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Expansion Characteristics of Bamboo Stand and Sediment Disaster in South Western Japan

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Abstract: The expansion of bamboo stands especially in the southwestern part of Japan has severe problems; invasion into reforested area will cause devastation of forest area and subsequently leads to the possibility of the occurrence of the slope failures. By the interpretation of aerial photograph, we have recognized many slope failures on the event of 1998 heavy rainfall disaster in Kochi prefecture. Out of the 59 points, about 1/3 of them were associated with bamboo stands. Thus, we have begun to investigate the relation between the bamboo expansion and the occurrences of sediment disasters. This study was done by the interpretation of aerial-photographs of Haruno town taken in 1962 and 1998. Based on the interpreted data, the expansion rate of bamboo stand in the study area was 204.02% (almost double) during the period of 36 years. Numbers of bamboo stands were also increased, area category size of 1000-2000 m^2 were the highest in number. Distribution of the expansion of bamboo stand was analyzed from the morphological point of view and the result shows that bamboo patches were towards the North Slope face under less than 30% slope gradient. By the fractal analysis in use of box counting method, the spatial distribution characteristics of bamboo stands in the study area were explained by the fractal dimension. The fractal dimension in 1962 is D = 1.54 and that of in 1998 is D = 1.60 and the increment of the number of bamboo stands as well as the area is expressed by the decrease of the fractal dimension.

Key words: Bamboo stands, expansion rate, fractal characteristics, sediment disaster, aerial photograph interpretation

INTRODUCTION

Bamboo stand in the fringe of city area shows chaotic expansion in southwestern Japan. Expansions are due to the indifference and the abandonment of the management of bamboo groves and have problems; like: ineffective use of productive lands, disturbance in forest biodiversity etc, invasion into reforested area will cause devastation of forest area and subsequently leads to the possibility of occurrence of slope failures. Japanese government had set up the forest policies to increase the plantation areas and recommended to use coniferous tress Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obtusa*) for reforestation all over the Japan in 1960s so that the total plantation areas were increased (Dura and Hiura, 2002). At present, these reforested forests have already passed the standard harvesting age. During last two decades, the forestry and wood industries in Japan faced difficult conditions; i.e., stagnation of timber prices, difficulties in maintaining labor force and competition with imported timber and wooden products. Under these economic and social conditions, the activities of management, maintenance and improvement of forests are gradually going down. Further more the declined number of people and aging of those who were engaged in the forest works have caused the increase of careless forests. Migration tendency towards urban areas and unwillingness of young people to be engaged in forest works also created the condition worse. Even agricultural lands are also left abandon in some places of hillsides.

The elongation growth of bamboo is very rapid and it takes only one or two months for young sprouts to reach canopy height of about 10 m, even under shady conditions. Wild pigs and deer feed on newly developed shoots and leaves and peel the bark. Wild pigs dig and feed on roots also. Because of these traits of bamboo and wild animals, tree seedlings are diminished and the biodiversity of forests is decreasing. In the future, these forests will be threatened. Thus, disturbances of

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regeneration by these biotic factors are becoming a serious problem in Japan.

Bamboo is popularly known as poor man's timber and plays an important role in the socio-economy of rural people as it has since ancient times (Singh *et al.,* 2003). It has multiple uses such as for construction, fuel, fodder, food, utensils, fencing, religious ceremony, paper manufacturing, craft, rope etc. Approximately 1500 commercial applications of bamboo have been identified mostly in Asia (Scurlock *et al.*, 2000). Bamboo shoots, both in raw and fermented forms, are largely consumed by the people and can earn a large share of household economy (Singh *et al.,* 2003). Bamboo shoots of a number of species are a well-known feature of Chinese and other Asian cuisine (Scurlock *et al*., 2000). One kind of bamboo "Mosochiku" (*Phyllostachys pubescens*) originally from China was introduced to Japan about 1750 for shoot purpose (Scurlock *et al*., 2000). Japanese people believe that the bamboo stand has the preventive function against natural disaster especially floods and earthquakes. Since ancient time, the function of the bamboo stand was well known in Japan. When bamboos are planted along the bank of river in strips, it protects the bank from erosion and breakage with the cluster root system. During flooding, water flowing into the bamboo stands results deposition of sediments due to the filtering effect of bamboo groves and consequently the clean water flows into the surrounding area with less damage. Japanese people have been taught to evacuate into bamboo stands in case of the occurrence of the earthquakes. The network of tightly weaved root system covering seamless above the ground surface guards people inside the bamboo stand on the cracked earth. In case of Tsunami also, bamboo stand is known to work as an effective raft. Other than these, bamboo stand could be an index of the existence of the ground water or the spring point in the landslide area because bamboos require abundant water for growing.

