Bull. Grad. Sch. Humanit. Soc. Sci. Hiroshima Univ : Stud. Educ., Vol.3, 2022, 36－41

A Case Study of the Relationship between Real Time Drawing of Rainfall Index R' Calculated Using AMeDAS Data and Sediment-Related Disasters Occurred in July 2018 in SW Japans

Kenichi Yoshidomi
(Received. October 7, 2022)

Abstract: In order to predict the site at risk for the occurrence of sediment-related disaster, the author has developed a system in which the value of rainfall index *R'* can automatically be calculated and the calculated results are represented as a contour map with interpolated information between AMeDAS stations. Verifying whether the *R'* value that calculated in real time using only AMeDAS data has a correlation with the timing and the place of sediment-related disasters occurred caused by the heavy rainfall in July, 2018, it was shown that the contour map of *R'* value is sufficiently effective for the prediction of "time" and "place" where sediment-related disasters would occur. Under existing circumstances, however, from the viewpoint of the guideline of evacuation, it should be emphasized that we have only a few minutes to judge the danger of landslide disaster on the basis of *R'* value alone..

Key words: Rainfall Index *R'*, Real time, Contour Map, AMeDAS, July 2018

1. Introduction

In July, 2018, heavy rain caused sediment-related disasters in various parts of western Japan. Causes of sediment-related disasters are classified into prime factors, including geological conditions and topography, and into inducements accompanied by rainfall. Geological conditions and topography doesn't change over several years, while only water contents in the soil do before and after slope failure. Therefore, in order to predict the occurrence of sediment-related disasters caused by rainfall, it is of considerable importance to monitor the change of rainfall and to judge whether a landslide disaster would occur or not, in the light of past instances with similar rainfall.

Sediment-related disasters due to rainfall are considered to be dependent on two factors: previous prolonged rainfall and the last short strong rainfall [1]. In order to express the influence of preceding rainfall with elapsed time, Ministry of Land, Infrastructure and Transport (MLIT) has proposed a method in which effective rainfall is represented as a combination of rainfall intensity for short-term and long-term rainfall indices [2]. However, this method requires one graph with respect to each rain gauge (station). Though it can be utilized for the prediction of the time when the sediment-related disaster occurs in the region, it was not possible to predict the site or place.

Proposing a method to express two rainfall indices collectively as rainfall index *R'*, Nakai et al. [3] have shown that based on the case analyses such as those of disasters that occurred in Hiroshima district on June 29, 1999, *R'* >125 mm and *R'* >250 mm are increasing the risk of hillside landslides and debris flows, respectively, in areas with widely distributed weathered granite. By using rainfall index *R'*, information from one rain gauge (station) can be expressed as one numerical value. Then, on the basis of these numerical values obtained from rain gauge, the distribution of *R'* value, which interpolates information between observation points, can be expressed as a contour map.

However, under the circumstances, because the calculation of *R'* value requires an enormous amount of past rainfall information and complicated calculation, it is not until the landslide disaster occurs that the calculation of *R'* value is carried out to confirm the correlation between rainfall and disaster occurrence points, in most cases.

In order to predict the sites at risk for the occurrence of sediment-related disaster, the author has developed a system in which the value of rainfall index *R'* can automatically be calculated and the calculated results are represented as a contour map with interpolated information between rain gauge (station) [4]. Thus, he has so far being published a map showing the distribution of hourly *R'* value in a wide area ranging from the northern Kyushu to the Kii Peninsula on the web to provide an indication of evacuation behavior during heavy rain. Rainfall information used to calculate the *R'* value is based on the AMeDAS of Japan Meteorological Agency, while the data for 332 observation points for two weeks are used to calculate the *R'* value in the wide area mentioned above.

AMeDAS stands for "Automated Meteorological Data Acquisition System", and rain gauges or stations are located at average intervals of 17km mesh to capture the phenomenon of the meso β scale. In order to grasp the effects of local severe rainstorm, that is, torrential downpour, often called "guerrilla heavy rain" in Japan, which tends to increase recently, more detailed analysis using rainfall information obtained by various organizations and local governments is desired. However, unfortunately, the method of providing and the timing of publication of rainfall information are different in each organization. Therefore, in order to provide information on the risk of sediment-related disaster relatively quickly on the web, the *R'* value is calculated using only the AMeDAS data under present circumstances.

