Hillslope-channel sediment production in a headwater catchment of Tanzawa Mountain

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INTRODUCTION

Sediment production in headwater catchments is an important factor for the dynamics of sediment transport and routing from up to downstream (Gomi et al., 2002). Sediment supplied from hillslopes is often directly linked to channel especially in steep mountainous catchments (Benda et al., 1998). For instance, Lehre (1982) reported sediment production during 4 years observation period in 1.74 km^2 Small Coast Ranges Drainage Basin, California ranges from 148 to 1575 t/km^2/yr, which mainly caused by landslide, sheet, and gully erosion.

Various methodologies have been used to estimate sediment production on hillslopes. In general, closed plot (e.g., 1 x 1 m plots) is commonly used for estimating sediment production (i.e., Ghahramani et al, 2011). Hence, such closed plots could not consider continuous soil movement from upper to lower parts of hillslopes because upper boundary prevents additional soil movement from the outside of plots. Furthermore, soil properties often change inside the closed plots by selective movement of soil. Therefore, the efforts still remains for estimating soil erosion from hillslope to streams which are important for developing catchment sediment budgets (Slaymaker, 1993).

For conquering these problems, we developed open plots for capturing the sediment on steep hillslopes. Various reseaches such as Imaizumi et al. (2015) used open plots (no upper boundary) for using the sediment transport based on the unit length of movement (e.g., weight/width of plot/period). Based on the topographic configuration, we applied open plot methods for estimating the sediment production rate (weight/area/period). Open plots also possible for estimating the sediment entering to the channels via up slope. Thus, the primal objective of this study is to estimates the amount of hillslope to stream sediment production in forested headwater catchments. Based on the field investigation, we discussed factors for temporal and spatial variability of sediment production in forested hillslopes.

STUDY SITE AND METHODOLOGY

This research conducted in two forested headwater catchments at the Oborasawa Watershed (35°28'N, 139°12'E) in eastern of Tanzawa Mountains, Kanagawa, Japan (Fig.1). The headwater catchments are further referred as catchment No.3 and No.4 with drainage area 7 ha and 5 ha, respectively. The climate is humid and mild with annual precipitation around 3000 mm. Mean hillslope gradient of the catchments are 36°, steep hillslope >40° is distributed along the stream (Gomi et al., 2013 in Hiraoka et al., 2015).

The sediment traps were placed in four different locations with gradients ranged from 41° to 53°. The sediment traps were designed to capture delivered sediment from hillslopes to the channels by installing a low-cost geotextile fences in the foot of the hillslopes. The sediment traps have 1 m width and located 4 to 15 m from the stream surface. Understory vegetation barely covered on hillslope. Distribution of leaf litter varied depending on availability of litter and micro-topography including tree stands, litter, and small tree branches found on forest floor. All of hillslope plots were considered to be planar shape.

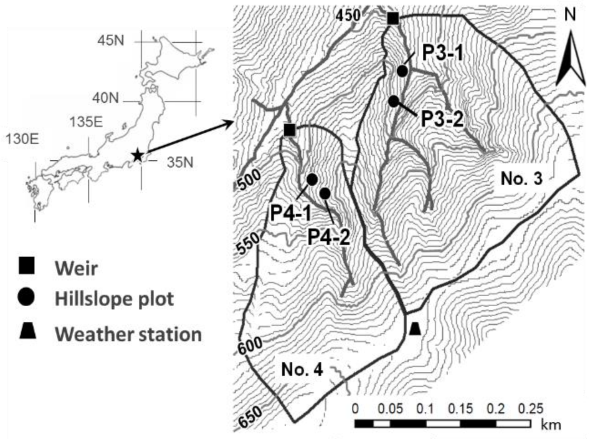

Fig 1. Research location in Oborasawa watershed

Further, sediment and litter inside the sediment traps were collected every one to two month and brought to the laboratory for further analysis. Sediment and litter were separated inside a bucket by washing of the remaining sediment on the litter with water. The remaining water and sediment were stored in the undisturbed storage to be left settled for 24 hours. The settled sediment in the bucket then roughly drained to reduce the water. The sediment and litter were oven dried with temperature 105° for 24 hours and weight to measure the dry mass.

RESULTS

Forty-four sediment samples from various observation periods were captured in continues monitoring from 2010 to 2015. The annual precipitation during the observation period was ranged from 3222 mm in 2014 to 2739 mm in 2013, with the mean annual precipitation of 2992 mm/yr and maximum 24 hours of 57 mm/hr in 2012. Total sediment during 6 year observation period was 0.4 tons, where 42% of the sediment is produced from sediment trap of P3-2. The lowest amount of sediment, consisted only 8%, found in P4-2 plot.

