Surface Soil Erosion Reduced by Contour-Felled Log Erosion Barriers in Recently Burned Forest Areas

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1. Introduction

Many natural resource managers are currently seeking eco-friendly and efficient restoration measures to control surface soil erosion over broad areas in burned forest regions. Contour-felled log erosion barriers (CFLEBs) made of fire killed trees could be an effective measure for controlling surface soil erosion and reducing turbidity in streams. Burnt trees are often cut down after forest fires in the Republic of Korea to prevent damage caused by insect epidemics, but these trees are considered waste material. The construction of CFLEBs using felled trees, therefore, could be an economically and ecologically useful method to reduce surface soil erosion and turbidity in streams over large scales.

The objectives of this study were 1) to examine the influence of forest fires on the physical properties of the soil and 2) to assess the effectiveness of using CFLEBs to reduce surface soil erosion. First, we investigated differences in bulk density and porosity of the surface soil in burned and unburned areas. Second, we quantified the effects of CFLEBs on sediment yields in the burned areas. This study was carried out with the support from Forest Science and Technology Project (S111213L050110) provided by Korea Forest Service.

2. Materials & Methods

2.1. Study Site

Our study site was located along the East Sea in the Gangwondo, Republic of Korea (Fig. 1). Initally, forests consisting of *Pinus densiflora* and *Quercus* spp. were widely distributed throughout the eastern coastal region. However, the forests were severely damaged by the forest fire occurred in April 2000. The Korea Forest Research Institute has created a Long-Term Ecological Research (LTER) site in the Samcheok region to study influence of fires on forest ecosystems and to develop effective restoration methods in the burned area.

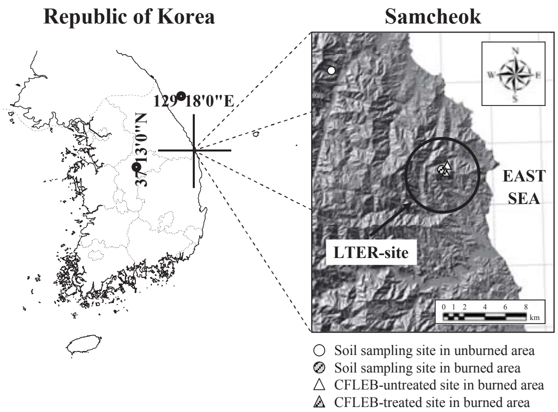

Fig. 1. Location of the study site.

Large proportions of the burned areas are recovered with regenerated roots and sprouts from fire-damaged oaks below 1.0 m in height. The soil parent materials in the areas are primarily granite and limestone. The surface layer in the study area was composed mostly of inorganic material due to the combustion of vegetation and the litter layer during the fires. The presence of such soils can heighten the risk for surface erosion and landslides.

2.2. Field Survey and Laboratory Analyses

Surface soil samples were collected during 2002-2005 from burned and unburned areas. The soil samples were collected at depths of 0-5 cm using a soil sampler (DIK-115B) equipped with 100 cm^3 stainless steel cylinders. Bulk densities of the surface soils were calculated after drying the samples for 24 h at 105°C. The porosity of the surface soil was calculated by the use of information obtained on the particle density and the bulk density. Soil porosity is the ratio of the soil pore volume to the total volume. From definitions that equate bulk density to the soil mass per total volume of soil and particle density to the soil mass per soil volume, porosity can be calculated from the ratio of the bulk density to particle density. The volume of soil pores was measured under low-pressure conditions at a pF of 2.7 with an automatic pressure controller (DIK-9211) after capillary saturation of the surface soil within a 100-cm^3 stainless steel cylinder. The soil volume was determined by subtracting the volume of soil pores from the total soil volume.

The study sites were classified by which it was treated with CFLEBs as either (i) treated sites or (ii) untreated sites. At each sites, three plots (3 m wide and 5 m long) were installed to evaluate the reduction in surface soil erosion with the application of CFLEBs (Fig. 2). At the base of each plot, a catchment barrel was installed to trap any sediment that was eroded from the plot. The sediment yield was annually measured over two years from May 2010 to June 2012. During the May 2010 to June 2011 sampling period, sediment yields were measured twice on May 2010-September 2010 and October 2010-June 2011. All collected sediment were sieved to separate leaf and wood particles from the sediment. The filtered samples were oven-dried at 110°C for 24h and then weighed to obtain sediment yield.