Bamboo species and uses in Japan: Bamboos are an amazing plant. Many people think of it as a tree since it grows to the size and height of a tree, but in fact bamboos are a group of woody perennial evergreen plants in the grass family Poacea and subfamily Bambusoideae. Over 75 genera and 1250 species of bamboo are reported to occur worldwide (Shanmughavel and Francis, 1996). Among them *Arundinaria* sp., *Bambusa* sp., *Chimonobambusa marmoreal*, *Pleioblastus* sp., *Phyllostachys* sp., *Pseudosasa owatarii*, *Sasa* sp., *Semiarundinaria* sp., *Sinarundinaria nitida*, *Shibataea kumasaca*, are the most important ones present in Japan. Japanese have recognized hundreds of varieties of bamboos and three are the most commonly distributed. *Phyllostachys bambusoides* (Madake in Japanese name) is the most widely spread species in Japan and *Phyllostachys pubescens* (Moso-chiku) is said to be the best for shoot consumption. Next one is *Phyllostachys nigra* va. henonis stapf (Hachiku). Though bamboo has multiple uses, but at present, it is mainly used for shoot consumption in Japan. Other uses are as for ornamental plants; charcoal, to make chopsticks, mats, fishing rod etc.

Table 1 show that the area of Moso (*Phyllostachys pubescens*) was increased gradually where as it was reverse in case of Madake (*Phyllostachys bambusoides*). It indicates that the main use of bamboo may be for shoot purpose because; Moso is the best variety for shoot consumption.

Besides the above functions, the main focus is on the role of bamboo stands when the sediment related disaster as slope failures or debris flows occur. In September 1998, many slope failures and debris flow had occurred in and around Kochi city due to the heavy rainfall. In most of the landslide sites, bamboo stands of Mosochiku were found at or very close to the site. With this scenario, a thorough study on the relation of bamboo growth to the landslide disaster was deemed necessary. Very few studies have been carried out focusing on the occurrence of sediment related disasters in the bamboo areas.

Hiura *et al.* (2004) have indicated the possibility of the occurrence of sediment related disasters in the bamboo stand area. By the interpretation of aerial photograph of Kochi city area, bamboo stands were found to be associated with landslides followed by heavy rainfall in 1998. Total 59 landslide points were interpreted on the photograph and among them 17 were associated with bamboo stands that were about 1/3 of the total. According to the results of Kochi disaster, focus was on the possibility of the occurrence of the sediment related disaster in the form of slope collapse and three typical

Table 1: Area distribution (ha) of 3 main bamboo species in Yamaguchi prefecture

	1962		1970		1975		1985		1997	
Year	Area	(%)	Area	(%)	Area	(%)	Area	(%)	Area	(%)
Hachiku	595	5	521	3.76	1050	11.70	1115	13.31	1182	10.44
Moso	1784	15	4538	32.71	3322	37.03	3767	41.60	5785	51.08
Madake	9515	80	8813	63.53	4600	51.27	4175	46.10	4359	38.49