The mean annual sediment production rate of four plots varied from 0.2 mm/yr in 2013 to 1.2 mm/yr in 2012 (Fig.2). Mean six years sediment production rate was 0.6 ± 0.6 mm/yr. Highest sediment production rates occurred in plot P3-2 with mean sediment production rates 1.0 ± 0.4 mm/yr. Order of magnitude of sediment production rate in P3-1 (0.5 ± 0.2 mm/yr) and P4-1 (0.1 ± 0.05 mm/yr) was similar, while the standard deviation substantially greater in P3-1.

Runoff litter occupied at least 7% of the total material collected from the traps. The mean annual litter runoff during observation periods was 60.9 ± 49.7

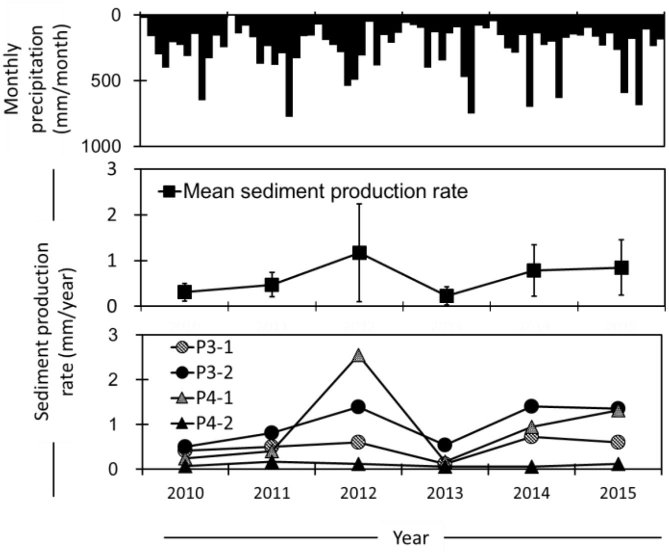

Fig 2. Annual sediment production rates

g/m^2/yr. The highest and the lowest runoff litter occurred in 2014 and 2010 with 122.0 ± 79.9 g/m^2/yr and 10.4 ± 7 g/m^2/yr, respectively. Greatest amount of litter runoff occurred in P3-1 with 92.2 ± 77.9 g/m^2/yr (13.0 % of total samples) and in P4-2 with 15.5 ± 9.1 g/m^2/yr (12.6% of total samples), respectively.

DISCUSSION

Our estimated sediment production from hillslope to channel was 2 to 3 times greater than that of the previous studies. For instance, on hillslope with gradient of 30^o to 33^o produced less than 0.02 kg/m/day of sediment (Imaizumi et al., 2015). Our estimated sediment production became 0.05 kg/m/day in winter (December to April) and 0.06 kg/m/day in summer (June to October). Similarly, 35^o to 40^o hillslope in Queen Charlotte Ranges, British Columbia produced 0.004 to 0.01 mm/yr, which was only 0.8 to 2 % of our estimated values (0.2 to 1.2 mm/yr).

Greater amount of soil production rate may associated various factors including climate, geology, and vegetation cover. In Tanzawa Mountain with high annual precipitation (3000 mm) during rainfall period and extreme fluctuation of temperature (above and below 0^o) during winter period instigates the pontential of soil detachment by raindrops during rainfall season (Nanko et al., 2008) and downslope movement of sediment by freeze-thaw during colder season (Ueno et al., 2015). Further, the presence of steep gradient and absent of understory vegetation might aggravate sediment production rates. Sediment production on hillslope increases rapidly as gradient become steeper (Roering et al., 1999). Additionally, lacks of understory vegetation lead to exposed soil surface to raindrop (Wainwright, 1996) and provide open sediment transport through hillslope (Ghahramani, 2011).

Fluctuated response of sediment production rate among plots suggested the variability sediment production associated with surface conditions. For instance, P3-2 and P4-1 tends to have less litters than the other plots. Litter cover is important for reducing soil detachment by rain splash and possibly reduce the freezing and thawing. Indeed, runoff litter under broadleaf trees, such as, P3-2 and P4-1 tends to easily transported on hillslope and makes the soil surface more susceptible to disturbance such as raindrop or freeze-thaw process (Bryan, 2000). Mix overstory vegetation such as Japanese cedar and broadleaf trees tends to create a stable litter cover that protect the soil surface from the impact of rainfall (Hiraoka et al., 2013).

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