Linkages among vegetation coverage, soil erosion, and nutrient conditions in forested headwaters

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1. INTRODUCTION

Soil erosion due to decreases in vegetation ground cover in headwater catchments produces excess sediment to down streams. Reduction of vegetation and litter ground cover can induce severe degradation of both soil physical and geochemical properties (Montgomery, 2007). For instance, Fierer and Gabet (2002) showed that hillslope vegetation types had strong effects on the loss of carbon and nitrogen. Changes of ground surface condition typically occurred due to forest cutting, burning, pasture establishment, abandoned plantation forest (Dung et al., 2011) and excess pressure of wildlife (Afshin et al., 2011).

Despite findings for the interactions among soil erosion, nutrient loss, and ground cover, most of the studies were conducted only in hillslope plot scales. Changes in hillslope condition can be propagating toward streams and further downstreams in watershed scales. In headwater streams, because of the linkages between hillslope to streams are tight (Gomi et al., 2002), soil erosion and nutrient conditions on hillslope can directly affect sediment transport (i.e., turbidity and suspended sediment concentration) and water quality (i.e., concentration of specific ions). Watershed perspectives are important for understanding how the land surface conditions and associated management practices affects soil erosion and nutrient accumulations in both hillslope and catchment scales. Therefore, the objective of this study is to evaluate the linkages among vegetation ground cover, soil erosion, and nutrient conditions in forested headwaters.

2. STUDY SITE AND METHOD

This study was conducted in two headwater catchments named as Watershed No. 3 (7ha) and Watershed No. 4 (4.6ha). The percentage of bare soil slope in Watershed No. 3 was 18%, whereas that in the Watershed No. 4 was 6%. Most of hillslope gradient was more than 45^{o}, which are located to adjacent to channels. The climate is moist and cool, with 2,600 mm mean annual precipitation and 9^{o}C mean annual temperature.

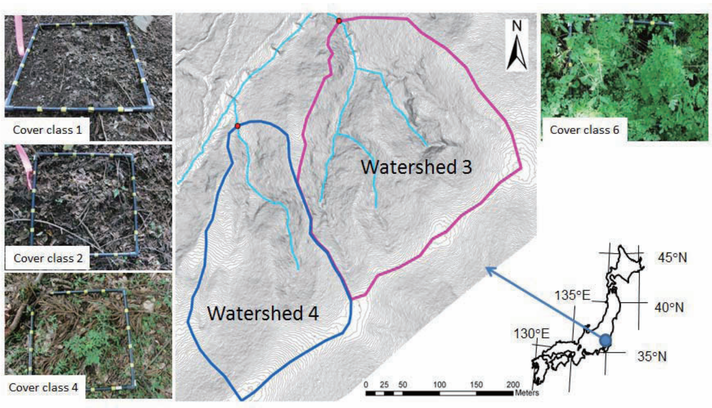

Figure 1. Outline of this study site

For investigating catchment-scale vegetation ground cover, we established 53 plots which in two watersheds. We then classified six categories: (1) bare land, (2) sparse litter cover, (3) rich litter cover, (4) understory groundcover < 40%, (5) understory groundcover 40 - 80%, (6) and understory groundcover > 80%. For each location, we set 50 x 50cm plots for measurement of above-ground biomass of understory vegetation and litters. All living biomass were clipped above the soil surface at each plot. For all plots, we also measured soil hardness, soil bulk density, water contents. We estimated canopy openness using a fish eye lens and a digital camera. We measured high of soil pedestal as the indication of soil erosion (Sidle et al., 2004). All of the field sampling was conducted in August to September, 2010.

For the further analysis, we also estimated activities of ^{137}Cs and ^{210}Pb$_{ex}$ of soil < 0.5 mm as indicators of soil erosion. We obtained soil sample and dried for 48h at 105℃, then analyzed by gammma-ray spectrometry. For soil < 1 mm, we estimated carbon and nitrogen contents using CN corder MT – 700 (Yannaco Ltd.).

3. RESULTS AND DISCUSSION

Despite the variably, hillslope gradients tended to be smaller with higher ground cover classes. Because the steep hillslope was located near stream channels, low ground cover areas (bare land and sparse litter), which can be potential sediment sources, were located adjacent to stream. Indeed, low ground cover areas tended to had greater soil pedestals. Mean soil pedestals high in bare land and sparse litter was approximately 2.5 cm, while soil pedestals in hillslope with understory vegetation was less than 1.5 cm. Because order of magnitude of soil pedestal heights can indicate short-term soil erosion rate (Sidle et al., 2004), soil ground cover conditions appeared to affect short term soil loss from the plots.

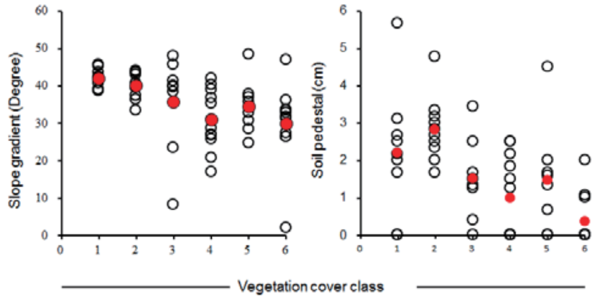

Figure 2. Vegetation cover condition and slope gradient, soil pedestal height.

Percentages of soil carbon ranged from 2.0 to 9.0 %, while the percentages of soil nitrogen ranged from 0.2 to 0.6 %. C/N ratio ranged from 11 to 16. Because the C/N ratio forested area around Tokyo areas was ranged from 14 to 18, the C/N ration of our study site tended to higher than the other forested area. Lower C/N ration potentially produce more NO^{3-} in the soil and increases in resultant stream NO^{3-} (Yoh, 2001).

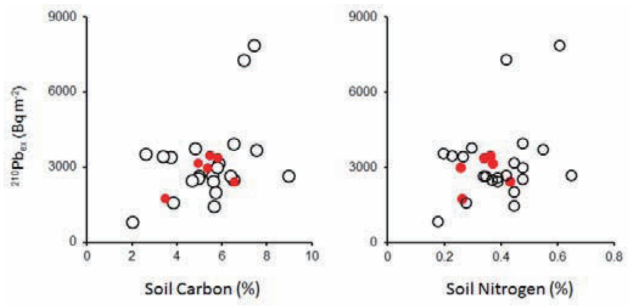

Figure 3. Relationship of $^{210}Pb_{ex}$ and soil nutrient

Soil $^{210}Pb_{ex}$ inventory ranged from 798 to 7844 Bq m^{-2}. Soil ^{137}Cs ranged from 156 to 866 Bq m^{-2}. Because, soil samples was analyzed using soil samples collected prior to Fukushima accident. Despite the variability, soil carbon tended to increase with increasing in inventory values of $^{210}Pb_{ex}$ (Figure 3). A relationship between soil nitrogen and $^{210}Pb_{ex}$ was more obscure than that of carbon. These results showed that carbon and nitrogen accumulations can depend on rather long-term soil erosion and production processes. Therefore, soil conservations both short and long term soil erosion can be important.

4. CONCLUSION

Findings of our study showed that soil carbon and nitrogen condition affected the amount of surface soil erosion and soil surface condition such as vegetation types and litter. Our finding suggested both short- and long-term mechanisms of soil erosion processes and productions are essential understanding the effect of management practices for soil conservation. For further developing catchment scale modeling, interactions among vegetation, soil nutrient, and erosion can be included.

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