Until now, the *R'* value, in most cases, has been calculated for confirmation after the occurrence of a disaster. In order to obtain a guideline for evacuation action during heavy rainfall, the present author, using *R'* value calculated in real time, has strived to investigate the possibility of the correlation between *R'* value and timing of sediment-related disaster occurrence, and the correlation between the area with high *R'* value and sediment-related disaster occurrence sites, on the basis of the rainfall in July 2018 heavy rain. Moreover, this paper evaluates whether the *R'* value, devised as a standard based on Hiroshima and its surrounding area with widely distributed granite, can be an effective guideline for evacuation behavior also in other regions.

2. Correlation of AMeDAS-based R' with sediment-related disaster occurrence area

Due to the effect of approaching Typhoon No. 7, rainfall was observed from July 1 in southern Kyushu and Shikoku district. After that, rainfall was observed in a wide area of northern Kyushu and Chugoku district from the dawn of July 3 to July 4 with approaching and passing of Typhoon No. 7. After the typhoon passed, there was no noticeable rainfall for about 20 hours. Since the seasonal rain front advanced south, from the early morning of July 5 to July 7, strong rain intermittently continued over a wide area of western Japan for almost 48 hours.

Landslide and debris flow occurred in Kumano Town, Aki County, Hiroshima Prefecture, on July 6, respectively. On the following day, a number of landslide and debris flow occurred in various places in western Japan, including Iwakuni City in Yamaguchi Prefecture.

Then, geological conditions, hourly rainfall and *R'* values are described, with time sequence, of major sediment-related disasters occurring points from July 6 to July 7, 2018. Widely drawn maps indicate those of contour of *R'* values automatically drawn on the server. Map for each region is manually redrawn contour map of *R'* value superimposed on the "isodistribution map of collapsed land" in "Heavy rain in July 2018" on the map by the Geographical Survey Institute.

2.1 Kumano-cho, Aki-gun, Hiroshima

At Kawakado 5, Kumano-cho, Aki-gun, a debris flow occurred near the top of Mt. Mitsuiwa-yama (449 m high) at around 20:20 on July 6. The area is composed of weathered granite classified as Kure granite, belonging to Hiroshima granite [5]. At Mt. Mitsuiwa-yama, debris flows also occurred during heavy rain in June 1999.

At around 20:00 on July 6, it was raining heavily from northern Kyushu to Hiroshima (Fig. 1). It is confirmed that the hourly rainfall (1 hour before) at 20:00 exceeded 50 mm and the *R'* value exceeded 320 mm at both the Higashi-Hiroshima and Kure stations located in the northeast and south, respectively (Fig. 2). In the southwestern part of Hiroshima Prefecture, the *R'* value exceeded 300 mm again from 4:00 to 7:00 on July 7.

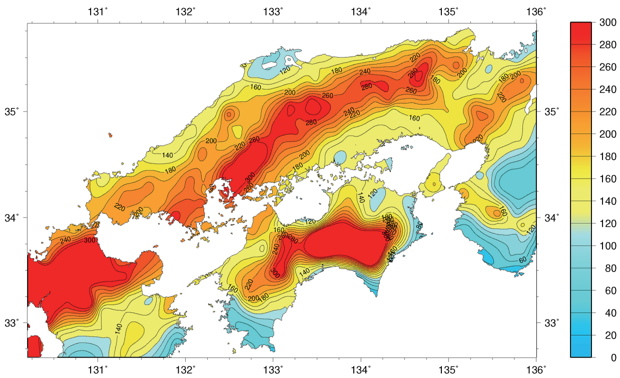

Fig. 1. Contour map of rainfall index *R'* (20: 00 on July 6, 2018)

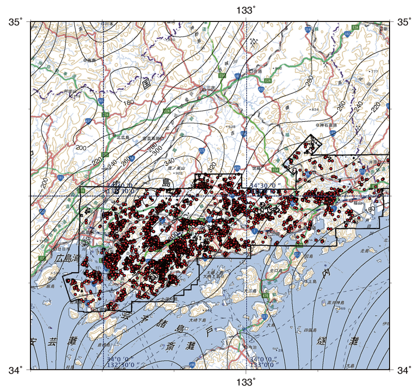

Fig. 2. Detailed Contour map of rainfall index *R'* (20: 00 on July 6, 2018). The dots on the map indicate the locations where landslides occurred (Geological Survey of Japan, AIST website : https://gbank.gsj.jp/geonavi/geonavi.php).

