Relationship between the fractal dimensions of debris-flow paths and the soil particle size distributions

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Introduction

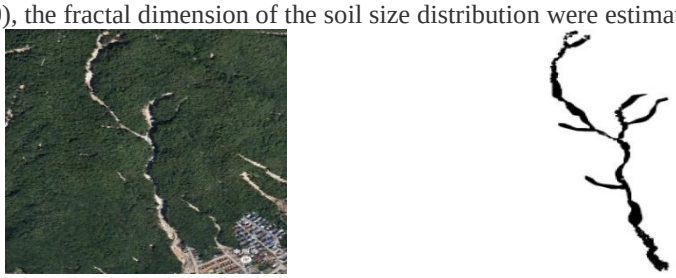
Fractals are defined as a geometrical set whose Hausdorff- Besicovitch dimension strictly exceeds the topological dimension. Most of biological and natural features tend to have a fractal dimension(Pentland, 1984). On 20 August 2014, Hiroshima prefecture was struck by a series of debris flows following the heavy rain. We have done field work for 4 sites of debris flow in Hiroshima including Yamamoto area, Midorii area, Hachiboku area, Kabehigashi. And eight soil samples from these areas were obtained to analyze the particle size distribution. In this paper, first we estimated the fractal dimension of the debris flows using the image of debris flow from google map using the box-counting method. Then, we analyze the soil samples to get the soil composition particle size distribution. At last we got the results indicate that the more fine particles the debris have, the less the FD value is, like Midorii and Hachihigashi. On the contrary, the more coarse particles the debris have, the bigger the FD value is, like Yamamoto area.

Method

The first box-counting method is described as formula (1), assumed the shape taken into account is a bounded set in Euclidean space (Mandelbrot, 1982). The fractal dimension describes how many new pieces of the set are resolved as the resolution scale is decreased. Since a fractal is isotropic due to self-similarity, the fractal dimension could be estimated through any two directions.

$$D = -\lim_{r \to 0} \frac{\log N_r}{\log r} \tag{1}$$

where D is fractal dimension, r is the side length of a box, N_r is the least number of boxes to cover the shape by box with side length r. As shown in the Figure 1, the Figure 1a is the debris flow in Midorii area, figure 1b is the extracted debris flow path. From this path, using the box-counting method the fractal dimension could be obtained. In addition using the van Genuchten model (Van Genuchten, 1980), the fractal dimension of the soil size distribution were estimated.



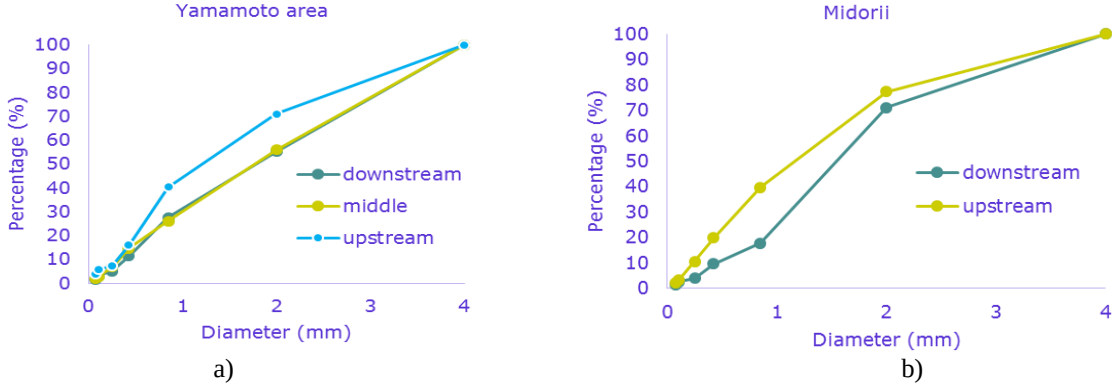
a) b)

