A Study on Setting Half-life of Effective Rainfall as a Standard of Debris Flow Occurrence by Considering Geology

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INTRODUCTION

Generally, both previous prolonged rainfall and the most recent short strong rainfall affect debris flow occurrences. The present study discusses the setting of the half-life of effective rainfall as a standard of debris flow occurrence using effective rainfall and rainfall index *R'*, which expresses the rainfall history by a value that combines long-term effective rainfall R_w and short-term effective rainfall r_w. We investigated debris flow disasters in Osumi district, Nagiso-town and Hiroshima-city (**Fig. 1** and **Table 1**), all of which have specific rain properties and geological feature conditions.

METHOD AND CONDITIONS

Effective rainfall

With effective rainfall R_t, which is a standard value of debris flow occurrences, we investigated the influence of past rainfall and calculated it by Eqs. (1) and (2):

$$R_t = r_t + \sum_{n=1}^{x} a_n r_{t-x} = r_t + a_1 r_{t-1} + \cdots + a_x r_{t-x} \qquad (1)$$

$$a_n = 0.5^{n/T} \qquad (2)$$

where t is the time, r_t is time's precipitation, a_n is the decrease coefficient, and T is the half-life. Generally, for T, 72 hours are applied for long-term effective rainfall and 1.5 hours are applied for short-term effective rainfall. In the present study, long-term effective rainfall is described by R_w, and short-term effective rainfall is described by r_w.

Rainfall index *R'*

Rainfall index *R'* is calculated by Eqs. (3) and (4):

$$R_{fw} = \sqrt{(R_1 - R_w)^2 + a^2 (r_1 - r_w)^2} \qquad (3)$$

$$R' = R_{fw0} - R_{fw} \qquad (4)$$

where R_{fw} is the long diameter of the oval, R_1 and r_1 are its central coordinates, R_{fw0} is a value for $R_w = r_w = 0$, and a is a coefficient to replace an oval with a circle (**Fig. 2**).

Fig. 1 Location of three actual basins

Table 1 Debris flow occurrence in Osumi district

No.	Occurrence Time	Rainfall gauging	Surface geology	Gradient (degrees)
[1]	7/14 12:00	Kihoku	Shirasu	25～30
[2]	7/11 7:00	Tashiro	Granite	25～35
[3]	7/14 11:00	Tashiro	Shirasu	20～25
[4a]	7/4 0:00	Sata	Shirasu	20～30
[4b]	7/11 2:00	Sata	Shirasu	20～30
[5]	7/11 7:00	Sata	Sandstone	15～20
[6]	7/11 9:00	Sata	Shale	25～35

※ [4a] and [4b] are different debris flows on the same slope.

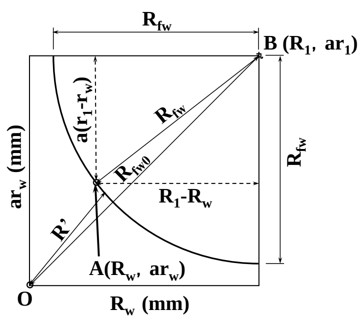

Fig. 2 Concept of rainfall index *R'*

Computational conditions

R_w and r_w are calculated based on the observed rainfall data (**Fig. 3**). In the computation, the condition of the long-term effective rainfall's half-life changes from 12 to 72 hours, and the short-term effective rainfall's half-life changes from 30 minutes to 2.0 hours.

R_1, r_1, and a are necessary for calculating R'. R_1 is given by the value of R_w (the cross axis of the graph) that can express all of the calculation results, and a is decided by the test calculations that produced R_1 and assumed a. In the present study, R_1 is given with 600mm and a is assumed to be 3, 4 and 5. As a result, since a=3 most closely matches all of the examples, we adopted these values: a=3, R_1 =600mm, and r_1 =200mm.

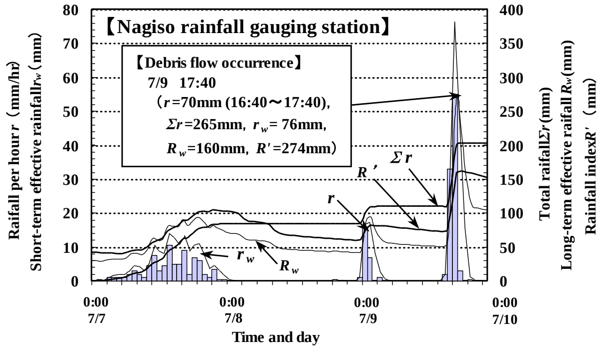

Fig. 3 Example of rainfall data (Nagiso-town)

RESULTS AND DISCUSSIONS

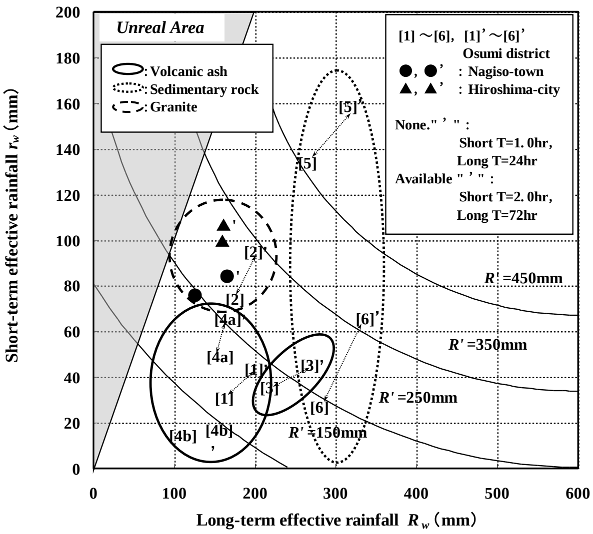

Fig. 4 Relationship between effective rainfalls of debris flow occurrence and curves of R'

Fig. 4 shows the relationship between the effective rainfalls of the debris flow occurrence and the curves of R', where around 20% of the R' increase and decrease is based on the geologic difference half-life setting, except [1], [3], [4a] and [4b]. These debris flow occurrences consist of shirasu and more than 20% of R' decreases after 12 hours of a long-term effective rainfall's half-life. Attention is required when the long-term half-life is less than 12 hours (for example, such volcanic ashes as shirasu).

In Osumi district, much of the debris flow occurred in the distribution of such volcanic sediment as shirasu (Table 1 ([1], [3], [4a] and [4b])), which is generally not too hard and poor at water. Each R' value was small at the time of these debris flow occurrences (**Fig. 4**). They also occurred in an incline area from 20 to 30 degrees (**Table 1**).

Spots exist where each R' was large at the time of these debris flow occurrences (**Fig. 4**). Their geological features are granite ([2] in Osumi district, Nagiso-town, and Hiroshima-city) and the sedimentary rock of such accretionary complexes as sandstone and shale (**Table 1** ([5] and [6])). They are harder than volcanic sediment. For such similar geological features as [5] and [6], R' shows a small tendency at the time of the debris flow occurrence when the incline is steep. Each is a proper geological result.

CONCLUSIONS

Geology greatly influences effective rainfall and R' through half-life. We expect to precisely predict debris flow occurrences by adding geological feature information to rain indexes.

Keywords: effective rainfall, half-life, rainfall index R', geology, debris flow occurrence