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The warning criteria analysis of sediment runoff, debris flows, shallow landslides along the mountainous torrent

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In mountainous areas, roads or railroads and local inhabitants sometime suffer from sediment related disasters along torrents. On this point of view, monitoring of the sediment runoff including debris flows, shallow landslides, and analysis of its characteristic in a mountainous torrent have carried out in order to set up the runoff criteria of sediment from the torrent and the local standard rainfall for warning and evacuation. The research is run on a torrent whose geology consists of Paleozoic metamorphic rocks (mainly schist) and whose vegetation consists of mainly Japanese cypress and cedar. Soil depth is approximately 50cm in average and permeability is k=10ˆ (-2) order. Rain, wind speed, soil moisture content, sediment discharge were monitored and the sediment runoff characteristic were obtained by the monitoring and the observation over 3 years. With these data, standard rainfalls for warning and evacuation against the sudden sediment runoffs or sediment related disasters along a torrent are analyzed by the sediment runoff intensity theory, the Self Organized Criticality Assumption (SOC), and the Elementary Catastrophe Theory (ETC). Then, the result can be compared with Mexico Nuevo Leon's and Indonesia Slawesh's case in the next step of this research.

1) Theoretical Critical Standard of Sudden Sediment Runoff based on the Hirano's discharge theory or the Self Organized Criticality Assumption (SOC) : PiCL is the critical line of sudden vast sediment runoff given with the equation (4) below. Theoretically, they are derived from equation (1) given by Dr. Muneo Hirano (1992). Q/A = M Pi

Pa cos(s) ..... (1) , here, Q: sediment runoff discharge, A: watershed area, M: function concerning with sediment deposit features on the upstream torrent or slopes (porosity, torrent bed slope gradient, sediment accumulation length and depth, cohesion), s: torrent bed or hillside slope gradient, Pa: total rainfall, Pi: rain intensity over 1 hour. Therefore, Q/A/M/cos(s) = Pi Pa ...... (2) After all, Pi Pa = Const ...... (3) While Qc >= Q, then we recognize the sediment discharge as sudden vast runoff that makes some effect to human activities or facilities. Whereas there always happens small runoff with small amount of sediment discharge such as suspended load with a certain amount of rainfall event, it can not recognize as dangerous sediment runoff. With this concept, we have the relation below. Qc/A/M/cos(s) = Pic Pac ...... (2)’ Hereafter, Pic Pac = C ...... (3)’ Pic, Pac are the critical rainfall intensity and total rain. Hence, evaluating the variable "C" by the empirical way with field observation data, following formulas are obtained for the critical line of sudden vast sediment runoff. Pic = 8000/Pac ...... (4) Along this torrent, sudden vast sediment runoff will happen in cases over PiCL. These formulas match the form of equation derived from SOC that is prescribed by power function. The soil moisture content along the torrent i.e. its riparian area is not affected by antecedent rainfall according to our field observation, so is not the sediment runoff from torrent bed, torrent sides, shallow landslides in close vicinity which does not include the runoff induced by large landslides or shallow landslides occurred in the distance. In this study period, any such large landslides were not observed along the torrent at which the monitoring was carried out.

The accuracy of this method contemplated by detective ratio or critical success index with the present data is sufficiently high (almost 100%).

2)Theoretical Critical Standard based on the Elementary Catastrophe Theory (ETC) : Providing that ETC can be applied to this critical line, the critical line is described by next equation adopting the wedge type catastrophe theory. Catastrophe function F is given as followings, F =(p^4)/4 - Pa (p^2)/2 + Pi p .... (5) , here p: probability of sudden runoff. And, the branching function BF is given as below. BF = p^3 - Pa p + Pi = 0 .... (6), and the critical state is described with next equation. 3p^2 - Pa = 0 ...... (7) Derived from these equations and with empirical coefficient based on the field observation, the next formula is obtained. Pi = 2828 - Pa^(3/2) ...... (8) However, it has the cross point with lateral axis i.e. Pi = 0. It is impossible for rain to take this combination of the Pa and Pi. Therefore, the ETC is not suitable in this study.

3. Conclusion : The critical standard rain of warning and evacuation for local area along the torrent can be given as formulas (4) based on theoretical analysis. Since the sediment runoff from torrent bed, torrent sides and shallow landslides in close vicinity of the torrent (which do not include large landslides) is not affected by antecedent rainfall according to the field observation, formulas (4) based on Pa and Pi is rather

simple and handy than the other methods to provide the warning criteria.