2.2 Shuto-cho, Iwakuni City, Yamaguchi Prefecture

In Shuto-cho, Iwakuni City, residents of the Osogoe and Kamisu-dori districts reported the incident to the police and fire department from 2:00 to 3:00 on July 7. This area is underlain by Osogoe Composite Granite and Shimokubara Granite, classified as Hiroshima granite, which are composed of weathered granite [6].

At around 2:00 on July 7, the rain that had once stopped began to rain heavily from the eastern part of Yamaguchi Prefecture to the western part of Hiroshima Prefecture (Fig. 3). According to the record of the nearest Kuga station, hourly rainfall (1 hour before) at 2:00 is 51.0 mm and the calculated *R'* value is over 360 mm (Fig. 4).

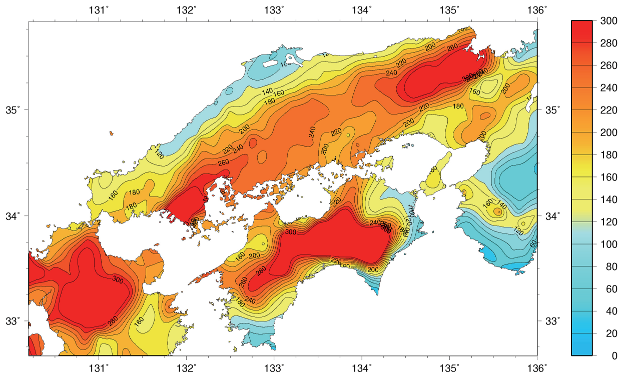

Fig. 3. Contour map of rainfall index *R'* (2 a.m. on July 7, 2018)

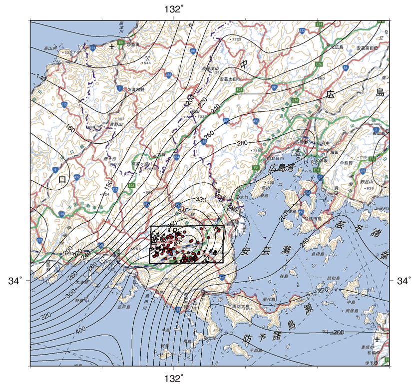

Fig. 4. Detailed Contour map of rainfall index *R'* (2 a.m. on July 7, 2018). The dots on the map indicate the locations where landslides occurred (Geological Survey of Japan, AIST website : https://gbank.gsj.jp/geonavi/geonavi.php).

2.3 Yoshida-cho, Uwajima City, Ehime Prefecture

At around 7:30 on July 7 in Yoshida-cho, Uwajima City, there was a report that hill behind a house collapsed and the house fell down. Ehime University Survey Team on July 2018 Heavy Rain Disaster announced that 2,271 slopes collapsed in the Yoshida-cho area. Geologically, the area where sediment disasters have so far been frequently occurred belongs to the northern Shimanto-belt, with alternating layers of sandstone and mudstone [7].

In association with southward advancement of the seasonal rain front, at around 7:00 on July 7, the region of strong rain moved southward, and the rain was about to stop in northern Kyushu and Yamaguchi Prefecture (Fig. 5). According to the nearest Uwajima station, hourly rainfall (1 hour before) at 7:00 is 49.0 mm. Sediment-related disasters occur in areas where the *R'* value exceeds 280 mm. In particular, they are dominantly localized in areas where the *R'* value exceeds 360 mm (Fig. 6).