Source: By CORVAC

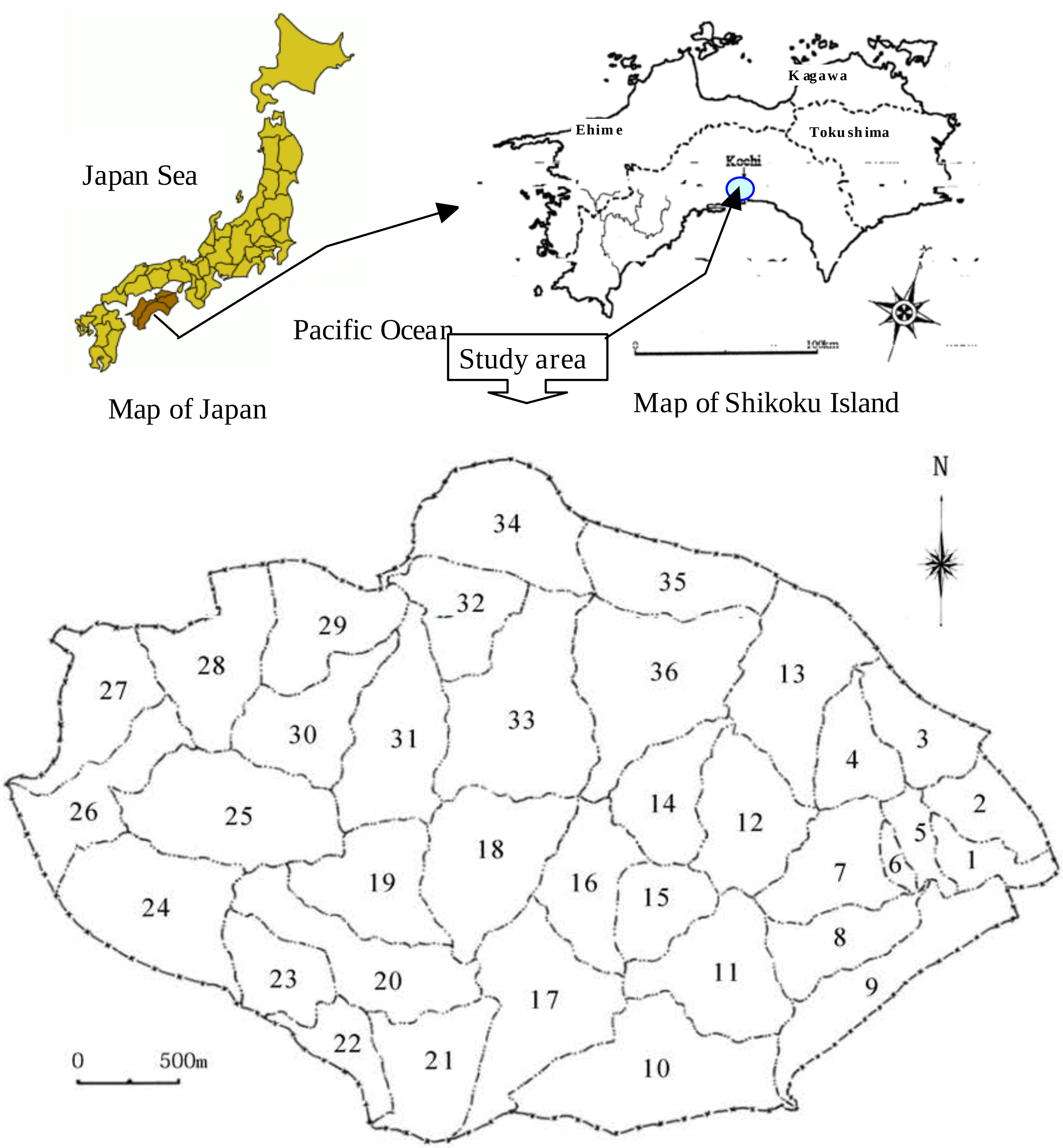

Fig. 1: Location map of the study area showing different sub-watershed areas

collapse models were proposed. A characteristic of bamboo root mat system by modeling is a superficial porous media. So rainfall water penetrates easily in the sub-surface soil layer and flow generates along the inclination of a slope.

The objective of this study was to find out the area expansion characteristics, spatial and size distribution characteristics of the bamboo stands, which will contribute to the understanding of the place preparing occurrence of sediment disasters in the study area in the near future.

Study area: The study area is located at Haruno town in the southern part of Kochi Prefecture, Shikoku Island, Japan. Figure 1 shows the location map of the study area. Haruno town has a total surface area of 44.94 square kilometers (Shivam, 2002). Out of that total area, only 1345.32 ha forest area within the boundary of 36 small sub-watersheds containing 230 bamboo stands was selected for the study. The regional climate in the study area is characterized by warm and humid summers and cold and dry winters. The highest temperature in summer is about 37 degrees Celsius, while the lowest is about minus (-) 4 degrees Celsius in winter. Precipitation in the area occurs mainly as rains and cyclonic storms in summer and autumn often causes a large surface runoff. The annual average precipitation in the area is approximately 2600 mm, whereby about 50% of the precipitation occurs during July to October (Shivam, 2002).

