Deep-Seated Landslides and Landslide Dams Characteristics Caused by Typhoon Talas at Kii Peninsula, Japan

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INTRODUCTION

There are many different factors that trigger landslides, namely prolonged and excessive rainfall, earthquakes, and snow melts. Mass movement involves flowing, sliding, toppling or falling movements, and generally combination of several types of movements [Varnes, 1978]. Landslides occur as a single disaster or multiple disasters which occur simultaneously in a period of time (hours or days). Landslide as a result of weakened self-retainability of the soil under the influence of rainfall or earthquake forms in many types of disasters, namely shallow landslide, debris flow, deep-seated landslide, landslide dam, slump, etc. Each type of slope failure form has different characteristic and condition for formation.

Most common types of mass movement that form landslide dams are rock and soil slumps, slides (mud, debris, and earth flows) and rock and debris avalanches [Schuster, 1986]. Costa [1988] remarked that landslide dams formed most frequently where narrow steep valleys bordered by high rugged mountains. Steep narrow valleys require relatively small volumes of material to form dams; thus even small mass movements present a potential for forming landslide dams. Damming of rivers by landslides is common in Japan because widespread of unstable slope and narrow valleys exist in conjunction with frequent hydrologic, volcanic, and seismic landslide triggering events [Swanson, 1986].

Kii Peninsula was severely damaged by Typhoon Talas (Typhoon No. 12) from 2nd to 4th September 2011 and cause precipitation about 1,500 mm, about half of the annual precipitation of Kii Peninsula that is about 3,000 mm. The typhoon caused more than 3000 landslides in Mie, Nara and Wakayama Prefectures, including thousands cases of slope collapses, debris flows, large-scale landslides, and landslide dams, and also numerous casualties and property damage. This research aims to analyze the landslides occurred at Kii Peninsula and its influencing geographical factors so that the characteristics of deep-seated landslides and landslide dams can be understood in order for further landslides prediction and mitigation.

METHODOLOGY

Kikuchi [2013] studied the shallow and deep-seated landslides characteristics in Kii Peninsula namely slope inclination, distance of collapsed area from valley, angle and direction of confluence of collapsed material and stream, and stream order. This research is continuing Kikuchi’s research in order to find more characteristics of landslides in Kii Peninsula specifically on deep-seated landslide cases and the formation of landslide dam. Factors that affecting landslides and material movement type in this research area are average slope inclination, distance to valley, stream order, and confluence angle [Kikuchi, 2013].

On this research, characteristics of the deep-seated landslides were observed further including riverbed gradient, slope height, upstream watershed area, equivalent coefficient of friction and characteristics correlation was investigated through multiple regression analysis.
RESULT AND DISCUSSION

There were 393 landslides found at the research area by comparing the satellite images of before and after the typhoon, where about 86% of the landslides are shallow landslides and the rest are deep-seated landslides. The deep-seated landslides were formed to 13 debris flows, 12 landslide dams and 9 other. Riverbed gradient was analyzed by calculating the gradient of the riverbed about 1 km along the landslide area. Landslides on riverbed gradient about 15-20° tend to form debris flows, whilst landslides on riverbed gradient about 0-5° tend to form landslide dams. The landslides, regardless the types, mostly occurs at 30-40° of slope inclination. The slope inclination works as the triggering factor of the landslides itself and not determining the landslide material movement.

Upstream watershed area was analyzed in order to know the correlation of flash flood to the landslide material movement. Larger watershed area means bigger rainfall catchment area, which influencing the large flood easily washed away the landslide material. The results show that debris flows mostly occur at watershed with less than 100 ha area, whilst landslide dams occur varies from 50 ha to 100,000 ha. Confluence angle between landslide area and stream was considered as one of influencing factors of landslide dam formation. Most of landslide dams occur when the angle of confluence of collapsed material and stream about 60-110°, while debris flows mostly occur at 0-40°. The smaller the confluence angle, the easier for landslide mass to flow into stream flow, thus the landslide will likely form as debris flow. The feasibility of landslide dam formation will increase when landslide is approximately perpendicular to the stream.

Figure 1 shows the correlation between riverbed gradient and confluence angle for each type of the landslide hazard. The landslides occur in red area, within 0-10° of riverbed gradient and 60-110° of confluence angle, are tend to form landslide dams. Whilst landslides occur in blue area, between 10-30° riverbed gradient and 0-40° confluence angle, are tend to form debris flows. Moreover, the landslides outside the blue and red area are ambiguous, it could not clearly determined whether the landslide mass will form landslide dams or debris flows.

CONCLUSION

Deep-seated landslides in Kii Peninsula caused by Typhoon Talas are only 14% of the total landslides occurred, however by area it is about 75% of the total landslides area. Landslides within 10-30° riverbed gradient and 0-40° confluence angle area are tend to form debris flow, whilst landslides within 0-10° of riverbed gradient and 60-110° of confluence angle areas are tend to form landslide dams. Landslides outside these two areas are ambiguous, there is no clarity whether it will turn to landslide dam or debris flow.

Keywords: deep-seated landslide, landslide dam, characteristics, typhoon talas, kii peninsula.