A Study on the Fractal Dimensions and Geological Condition of Landslides

Tetsuya KUBOTA*

要 約

地すべりの危険箇所や危険度調査においては極力少数の要因を用いて定量的な判定ができることが望ましい。その観点から、地すべり面積率や箇所数では表現できず、これまで定性的にのみ表現されて来た発生形態の複雑さを定量的に表現するフラクタル次元 D を用いた危険度判定が有意義なものと思われる (久保田 1994)。本研究では、特に地質情報と D との関係に着目、その間に有意な関係があるかどうかを検討し、初生を含めた地すべりの危険箇所・危険度判定要因としての有用性を考察した。その結果、 D は実際の地すべりにおいて地質ごとに判別可能な程度に有意な差をもち、地質から D すなわち発生形態を含めた地すべりの定量的な概略の危険度を判断することに利用可能と思われるので報告する。

キーワード: 地すべり地形, 地形要素, フラクタル*, 危険度*

1. Introduction

It is desirable to know the location of landslide susceptible areas in order to avoid landslide disasters. However, it is very difficult to find such places especially if they are concerning to primarily landslides. For this reason, topographical and geological features over the areas to investigate have been using to find out that kind of areas. In this paper, topographical "Fractal" characteristics of landslides are discussed on the view of the tool for investigation of landslide susceptible areas and their risk level. The "Fractal" is a mathematical theory that has developed by B. Mandelbrot in order to describe the quality of complex shapes or images in the nature. And, it is suitable for measuring landslides complex topography. Here in this paper, Fractal Dimension of landslides " D " are discussed as a index factor for landslide risk level especially for primarily landslides. And the relation between D of actual landslides and geology are investigated here with multi-discriminant analysis. Finally, it has come to be clear that " D " can be an index for landslides susceptibility or risk level.

2. Study Method

The self-affinity of landslides landform and meaning of the landslides fractal dimension D were discussed in former study (Kubota 1994), concluded that the

self-affinity can be guaranteed as long as it is applied for adjacent landslide group within distance of 1 km, and D means complexity of group landslide occurrence i. e. risk level of landslides. On this point of view, the relation between one of the important susceptibility factor "geology" and " D " is considered here to obtain a standard index for landslide risk analysis.

To acquire the Fractal Dimension " D ", so called Box Counting Method is adopted in this study like as former study (Kubota 1994), that is suitable for the 2-dimensional images like landslides group landform, using actual landslides in Hyogo, Tottori, Okayama, as well as one from Niigata prefecture (Fig. 1).

Fig. 1 Location of the Target Landslides Areas.

* Dept. of Environmental Science, Faculty of Agriculture,
Tottori Univ.

Each D is gained by the line slope derived from regression analysis, and classified with the geology. Then, all D are provided for the multi-discriminant analysis among different geologies, checked by Wilks' Λ -Test which can be reduced F-test.

3. The Object Field of this Study

The field in which the target landslides are situated consists of areas in Northern Hyogo, Sanda Basin (Hyogo pref.), Southern Awaji Island (Hyogo pref.), Eastern Tottori, Northern Okayama, Serpentin zone (Western Tottori pref., Northern Okayama pref.) and Jōetsu (Niigata pref.; for comparison). These areas have mainly geology of Tertiary madstone or tuff, on the other hand Serpentin zone has geology of crushed serpentinite, and Southern Awaji Island area has tectonically crushed mesozoic sandstone madstone alternated beds (Shattered zone). In Northern Hyogo, it is divided into two formations called Hokutan Formations (mainly madstone), Teragi Formations (mainly tuff). The geology in Sanda Basin is represented by Kobe Formations (mainly madstone) that shows slight Cuesta structure, and Southern Awaji Island area has Izumi Formations (mainly madstone). Eastern Tottori area consists of Tottori Formations (madstone, tuff), while Northern Okayama area is formed by Katsuta Formations (madstone, shale, tuff). Adding to that, Serpentin zone consists of Paleozoic metamorphic rock like, of course, mainly serpentinite and schist, whereas Jōetsu area consists of Tertiary Teradomari-Shiiba Formations (madstone) with andesite intrusive rock structure (Editorial committee of KINKI 1987, Editorial committee of CHUGOKU 1987, Editorial committee of CHUBU I 1988, Nakamura et. al. 1987).

4. Results

4.1. Fractal Dimension "D"

Box Counting diagram is shown in Fig. 2. In this figure, "D" has a relation to the number of meshes N (η) that includes landslide and the width of the rectangular meshes η as form of below.

$$D = -d(\ln N(\eta))/d(\ln \eta) \dots \dots \dots (1)$$

, here d means differential.

Fractal dimensions gained from this relation are in Tab. 1 with correlation coefficient by regression analysis. And actual landforms are given in Fig. 3.