METHODS AND MATERIALS

Necessary data was prepared by the interpretation of two different period's aerial photographs taken in 1962 and 1998 (Fig. 2). 1:5000 scale aerial photographs was used for the interpretation and the same scale of topographical map was used to plot the interpreted data (Fig. 3). Total study area was divided into 36 sub-watersheds (Table 2) based on drainage system and the total bamboo stands were numbered into 230 stands based on the expansion characteristics of the bamboo stands. Measurement of the area of sub-watersheds and bamboo stands were done by planimeter. Box counting method was applied for analyzing the fluctuation of spatial distribution characteristics of bamboo stands.

RESULTS AND DISCUSSION

Based on the interpretation of 1962 and 1998 aerial photographs following results were obtained. Watershed numbers, bamboo area in 1962 and 1998 and increment ratio are shown in Table 2.

Morphology and the bamboo stand: Highest numbers of bamboo stands i.e., 31.2% are present in the North Slope face where as 26.6% are in the south face (Table 3). Like wise highest number of bamboo stands (61.35%) are in the low slope percent along the site of streams (42.2%) and least (3.19%) are in the high slope percent along the site of ridges (19.15%) (Table 3). These results show that the bamboo stands thrives on north face, low slope percent and along the sites of streams.

Table 2: Watershed numbers and increment ratio

Watershed No.	Bamboo area (sq. m) 1962	Bamboo area (sq. m) 1998	Area increment ratio	Watershed area (sq. M)	Bamboo area (%) 1962	Bamboo area (%) 1998
1	730.91	4804.69	6.57	118335.77	0.61	4.06
2	1042.00	8190.64	7.86	167728.22	0.61	4.82
3	17624.56	39685.24	2.25	208395.86	8.45	19.04
4	19021.31	55634.56	2.92	188179.21	10.10	29.56
5	18611.30	38605.17	2.07	90498.51	20.56	42.65
6	1707.13	2919.31	1.71	33501.5	5.09	8.71
7	32531.43	73268.42	2.25	267129.41	12.17	27.42
8	19855.47	55801.04	2.81	222219.75	8.93	25.11
9	640.40	8776.54	13.70	343606.93	0.18	2.55
10	4349.75	3211.63	0.73	533674.53	0.81	0.60
11	21572.58	40460.73	1.87	348064.36	6.19	11.62
12	22463.31	61500.67	2.73	327647.95	6.85	18.77
13	38173.24	62989.11	1.65	432003.96	8.83	14.58
14	10728.61	22979.78	2.14	240014.62	4.46	9.57
15	9881.72	25040.85	2.78	181119.99	4.95	13.82
16	24752.13	60665.79	2.45	267887.51	9.23	22.64
17	6807.66	18904.00	2.77	476847.93	1.42	3.96
18	58687.21	155518.12	4.64	427183.03	13.73	36.40
19	23904.44	39668.60	1.65	318041.46	7.51	12.47
20	54237.21	123408.16	2.27	369103.76	14.69	33.43
21	35476.11	53306.97	1.50	303150.88	11.70	17.58
22	10509.60	20537.48	1.95	147003.79	7.14	13.97
23	10664.40	29763.55	2.79	198490.27	5.37	14.99
24	14159.44	32042.51	2.26	162658.83	8.70	19.69
25	21864.74	49947.04	2.28	483426.56	4.52	10.33
26	13836.42	31806.23	2.30	293406.74	4.71	10.85
27	24081.83	25978.85	1.07	296990.99	8.21	8.86
28	34407.81	47325.77	1.37	352166.36	9.77	13.43
29	18436.18	24980.24	1.35	305073.72	6.04	8.18
30	18060.23	18054.55	0.99	2853978.85	0.63	0.63
31	13875.23	52723.70	3.79	406860.3	3.41	12.95
32	14882.00	29593.70	1.98	241295.25	6.16	12.26
33	47705.49	78807.83	1.65	584135.1	8.16	13.49
34	10360.70	16826.22	1.62	406078.46	2.55	4.14
35	62761.10	95157.09	1.51	310718.21	20.19	30.62
36	32191.39	61441.98	1.90	548672.62	5.86	11.19
Total	769695.07 (76.96 ha)	1570380.76 (157.03 ha)	2.04026 204.02%	1353291 (1345.32 ha)	5.72	11.67

