow landslides, it is important to understand an occurrence pattern. The purpose of this study is to analyze distribution pattern of shallow landslides in Amakusa Islands from geology point of view with Fractal dimension and Morishita's Id.

STUDY AREA

A study area of 97.8 km^2 is located at the southern part of Amakusa Kamishima Island in west of Kumamoto prefecture as shown in Figure 1. Low mountain range of Mt. Nenjyutake (503 m from sea level), Mt. Ryugatake (470 m), and Mt.Kuratake (682 m) run from north to south along east coast, which cross sectional profile shows an asymmetrical cuesta. Front slopes in east side are steeper than dip slopes in west side. These slopes are coated with thick evergreen broadleaved forest mixed with Japanese ceder. Basic geology of the study area is of late Cretaceous and Paleogene sedimentary rocks, Permian crystalline rocks, and Miocene intrusive rocks, which are distributed in parallel way of gentle fold structure as shown in Table 1 and Figure 1 (Karakida, 1992). A heavy rainfall

Table 1:Geology in Amakusa Kamishima Island.
Tab. 1: Geologische Verhaeltnisse auf den Amakusa Kamishima Inseln.

Era	Group	Rock
Miocene		Rhyolite, Lithoidite, Granodiorite
Paleogene	Kyoragi	Sandy siltstone
	Miroku	Sandstone
Late Cretaceous	Himenoura	Siltstone
Permian		Black schist, Limestone

hit this area in 6th June 1972. The maximum hourly rainfall was 130 mm (Kumamoto meteorological station, 1972). By the total rainfall 437 mm, many rapid shallow landslides were triggered. Some of them changed into debris flows and resulted in a disaster as listed in Table 2.

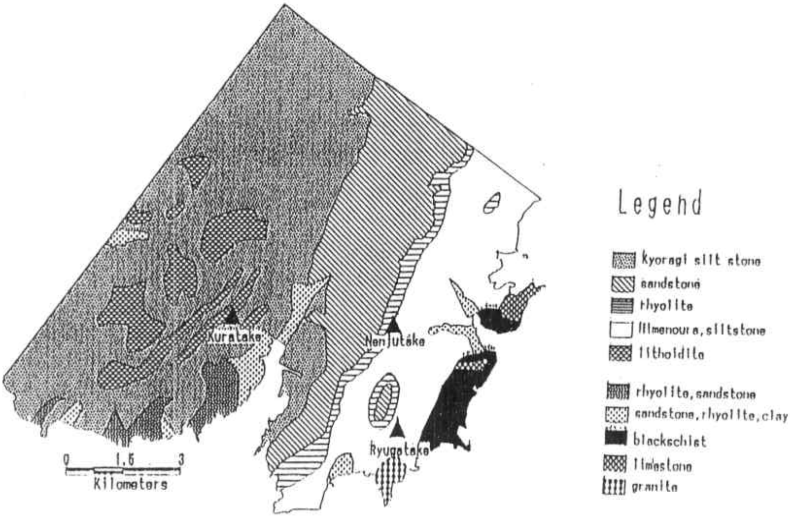

Figure 1: Study area.
Abb. 1: Untersuchungsgebiet.