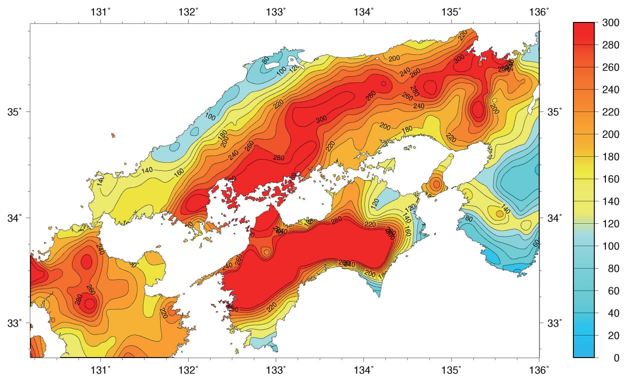

Fig. 5. Contour map of rainfall index *R'* (7 a.m. on July 7, 2018)

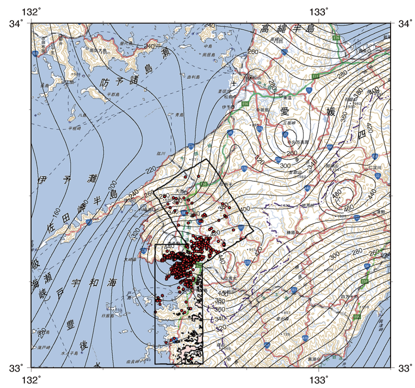

Fig. 6. Detailed Contour map of rainfall index R' (7 a.m. on July 7, 2018). The dots on the map indicate the locations where landslides occurred (Geological Survey of Japan, AIST website : https://gbank.gsj.jp/geonavi/geonavi.php).

3. Results and Discussion

Shown in Table 1 are the sediment disaster occurrence sites, their geological conditions, the date and time of the disaster occurrences, the *R'* values of the time before one hour, and the *R'* values of the previous time zone. As for the prediction of the "time" of sediment-related disaster occurrence based on a real time drawing of Rainfall Index *R'* calculated using AMeDAS data, it was demonstrated that massive slope failures and debris flows occurred after the *R'* value exceeded 250 mm in all cases. It was also found that as for the prediction of the areas where massive slope failures and debris flows would occur, there is a possible correlation between the occurrence of such disaters and the *R'* value exceeding 250 mm.

Table 1. Rainfall Index *R'* value before sediment-related disaster occurrence for each site

Occurrence site	Geology	Date and time of occurrence	Before one hour *R'* value (inferred)	Previous time zone *R'* value (inferred)
Kumano-cho, Aki-gun, Hiroshima Prefecture	Granites	20:20 7/6/2018	320 mm	220 mm
Shuto-cho, Iwakuni City, Yamaguchi Prefecture	Granites	02:00 7/7/2018	360 mm	280 mm
Yoshida-cho, Uwajima City, Ehime Prefecture	Sedimentary rocks	07:30 7/7/2018	360 mm	240 mm

From this, it was shown that the contour map of *R'* value, which was calculated and drawn in real time using only AMeDAS data, is sufficiently effective for the prediction of "time" and "place" where sediment-related disasters would occur. However, since a regional difference in predisposing factors is related to the occurrence of sediment disasters, it should be stressed that the criteria alone using the *R'* value based on rainfall do not necessarily imply the occurrence of sediment disasters.

From the viewpoint of the guideline of evacuation of residents from the site of the sediment-related disaster, there is a disadvantage that the time is too short to judge the danger of landslide disaster on the basis of *R'* value. It takes some time for the Meteorological Agency to compile the rainfall data and publish it on the web. In addition, about 4 minutes are necessary to calculate the *R'* value, draw the contour map, and to publish the results on my web just after the rainfall information is opened to public by the Meteorological Agency. Taking Moji's case as an example, about 14 minutes when the calculated *R'* value was found to exceed 250 mm, a landslide disaster occurred.

In this study, it is also revealed that at all sites, the *R'* value one hour before the disaster occurrence exceeded 125 mm, a rainfall which is thought to be at high risk for slope collapse. The dangerous situation can only be recognized immediately before the slope failure. However, even if such situation could be recognized at midnight, it is not realistic to evacuate in the dark night in a heavy rain. After all, in the area where the risk of sediment related disaster occurrence is increasing, it is recommended to evacuate as early as possible in the daytime.