Fig. 2: Part of the aerial photograph of Haruno town area taken in 1998

Distribution of bamboo stands in 1962

Distribution of bamboo stands in 1998

Fig. 3: Comparative maps of bamboo stands distribution

Table 3: Morphology and bamboo stands

Stop face	Number of small bamboo patches	Percent
North	88	31.20
South	75	26.60
East	62	21.99
West	57	20.21
Total	282	100.00
Morphology		
Stream	119	42.20
Ridge	54	19.15
Others	54	19.15
Stream+ridge	55	19.50
Total	288	100.00
Slope		
High (>61%)	9	3.19
Medium (31-60%)	100	35.46
Low (<30%)	173	61.35
Total	282	100.00
Location		
Forest area	142	50.36
Settlement	48	17.02
Field	87	30.85
Grassland and others	5	1.77
Total	282	100.00

Table 4: Changes of the scale of bamboo forest in Kyoto prefecture by Torii and Isagi (1997)

	Tanabe town (Area 1934 ha)			Yamashiro, Ide town (Area 1539 ha)		
Year	1953	1975	1985	1953	1975	1985
Number of bamboo stands	24.00	112.00	174.00	40.00	66.00	86.00
Mean area of a single stand	0.73	1.42	1.59	1.36	5.24	5.03
Total area of bamboo stands	17.00	159.00	277.00	54.00	346.00	432.00
Number of no-bamboo forest stands	23.00	42.00	53.00	23.00	42.00	48.00
Mean area of a single stand	41.95	20.41	14.70	29.84	16.84	13.37
Total area of non-bamboo stands	965.00	857.00	779.00	686.00	707.00	642.00
All total (bamboo + usual forest)	982.00	1016.00	1057.00	741.00	1053.00	1074.00

Distribution characteristics of bamboo stands

Area expansion rate or increment ratio: Out of the total study area (1345.32 ha) of Haruno town, 76.96 ha (5.72%) area was covered by the bamboo stand in 1962, where as it was increased by 157.03 ha (11.67%) in 1998. So total area expansion rate during 36 years period was 204.02% that is almost double (Table 2). The highest area increment ratio of bamboo stand was under the class increment ratio of less than two i.e., 60.28%. Figure 4 shows the highest number of bamboo stands under the same increment class ratio.

One study conducted by Torii and Isagi (1997) in Kyoto prefecture, Japan shows that areas of bamboo forest in Tanabe town and Yamashiro, Ide town was increased by 16.29 times or 1629.41% and 8 times or 800%, respectively (Table 4) during 32 years (1953~1985) period. This result of expansion rate of bamboo forest area in Kyoto prefecture seems extremely high and non-bamboo forest areas are decreasing gradually. If this tendency remains constant, then it may create serious problem there.

Forest resources statistical data of Kochi prefecture shows that the expansion rate of bamboo forest in Kochi

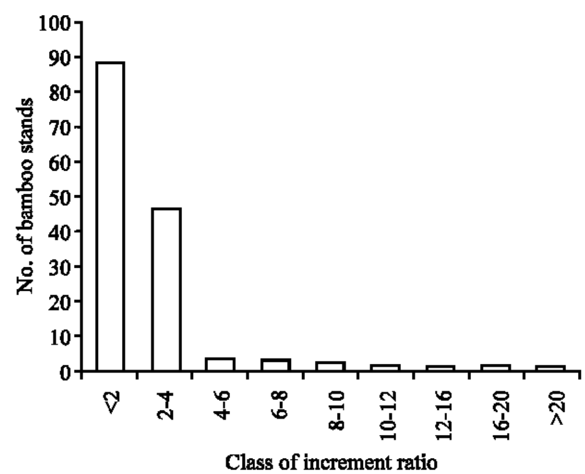

Fig. 4: Expansion rate of bamboo stands

prefecture is also high (115.56%) but other forest area is slightly increased (103.19%) during 25 years (1965-1990) period (Table 5). Another statistical data shows that the area of bamboo forest in Kochi city is also increased by 168.39% but other forest area is slightly decreased. The tendency of increment of bamboo forest areas and

Table 5: State of forest resources of Kochi prefecture

Year	Forest area other than bamboo (ha)	Bamboo forest area (ha)
1965	563888	3868
1978	569119	4003
1990	581917	4470