With Tab. 1 "D" can be found to take the value of 1.0~1.46 whereas it should be 1.0~2.0 for plane,

and it can take 1.1~1.3 for river system (Kubota 1994, Feder 1988). D of landslides seems bit bigger than the one of rivers. It can be shown the fact that this D values are different from geology to geology if the number of landslides is exactly or approximately same as described in former study (Kubota 1994). The average D is 1.26 for Northern Hyogo area that has Hokutan-Teragi Formations. And the ones for Sanda Basin, Eastern Tottori area, Northern Okayama area, Serpentin zone are 1.29, 1.34, 1.14 and 1.20 respectively, while the each D for Southern Awaji area, Jōetsu area are 1.18 and 1.39. According to these values, Fractal Dimension has sufficient discrepancy to express the risk level among areas that belong to each other geology. Since Fractal Dimension D is a landslide risk index because of its feature that describes landslide complexity and packing rate as it is mentioned in former study (Kubota 1994), the geology that has high D value is judged that it has high landslide risk. And it is obvious that D in the typical landslide zone like Jōetsu area seems to be bigger than others, but it doesn't make very bigger value.

4.2. Multi-Discriminant Analysis

This analysis is carried out, after the landslides are classified to 5 groups "Hokutan-Teragi, Kobe, Tottori, Katsuta Formation area, and Serpentine-Shattered zone" with geology. Since serpentinite zone is understood to be formed in a shattered zone, this two group are combined together. Jōetsu area is not involved in the analysis, because it is only for D value comparison.

The result of multi-discriminant analysis is described in form of Wilks' Λ , and also the scatter diagram is given. Wilks' Λ is defined by

$$\Lambda = Sw/St \dots \dots \dots (2)$$

here, Sw: within-class sum of squares, St: total sum of squares. The smaller ($\Lambda < 1.0$) it is, the more effective the discrimination is. With landslides classified above in this study, $\Lambda = 0.577$ is gained. And it is reduced to F-distribution's "F" (Okuno et. al. 1971), and it is given as $F = 4.04$ in this case. This value is larger than $F(0.025) = 3.44$ for 2.5% significance level, i. e. these geological groups mentioned above are discriminated efficiently on the significance level of 2.5%. The scattered diagram is given in Fig. 4, as well. From this diagram, the "D" difference by geology i. e. landslide risk level difference is distinct, although Hokutan-Teragi Formation has certain variance in D.

(1) Northern Hyogo

(3) Northern Hyogo, Eastern Tottori etc.

(2) Northern Hyogo, Sanda, Southern Awaji Island

(4) Eastern Tottori, Northern Okayama etc.

Fig. 2 Box Counting Diagram (Relation between $N(\eta)$ and η).

(1) Northern Hyogo

(4) Northern Okayama

(2) Northern Hyogo, Sanda Basin

(5) Serpentine Zone, Jōetsu

(3) Eastern Tottori

(6) Serpentine Zone

Fig. 3 Samples of the landslides landform (Typical examples).

Fig. 4 Scattered Diagram of "D" for the Each Geology.

Tab. 1 Landslide Fractal Dimension of Each Area.

No.	Area Name	Geology	D	r	NL
1	H,Takeno 1	HT	1.34	-0.999	18
2	H,Hidaka 1	HT	1.19	-0.999	4
3	H,Muraoka 1	HT	1.15	-0.999	7
4	H,Muraoka 2	HT	1.35	-0.999	13
5	H,Muraoka 3	HT	1.27	-0.999	20
6	H,Muraoka 4	HT	1.29	-0.999	18
7	H,Muraoka 5	HT	1.26	-0.999	19
8	H,Muraoka 6	HT	1.46	-0.999	53
9	H,Mikata 1	HT	1.13	-0.997	8
10	H,Mikata 2	HT	1.27	-0.997	12
11	H,Yoka 1	HT	1.14	-0.999	13
12	S,Kobe 1	KOBE	1.33	-0.997	11
13	S,Kobe 2	KOBE	1.20	-0.999	16
14	S,Takarazuka 1	KOBE	1.35	-0.999	17
15	T,Tottori 1	TORI	1.36	-0.999	40
16	T,Kawahara 1	TORI	1.33	-0.999	18
17	T,Kawahara 2	TORI	1.37	-0.996	7
18	T,Kawahara 3	TORI	1.34	-0.999	7
19	T,Koge 1	TORI	1.34	-0.999	10
20	T,Saji 1	TORI	1.32	-0.9995	13
21	O,Nagi 1	KATSU	1.22	-0.991	5
22	O,Nagi 2	KATSU	1.00	-0.999	11
23	O,Nagi 3	KATSU	1.23	-0.976	8
24	O,Nagi 4	KATSU	1.12	-0.994	14
25	Sp,Hino 1	SS	1.22	-0.997	19
26	Sp,Mikamo 1	SS	1.18	-0.998	37
27	A,Nantan 1	SS	1.18	-0.999	26
28	J,Itakura 1	TS	1.39	-0.997	32

Regent

Area; H:Northern Hyogo, S:Sanda Basin, T:Eastern Tottori, O:Northern Okayama, Sp:Serpentine zone, A:Southern Awaji Island, J:Niigata Jo-etsu Area.