R' was originally developed as a standard for the occurrence of sediment related disasters for the area where weathered granite is widely distributed, as in around Hiroshima. Therefore, we need further investigation on the correlation of *R'* with sediment related disaster in the region with different regional characteristics. However, since *R'* can express the risk of sediment disaster as a single index, unlike the conventional rainfall index, it has the potential to express the "Location" and the "Time" as numerical values during sediment disaster occurrence, not only in granite areas, but also in other areas. In addition, it is a very effective method to present in an understandable way for general citizen the site where sediment disaster is likely to occur on the map.

Finally, it is revealed that the value lower than the original *R'* is displayed on the contour map of *R'* value, as in some observation data, including those obtained in Yanase, northeastern part of Umajimura, Kochi Prefecture. This is because there was a time zone when the long-term rainfall (R_w) exceeded 1,000 mm on July 6. In calculating *R'*, the coefficients R_1 and r_1 for calculating rainfall index *R'* should be larger than the long-term rainfall (R_w) and the shor-term rainfall (r_w), respectively. Originally, R_1 = 600 mm and r_1 = 200 mm have been used on the basis of the case experienced in the Chugoku region, southwest Japan [8]. In the case of heavy rain in northern Kyushu in 2017, the long-term effective rainfall exceeded 600 mm. Therefore, the numerical values of R_1 and r_1 changed to 900 mm and 300 mm, respectively [9]. Also in this study, *R'* was calculated using the same numerical values. The *R'* value does not change significantly if the ratio of R_1 and r_1 and the coefficient a are the same. However, it is suggested that assuming that incommensurable heavy rain will increase in the future, it is necessary to review the coefficient on the basis of recent disaster cases.

Acknowledgements

The author thanks for Dr. Makoto Watanabe and Dr. Shinji Nakai for their helpful comments.

References

[1] Senoo, K. and Funazaki, M., "Relation between landslide disaster (mainly debris flow disaster) and rainfall", Shin-Sabo, JSECE, Vol. 26, No. 2, pp. 22-28, 1973. (in Japanese with English abstract)

[2] Ministry of Construction, "Guidelines for Precipitations for Warning and Evacuation against Debris-Flow Disaster (Draft)", 1984. (in Japanese)

[3] Nakai, S., Sasaki, Y., Kaibori, M., and Moriwaki, T., "Rainfall Index for warning and Evacuation against Sediment-Related Disaster: Reexamination of Rainfall Index *Rf*, and Proposal of *R'* ", Soils and Foundations, JGS, Vol.46, No.4 pp.465-475, 2006.

[4] Yoshidomi, K., "Development of Visualization System for Hazard Prediction of Sediment Disasters", Bulletin of the Graduate School of Education, Hiroshima University. Part. II, Arts and science education, Vol. 61, pp. 29-37, 2012. (in Japanese with English abstract)

[5] Higashimoto, S., Matsuura, H., Mizuno, K. and Kawada, K., "Geology of the Kure District. Quadrangle Series, scale 1:50,000", Geol. Surv. Japan, 93 p, 1985. (in Japanese with English abstract)

[6] Higashimoto, S., Nureki, T., Hara, I., Tsukuda, E., and Nakajima, T., "Geology of the Iwakuni district. Quadrangle Series, Scale 1:50,000", Geol. Surv. Japan, 79 p, 1983. (in Japanese with English abstract)

[7] Teraoka, Y., Ikeda, Y., and Kashima, N., "Geology of the Uwajima district. With Geological Sheet Map at 1:50,000," Geol. Surv. Japan, 91 p, 1986. (in Japanese with English abstract)

[8] Nakai, S., Kaibori, M., Sasaki, Y., and Moriwaki, T., "Study on setting up of a critical *R'* value and proposal of a new index R_R as a remarkable rainfall intensity -Its applicability reflected rainfall history-", Journal of the Japan Society of Erosion Control Engineering, Vol. 60, No. 6, pp. 4-10, 2008. (in Japanese with English abstract)

[9] Nakai, S.,Nagai,M.,Yoshidomi,K.,andKaibori,M., "Application of the Rainfall Index *R'* to Sediment-Related Disasters caused by localized torrential rains - Verification of cases in southern China and northern Kyushu", Japan Society of Erosion Control Engineer- ing 2018, pp. 341-342, 2018. (in Japanese)