Ref: Association of statistics of Kochi prefecture

Table 6: State of forest resources of Japan

Year	Forest area other than bamboo (ha)	Bamboo forest area (ha)
1957		168406
1965	24486377	171140
1975		122702
1978	23623429	146700
1990	24587692	145236

Ref: Association of statistics of Kochi prefecture

Table 7: State of forest resources of Kochi city and Haruno town

	Kochi city		Haruno town	
Year	Forest area other than bamboo (ha)	Bamboo forest area (ha)	Forest area other than bamboo (ha)	Bamboo forest area (ha)
1965	5294	212	1803	140
975	4792	275	1646	127
1999	5149	357	1527	142

Source: Association of statistics of Kochi prefecture

Table 8: Distribution pattern of the size of bamboo stands

Area category	No. of bamboo stands	
(x100 m^2)	1962	1998
<5	8	0
5-10	35	20
10-20	43	43
20-30	30	34
30-50	26	36
50-70	11	18
70-90	6	10
90-110	5	4
110-150	3	8
150-200	4	7
200-300	5	6
300-500	1	6
500-600	1	1
600-1000	0	4
>1000	0	1
Total	178	198

decrease of other forest areas are almost the same in case of whole Haruno town area like as in Kochi city (Table 7). As a whole in Japan, area of non-bamboo forest shows less fluctuation but as for the area of bamboo is decreasing (Table 6). It is due to the development and expansion of residence areas in urban where bamboo stands exits. Mostly, the settlements are on the foothill sides in Japan and the bamboo stands are close to the residence areas. In Kochi city also the development of the surrounding area is same as in other parts of Japan. The area ratio of bamboo forest and other forest in Haruno town is 140/1803 (or 0.07) in 1965 and 142/1527 (or 0.09) in 1999 (Table 7). So Haruno town shows temporal decrease of bamboo area in 1975. This is due to the development for the residence area, thus the bamboo area showed temporal decrease. Amazing thing is that the fluctuation of bamboo area which shows 140 ha in 1965 and decreased to 127 ha in 1975 and increased by 142 ha in 1999 (Table 7). This will be the proof of high expansion rate of bamboo areas. The study area also exists in Haruno town so the result of the study shows the present state of bamboo areas.

Distribution characteristics and size of bamboo stand area: Sizes of the area of bamboo stands were classified into 15 categories ranging from less than 500 m^2 to more than 10 ha. The highest number of bamboo stands was under the area category class of 1000-2000 m^2 both in 1962 and 1998 (Table 8). Number of bamboo stands and sizes were increased in 1998 as compare to the year 1962. In 1962, the biggest and the smallest size of bamboo stands were 58451.27 and 166.17 m^2, respectively. In 1998, they have expanded by 115906.89 and 507.93 m^2, respectively. According to the aerial photograph interpretation, it was recognized that some bamboo stands that were seen on the photograph of 1962 were disappeared and some new additional were appeared in 1998. Thus, it can be recognized that some bamboo stands which were so small but abundant will be combined each other due to the expansion of areas during that 36 years period. Based on the distribution pattern of the size of bamboo stands indicated in Table 8, tendencies of the size change of the bamboo stands; the bamboo stands whose area is less than 1000 m^2 have decreased during 36 years and the area less than 500 m^2 has disappeared.

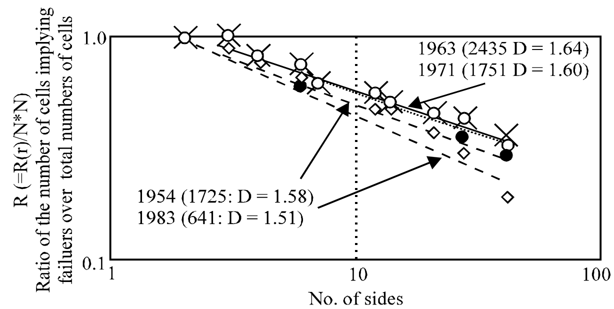

Fig. 5: The fluctuation of the spatial distribution of shallow slides expressed by the fractal dimension (by Hiura *et al.*, 2004) {Year (number of slides), D = fractal dimension}