3. Results

3.1. Changes in Soil Properties by Forest Fires

The results analyzed to evaluate the influence of forest fires on the physical properties of the soil showed that the bulk densities and porosity of the surface soil were significantly changed by forest fire ($p < 0.05$). The bulk densities of surface soil were 1.11 and 0.92 $g \cdot cm^{-3}$ in the burned and unburned areas, respectively. The porosity of surface soil were 0.35 and 0.41 in the burned and unburned areas.

3.2. Reduction in Surface Soil Erosion by CFLEBs

The sediment yields at the CFLEB-treated sites were significantly lower than those at the untreated sites ($p < 0.05$). The average sediment yields at the CFLEB-treated and the untreated sites were 17.8 and 133.6 $g \cdot m^{-2}$, respectively. The results of this study indicate that CFLEBs arranged at a density of roughly 0.34 m^3 in the study area were responsible for an approximately 8-fold reduction in the sediment yield from burned slopes. In addition, these results should represent typical patterns since the measurement were taken under conditions of average precipitation.

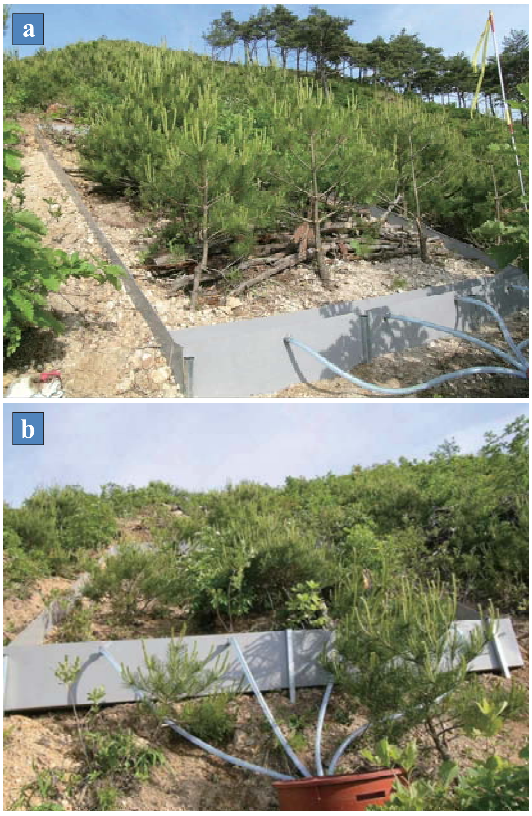

Fig. 2. The plots installed at (a) the CFLEB-treated site and (b) the untreated site.

4. Discussion

The increase in bulk density and decrease in porosity of burned areas implied that previous forest fires destroyed most of the surface soil structure. The destruction of the soil structure has likely made the soil more vulnerable to post-fire runoff and surface soil erosion on the burned hillslopes (DeBano, 2000). In addition to the influence of forest fires, the steep slopes and decomposing granite in the area likely contributed to the acceleration of surface soil erosion. The burned areas in the eastern coastal region of the Republic of Korea have been recovered by the natural regeneration of roots and sprouts from fire-damaged oaks (Choung *et al.*, 2004) as well as via *P. densiflora* planting efforts. However, the physical structures of the burned area surface soils were not fully recovered. Thus, there is still the potential for severe surface soil erosion and high water turbidity during rainfall events.

In the Republic of Korea, post-fire management activities have been implemented to decrease potential for soil erosion events due to intense rainfall (Lim *et al.*, 2010). Unfortunately, these emergency rehabilitation activities are difficult to implement over large spatial scales because of the substantial costs associated with such projects. Previous studies have shown that cost-effective CFLEB treatments can reduce water velocity, break up concentrated flows, create hydraulic roughness, and prevent sediment erosion in burned watersheds (Robichaud *et al.*, 2005). This study showed that the use of CFLEBs in burned areas can significantly reduce sediment yields. The trapped sediments were concentrated in the upper sections of the treated sites, where burned trees were stacked on top of each other. This suggests that the stacking of burned trees along topographic contours in burned areas might be an effective and practical treatment mea- sure for controlling soil erosion and reducing stream water turbidity over large areas of burned forest. Damaged trees in burned areas are often cut down to prevent damage from insect epidemics and the felled trees are considered to be waste material (Lim *et al.*, 2010). The construction of CFLEBs using the felled trees would represent an effective, economically sound, and ecologically useful measure for controlling surface soil erosion and reducing turbidity in streams.

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