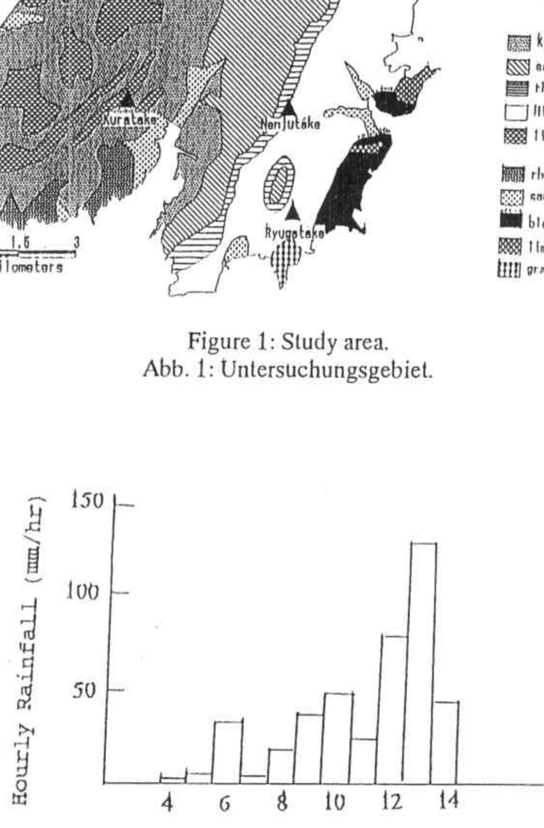

Figure 2: Hyetograph at Ryugatake 6th June 1972.
Abb. 2: Regenschreiber-Aufzeichnung in Ryugatake, 6. Juni 1972.

Table 2: Disaster in Amakusa Island.
Tab. 2: Katastrophe auf der Amakusa Insel.

District	People		House		Community	
	Killed	Injured	Destroyed	Damaged	Population	Family
Himedo	45	74	124	38	4636	1137
Ryugatake	36	80	248	84	7079	1703
Kuratake	28	88	74	177	5524	1371
The other	6	7	66	219	13823	3347
Total	115	249	482	518	31062	7558

METHOD

Shallow landslides were interpretated using a series of white and black aero-photographs of scale 1/10000 taken in 14th July 1972 through a stereoscope. Locations of landslides were marked on the maps of scale 1/25000, and scanned by a scanner connected with a computer conducted under the soft program of MapInfo-Professional to measure geometrical data. Fractal dimension was calculated by equation 1 to the box counting method (Takayasu 1986). Also Id was calculated by equation 2 (Morishita 1956).

$$Nc = kS^{-D} \quad \ldots 1$$

$$Id = n\sum_{i=1}^{n} x_i(x_i - 1)/N(N-1), N = \sum_{i=1}^{n} x_i \quad \ldots 2$$

Nc, S, k, and D are number of box, which includes landslide, scale of boxes for measuring, coefficient, and Fractal dimension, respectively. If D = 1, a geometrical pattern of distribution is linear. If D = 2, it is plane. n, Xi, and Id are number of boxes, number of landslides included in i-th box, and dispersion index, respectively. If Id>1, a spatial pattern shows a concentrated distribution. If Id 1, it shows an uniform distribution.

RESULTS AND DISCUSSION

Distribution of shallow landslides is shown in Figure 3. Relation between scale of box and number, which includes landslides, is shown in Figure 4. The minimum size of box is 125 x 125 m^2, which is 53 times as the mean size 296 m^2 of landslides. As the results, the average value of Fractal dimensions of spatial distribution is 0.92 ranging from 0.51 in limestone area to 1.16 in siltstone area as listed in Table 3.

Comparing with values 1.78 measured in granite area and 1.18 in soft sandstone (Ōmura, 1995), these lower values mean the spatial distribution of landslides in Amakusa shows some linear patterns. Because more than 35 % of the total events occurred along the belts of geologic border, and normal faults, where there might be any high potential zone due to weak combination between layers, differences of permeability to underground water, and fragile zone crushed by the past tectonic movement. Particularly on the border between black schist and limestone, and the fault in lithodite area, the densities of landslides are

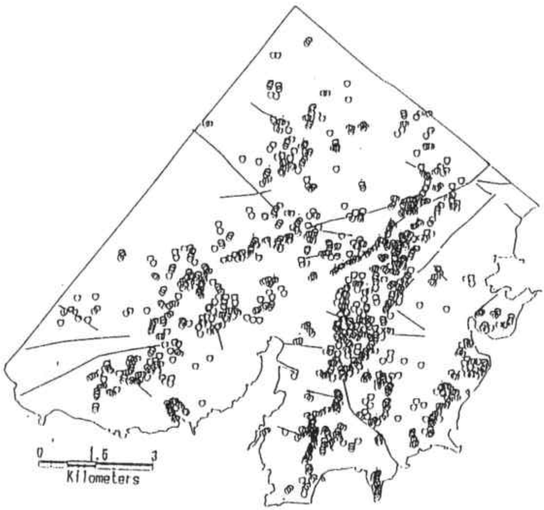

Figure 3: Distribution of faults and shallow landslides.
Abb.3: Verbreitung von Verwerfungen in Kombination mit Rutschungen.