Geology; HT:Hokutan-Teragi Formations, KOBE:Kobe Formations, TORI:Tottori Formations, KATSU:Katsuta Formations, SS:Serpentine-Shattered zone, TS:Teradomari-Shiia Formations.

r: correlation coefficient, NL: numbers of the landslides.

5. Conclusion

As it is discussed so far,

① Fractal Dimension "D" takes the value of approximately 1.0 to 1.5 in the area above,

② each geology groups are distinguished by "D" that means landslide risk level, and it is obvious with the significance level of 2.5% by multi-discriminant analysis,

③ therefore it can be available to acquire the susceptibility, especially the risk level for landslides concerning with geology.

Thus, it should be the important index to landslide risk level investigation including primary landslides at least for the specific area mentioned above, and it is believed that this study offers the effective information for landslide risk analysis.

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地すべりの地形、地質および変質特性—北海道紋別郡生田原町東部地域の例—

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前田寛之

北海道紋別郡生田原町東部地域の 29 の古期地すべり地形のうち、22 が上部中新統生田原層および矢矧層分布域にあることが確認された。これらの分布は、褶曲構造、同斜構造、キャップロック構造などとともに、熱水変質帯分布に強く規制されていた。熱水変質帯で起こる地すべりを“熱水変質帯地すべり”と呼ぶことにすると、これが膨張性粘土鉱物で特徴づけられるセリサイト/スメクタイト混合層鉱物帯およびスメクタイト帯と、カオリン鉱物帯とに分布していたことは地すべりの熱水変質特性として注目に価する。

定常浸透状態における水中重量法と一般分割法の計算式

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古谷 保

斜面安定解析における定常浸透状態の水中重量法として、動水勾配を考慮して浮力ベクトルの方向を修正する方法を提案し、この方法が間隙水圧や貯水圧、側面水圧などの水圧を個別に計算する方法と実質的に同じ結果を与えることを示した。またこの方法における一般分割法の式を提案している。そしてモデル断面について安全率の計算を行い、この式が一般分割法として、Morgenstern-Price 法や Spencer 法と同じ結果を与えることを示した。

ファジィネスを考慮した質点系モデルによる崩土の流下範囲の予測

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吉松弘行

崩土の流下範囲予測のため、解析モデルの現実斜面の崩土挙動との不一致性及び斜面特性因子の計測誤差をファジィネスとして流下範囲の可能性について、質点系モデルによる解析を実施し、流下時の流動抵抗力が重要であることを示した。

東北地方の新第三紀・泥岩層における褶曲及び断層構造の成因と地すべりとの関連性

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阿部真郎

我々は東北地方・グリーンタフ地域の地すべり多発地点において地すべりに関連して形成された褶曲、断層構造をいくつか確認した。これらは、泥岩堆積当時の海底地すべり、第四紀以降の初生の岩盤すべり及び現在に至る地盤隆起などによって形成されたものである。

A Study on the Fractal Dimensions and Geological Condition of Landslides

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久保田哲也

本研究では、地すべり被災危険度の高さがその発生形態の複雑さに比例すると考え、地すべり面積率や箇所数では表現できず、これまで定性的にのみ表現されて来たこの発生形態の複雑さを定量的に表現する幾何学の新しい概念であるフラクタル次元 D (Fractal Dimension) と地質の関係を研究した結果、実際の地すべりでは D に関して地質ごとに判別可能な程度の有意な差をもち、初生地すべり危険度調査指標として地質情報から D すなわち発生形態を含めた地すべりの概略の危険度を定量的に判断し得ることが明らかとなった。

地すべり地におけるすべり面形状の推定に関する検討

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丸山清輝

本研究では、現在移動を停止している地すべりのすべり面調査にも適用できるすべり面形状推定法を提案することを目的として、曖昧さが伴っているボーリングコア観察結果に、地すべりブロックの形態とすべり面深度との統計的關係及び臨界すべり面解析結果を加え、地質学的及び工学的に妥当なすべり面形状の推定法について検討した。

弱面探査による新規地すべりの予知

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玉田文吾、福田順二

地層中のある部分に、地質構造に起因する不連続な弱面帯が分布することがあり、これを潜在 (すべり) 域と言う。この領域に連続したせん断面が形成されると地すべりが発生する確率が高く、同時に大規模な地すべり程、前兆が現れるケースが多い。地すべり予知の第一歩は地層中に潜在域が分布するか否かを把握することである。

本文は、試験過程における弱面 (地すべり面) 探査装置の原理と構造、および探査例などについて説明、予知に有効な探査地点の選定方法を地形、地質構造の観点から述べたものである。

飽和—不飽和浸透流解析による集水井工の評価

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亀井健史、榎本雅夫

地すべり対策工のなかで抑制工に分類される集水井工に関しては、その設置位置等を含め定量的な評価はなされていない。本研究では集水井が斜面内の間隙水圧挙動に及ぼす影響を把握するため、砂および粘性土から成るモデル斜面を対象に飽和—不飽和浸透流解析を行った。その結果、集水井の設置位置が斜面内の間隙水圧挙動および浸透流に与える影響を定量的な観点から明らかにしている。