Figure 1 Extracted debris flow path

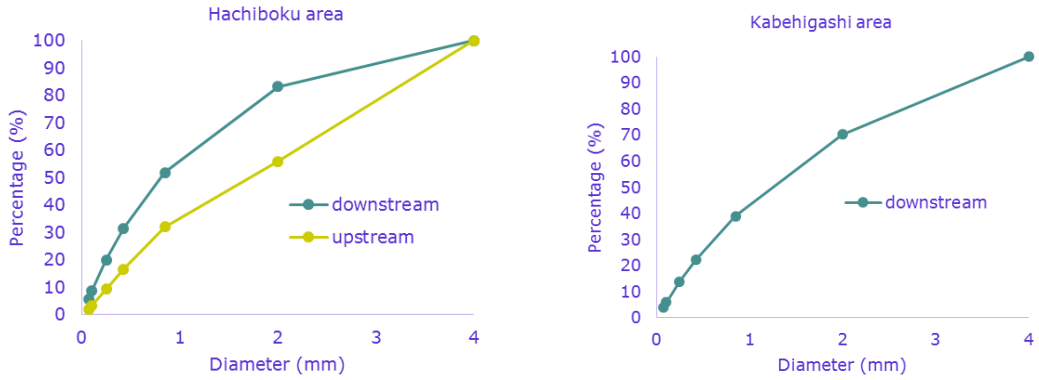
Results

Soil size distribution for four areas

Figure 2a shows the debris flow in Yamamoto area. There are 3 soil samples for this debris flow, which were taken from downstream， middle area and upstream respectively. The green line represents the downstream. The orange line represents the middle area. And the blue line represents the upstream area. Obviously, we can find the downstream area and the middles area has almost the same particle size distribution. However, in the upstream there is more fine particles with diameter less than 2mm. This results about the debris flow in Midorii is shown in figure 2b. There are 2 soil samples for this debris flow, which were taken from downstream and upstream. The green line represents the downstream. The orange line represents the upstream. Obviously, in the upstream there is more fine particles smaller than 1mm. Figure 2c shows about the debris flow in Hachiboku area. There are also two soil samples for this debris flow, which were taken from downstream and upstream. The green line represents the downstream. The orange line represents the upstream. Obviously, in the upstream there is more fine particles smaller than 2mm. This results about the debris flow in Kabehigashi area is shown in figure 2d. There are only one soil sample for this debris flow. Figure c shows the particle size distribution for the sample, which were taken from downstream. From the figure, we can found the fine particles with diameter less than 2mm is about 70%.



a) b)



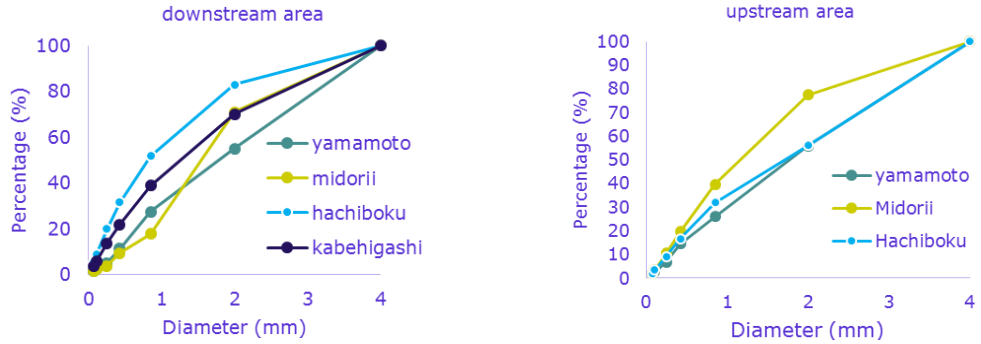
c) d)

Figure 2 Soil particle size distribution for four areas

From Figure 3a, we can find that the debris flow in Hachiboku area has the most fine particles with diameter less than 2mm. The debris flow in Yamamoto area has the least fine particles with diameter less than 2mm. However, for debris flows in Midorii and Kabehigashi area have nearly the same amount of fine particles. From figure 3b, for upstream area, the debris flow in Midorii area has the most fine particles. For Hachiboku, the debris flow has less fine particles. And the debris flow in Yamamoto area has the least fine particles.

Fractal dimension for the debris flow path and the soil size distribution

Table 1 shows the estimated fractal dimension of the four debris flows. Debris flows in Yamamoto and Kabehigashi area has larger FD values. However debris flows in Midorii and Hachiboku area has smaller FD values. Compare the size distributing results and the FD results, we can found the more fine particles the debris have, the less the FD value is, like Midorii and Hachihigashi. On the contrary, the more coarse particles the debris have, the bigger the FD value is, like Yamamoto area. The fine particles are easier to be blocked by obstacles to decrease the width of the flow path and make more braches. The coarse particles is more destructive making the flow path wider and less branches. Table 2 shows the estimated fractal dimension of the soil size distribution for the soil samples.



a) b)

Figure 3 Comparison of particle size distribution for 4 sites of debris flows

Table 1 fractal dimension for 4 sites of debris flow

Location	Fractal dimension
Yamamoto	1.46
Midorii	1.31
Hachiboku	1.32
Kabehigashi	1.53

Table 2 Fractal dimension for the soil size distribution

Fractal dimension	Down area	Middle area	Upper area
Yamamoto	1.05	1.02	0.86
Midorii	1.10		1.01
Hachiboku	0.73		0.96
Kabehigashi	0.83		

Conclusions

Comparing the particle size distribution results with the FD results, we can find that the more fine particles the debris have, the less the FD value is, like Midorii and Hachihigashi. The fine particles are easier to be blocked by obstacles to decrease the width of the flow path and make more braches. The coarse particles is more destructive making the flow path wider and less branches. On the contrary, the more coarse particles the debris have, the bigger the FD value is, like Yamamoto area.

References

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