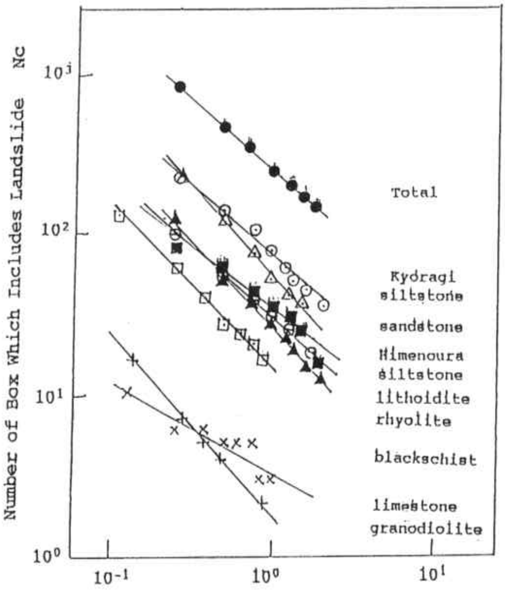

Figure 4: Relation between scale of box and number of box which include landslides.
Abb.4: Verhaeltnis zwischen dem "Rasterzellen-Massstab" und der Zahl von "Rasterzellen" mit Rutschungen.

Table 3: Rock, Fractal dimension, Morishita's Id, and landslide density in Amakusa Island.
Tab.3: Fraktale Dimension, Morishita Id und Dichte der Rutschungen auf der Amakusa Insel

Rock	Surveyed area [km^2]	Fractal dimension D[-]	Correlation coefficient r[-]	Id [-]	Landslide density [n/km^2]
Sandstone	16.8	1.16	-0.995	2.81	19.8
Granodiorite	0.6	1.02	-0.979	4.25	28.6
Lithoidite	3.9	0.94	-0.997	1.72	38.9
Sandy siltstone	44.2	0.88	-0.991	7.30	7.8
Rhyolite	7.0	0.81	-0.981	2.85	13.3
Blackschist	2.8	0.80	-0.988	2.26	28.1
Siltstone	16.9	0.70	-0.964	9.51	6.2
Limestone	0.7	0.51	-0.924	4.56	18.0
Total	97.8	0.92	-0.994	4.89	11.7

51.8 and 52.9 events per 1 km^2 as listed in Table 4 and 5, relatively. Values of Id range between 1.72 in lithoidite area and 9.51 in siltstone area depending on the density 38.9 and 6.2 events per 1 km^2, respectively, which corresponds to the uniform distribution in high density and the concentrated distribution in low density. The former area has uniformly the high potentiality for occurrence of landslide. But in the latter area, high potential place is locally limited, where it is difficult to point out such places in forecasting. Based on these values, the forest and watershed should be adequately managed to reduce any occurrence of shallow landslides.

Table 4: Landslides located on boundary belt between different rocks.
Tab.4: Rutschungen im Grenzbereich zwischen unterschiedlichen Gesteinen.

Rocks	Area [km^2]	Landslide density [n/km^2]
Black schist/Limestone	0.56	51.8
Sandstone/Lithoidite	4.89	33.3
Black schist/Siltstone	0.81	18.5
Rhyolite/Sandy siltstone	6.85	14.6

Table 5: Fault and rapid shallow landslides.
Tab.5: Verwerfungen und Dichte von Rutschungen.

Line	Fault			Rock	Landslide density [km^2]
	Length [km]	Aspect	Type		
AB	1.21	S60	Normal	Sandy siltstone	22.1
CD	5.51	N60	Normal	Lithoidite	52.9

CONCLUSION

Because of high density of shallow landslides occurrence on the boundary between parallel sedimentary rocks and faults, spatial distribution shows some linear pattern, which are confirmed by the values of Fractal dimension. Morishita's dispersion indicator Id shows the uniform distribution in high density area and the concentrated one in low density area. Taking account these values, forest and watershed should be adequately managed to reduce the level of potentiality of landslides occurrence.

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