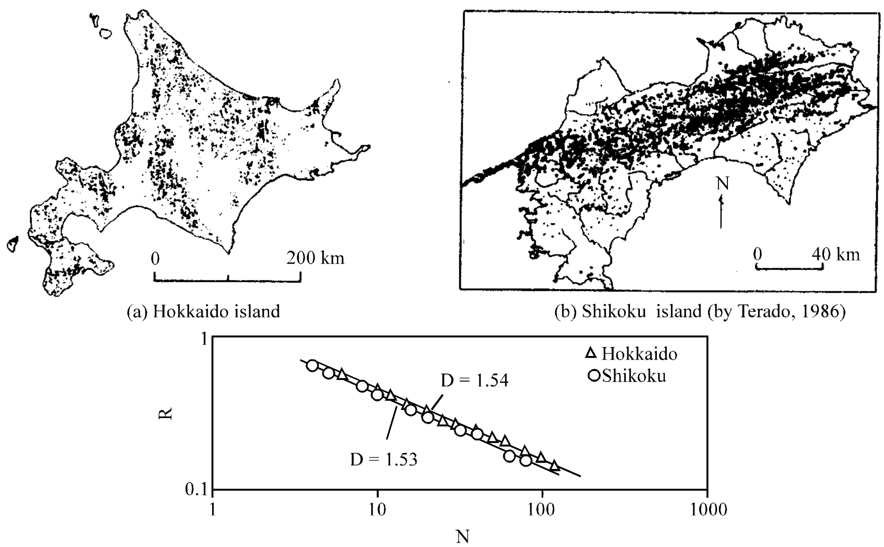

Fig. 6: Distribution and the fractal dimension of landslides by way of the Box-counting method

Fractal characteristics: The self-similarity is the important concept of fractal. The term "fractal" comes from Latin "fractus" expressing the state of the accumulation of a broken stone, which is fragmented and irregular shaped. Mandelbrot (1967) has shown that the geometry of a coastline is fractal. Because of scale invariance, the length of the coastline increases as the length of the measuring rod decreases according to a power-law; the power determines the fractal dimension of the coastline. The self-similarity manifests itself in the power-law. In a fractal distribution the number of "objects", which are larger than a specified size have a power-law dependence on the size. While it is not clear that a single mathematical definition can compass all aspects of fractals, a fractal set is generally defined as the relation below.

$$N\,(R) = C / R^{D}$$

Where, N (R) is the number of objects with a characteristics linear dimension R, C is a constant of proportionality, and D is the fractal dimension. For example, the size distribution of the earthquakes, it corresponds to Gutenberg-Ritchter's magnitude-frequency relation. Incase of the special distribution of the hypocenter, N (R) is the number of events within the distance R from a given event.

Since the original introduction by Mandelbrot, many geological phenomena as frequency-size distributions of rock fragments, faults, earthquakes, volcanic eruptions, mineral deposits, oil fields and forming forks of rivers have been studied and are proven to have the fractal dimension, in other words, "the fractal structure". The two dimensional special distribution of the landslides is also expected to have the fractal structure. Hiura and Fukuoka (1993) have investigated on the spatial distribution characteristics of landslides in Hokkaido Island (Fig. 5 and 6).

Box counting method and fractal dimension: Figure 5 and 6 show the results of box counting method to investigate the distribution characteristics of shallow slides and landslides respectively. The box counting method is the most common way to find whether the

