Drainage Density as Rainfall Induced Landslides Susceptibility Index in Small Catchment Area

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1 Introduction

Drainage density has been defined as total stream length per unit area of a river basin (Horton, 1945). Numerous researchers have measured values of drainage density from topographic maps and have analyzed variables controlling drainage density and found that drainage density is related to climate, vegetation, bedrock geology, time. Usually, it is noticed that increasing drainage density always responsible to the slope failure. Onda (1993) noticed that terrain having higher drainage density and thin soil layer was comparatively damaged more by shallow seated landslide. Hasegawa et al. (2008) noticed that The studies shows that during heavy rainfall, area having higher drainage density is usually prone to shallow-seated landslide where as large scale landslide is frequent in area having lesser drainage density (Fig.1). In this context, this paper describes some of aspects of drainage density and its relation to the rainfall index for landslides and debris flows in southwest Japan.

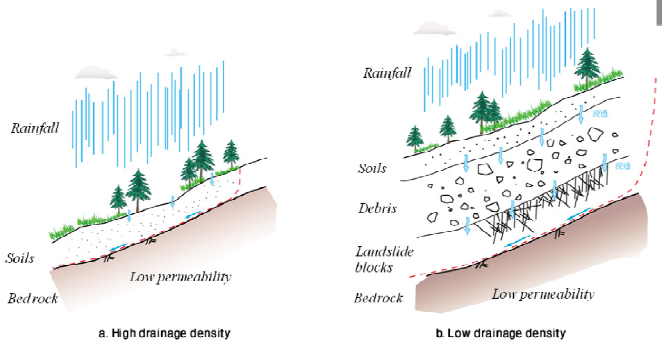

Fig1. Relation between drainage density and hydrological structure of slopes (Hasegawa et al., 2009)

2 Study area

In this study, total 34 debris flows and landslides whose occurrence times are confirmed were selected for the study from Hiroshima disasters in 1999, Bofu disasters in 2009, Shobara disasters in 2010 and Kii Mountains disasters in 2011 (Fig 1). The catchment areas which have source areas of sever debris flow disasters were selected for drainage density calculation and it is compared with rainfall index at the occurrence of flows and landslides.

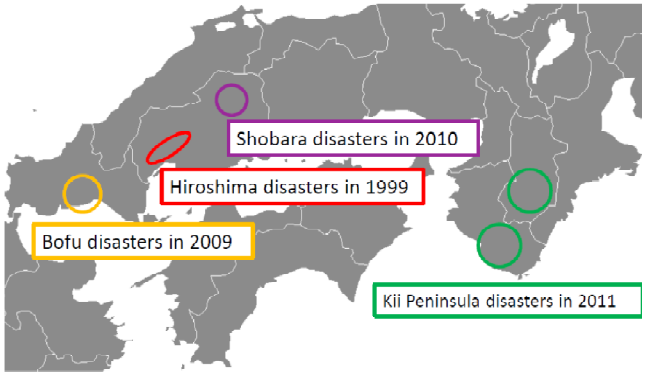

Fig 2. The study area in southwest Japan

3 Drainage density measurement

Drainage density is defined as length of drainage per unit area watershed. In this study, rules are proposed for measuring drainage density by using 10-m resolution DEM. Fig. 3 shows an example of measuring drainage density of a small catchment area.

Rule1: Definition of valley

Valley is defined by pixel whose average curvature is equal or larger than 1.0.

Rule2: Draw thin line on valley

If width of valley is over one pixel, the maximum pixel is selected.

Rule3: Calculation of drainage density

Drainage density [km^{-1}]=((Numbers of pixels defined as valley)×10m)/(Numbers of pixels defined as catchment area))

Rule4: Size of catchment area

Catchment areas were selected by topographic map. Area of a catchment is around 1km^2.

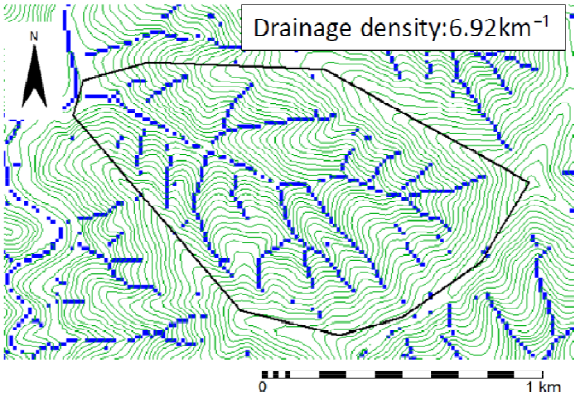

Fig 3. Example of measurement of drainage density

4 Rainfall index R'

Rainfall indexes relating to rainfall-induced landslides and debris flows usually have two parameters: short-term parameter such as rainfall intensity and long-term parameter such as duration. These rainfall indexes are not applicable to comparison with drainage density. Therefore, a new rainfall index R' proposed by Nakai et al. (2008) is introduced for this study. R' has a single value comprising two kinds of influence by long term and short-term rainfalls (Fig.4)

$$R' = R_{fw0} - R_{fw}$$

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

Where

Rw : Long-term effective rainfall(mm),

Rw : Short-term effective rainfall(mm),

R1: Point of reference on horizontal axis

r1 : Point of reference on vertical axis

a : Weight of coefficient

Rfw0 : Value of Rfw when Long-term and short-term effective rainfall are zero

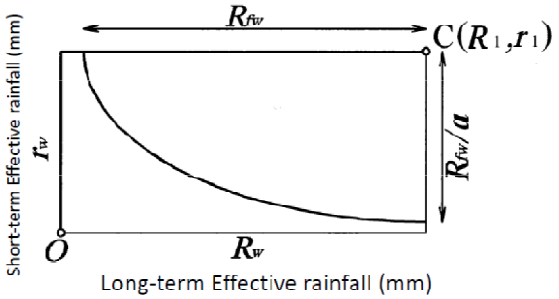

Fig4. Definition of the rainfall index Rfw and R' (Nakai et al., 2008)

5 Relation between drainage density and rainfall index R'

Fig. 5 shows relation between drainage density and rainfall index R'. Lowest value of R' decreases, as drainage density increases. This indicates that drainage density will be a good susceptibility index for rainfall-induced landslides and debris flows in small catchment area.

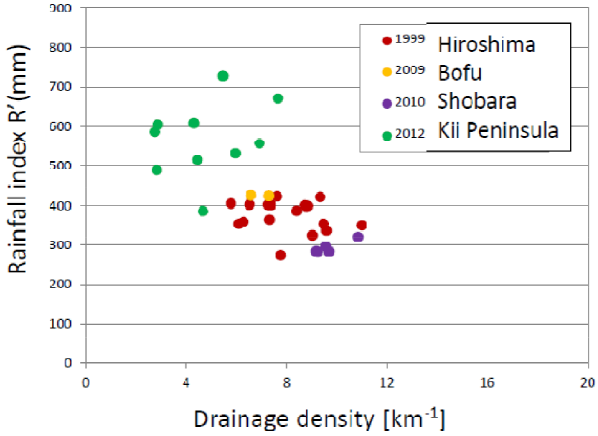

Fig 5. Relation between drainage density and rainfall index R'.

6 Conclusion

Drainage density is easy to measure without field survey. Drainage density would be good index for estimating evacuation rainfall by small catchment-base where past disaster data are not available. Therefore, study of drainage density is practical approach for disaster management.

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