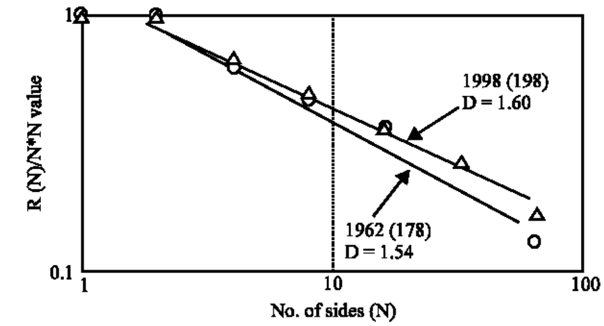

Fig. 7: Distribution of bamboo stands by the Box-counting method

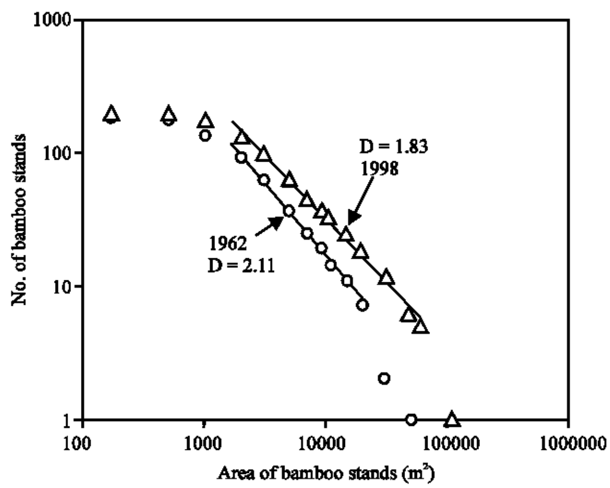

Fig. 8: Histogram of bamboo stand size distribution

spatial distribution has fractal structure or not (Hiura and Fukuoka, 1993). At first the whole study area is enclosed by a large regular square and after that the large square is divided by different size of square cells, respectively. The number of total cells, the number of cells including landslides and those without landslides for each cell size are counted. The results are plotted on the log-log diagram. Where, the abscissa N indicates the division number of the side of the large squares. The ordinate R indicates the ratio of the total number of meshes including landslides to the total number of meshes for each mesh size. Even a mesh, which includes only one landslide, should be counted. If the distribution has the fractal structure, the relation of R and N has following power-law form $R = N^{D-2}$.

Here, D is the fractal dimension. On Fig. 6, the fractal dimension D = 1.54 in Hokkaido and D = 1.53 in Shikoku. Thus, the distribution of the landslides in Hokkaido Island as well as Shikoku Island has a fractal structure. From Fig. 5, when the number of shallow slides increases, then the fractal dimension D increases, while in case of the decrease of the number of shallow slides, the fractal dimension decreases. And from Fig. 6, even in two different districts where the distribution status is similar, then the value of fractal dimension becomes similar.

Table 9: Size distribution of bamboo stands

Category area m² >	No. of bamboo stands > category 1962	1998
166	178	198
500	170	198
1000	135	178
2000	92	135
3000	62	101
5000	36	65
7000	25	47
9000	19	37
11000	14	33
15000	11	25
20000	7	18
30000	2	12
50000	1	6
60000	0	5
110000	0	1

Similarly, on Fig. 7 which indicates the spatial distribution of the number of bamboo stand, the fractal dimension D = 1.54 in 1962 and D = 1.60 in 1998, respectively. This tendency seems to be due to the increase of the bamboo stands during 36 years, thus D value becomes bigger as well as that of shallow landslides. As indicated in Table 9, the number of smaller bamboo stands becomes bigger and also the size of bigger bamboo stands becomes larger together with jointing each other. By the similar way of earthquake occurrence analysis given by Gutenberg-Richter law, in Fig. 8, the abscissa indicates the area and the ordinate is the number of bamboo stands bigger than the area indicated by the abscissa. As the power law can be seen in case of size distribution of bamboo stand, this also has the fractal structure. More the number of bamboos stand increases, and then the fractal dimension has less value. This is the contradictory tendency against the spatial distribution as shown in Fig. 7.

Distribution characteristics of the expansion of bamboo stand were analyzed from the morphological point of view. Following things were recognized:

- Based on the aerial photograph interpretation, the distribution characteristics of the bamboo patches were towards the North Slope face, along the streams, and under less than 30% slope gradient.
- Though the expansion rate of the bamboo stands in the study areas were high that was almost double (204.02%) during 36 years (1962-1998) but the result of the study shows the present state of bamboo areas.

- Spatial distribution of the number has the fractal characteristics and when the number of bamboo stands increases, the fractal dimension D increases, whereas the size distribution behaves as the magnitude-number distribution characteristics of earthquakes and has less value of D with the expanded state of bamboo stand.

All most all mountains of Japan have very good forest cover especially with reforested coniferous forests. It is also same in the study area too. But, high expansion rate of bamboo stands may cause devastation of forest areas and subsequently leads to the possibility of the occurrence of sediment related disasters especially in southwestern Japan. Consequently the proper management of bamboo stand is necessary. For this, other commercial uses of bamboo except shoot consumption should be introduced so that people pay attentions towards the management of it. Bamboos are recognized as the fastest growing plants (5-100 cm/day), having high photosynthetic efficiency and low photorespiration, their culms mature and acquire full strength and density in about 2-3 years (Singh *et al*., 2003).

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