Ecological Engineering 109 (2017) 15–24

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Research paper

Effectiveness of sawdust and straw mulching on postharvest runoff and soil erosion of a skid trail in a mixed forest

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A R T I C L E I N F O

Keywords:
Skid trails
Runoff
Sediment yield
Mulching
Sawdust
Straw

A B S T R A C T

Loss of vegetation cover by forest harvesting has increased the average surface runoff volume and sediment yield in the Hyrcanian forest in Iran. Hence, treatments are needed to mitigate the effects of skidding operations on hydrological characteristics and sediment delivery into streams. The present study evaluated the efficacy of straw and sawdust mulches in reducing soil erosion relative to untreated control plots in a severely compacted loam soil area in the Hyrcanian forest during the first year after harvesting. Immediately after skidding operations, triplicate skid trail plots received straw mulch (16.5 kg m^{-2}) sawdust mulch (2.8 kg m^{-2}) or were left untreated for the control plots (8 m^2). The experimental design was completely randomized; plots were randomly assigned to treatment, season, and leafless and leafed periods. The results of generalized linear modeling showed that season and treatment significantly affected the amount of runoff and sediment. Runoff was significantly lower in the summer than in the other seasons. Applying straw mulch to the skid trail decreased runoff by 36.5%, and sawdust mulch decreased runoff by 72.8% compared with the control. The straw and the sawdust mulch also decreased sediment yield by 51.9% and 94.9%, respectively. A regression analysis revealed that the runoff response to rainfall for all the treatments was linear. Also, the total measured runoff in all seasons after the straw and the sawdust mulch was less than the runoff of the control plots. However, the measured runoff in the leafless period was greater than in the leafed period. In the straw and the sawdust mulch, measured runoff in the leafless period was 91.7% and 89.8% of the total runoff, respectively. In the straw and sawdust treatment, 99.4% and 98.4%, respectively, of the sediment occurred in the leafless period. Covering the bare mineral, compacted soil on skid trails thus greatly reduces surface runoff and sediment yield.

1. Introduction

Since forest soils have high organic matter, low bulk density, high porosity, high permeability, and low resistance to penetration, they are sensitive to soil compaction (Ampoorter et al., 2007; Jourgholami et al., 2014) and shear stress (Horn et al., 2007; Eliasson and Wasterlund, 2007), especially from logging activities. A mechanical load (e.g., skidding machine) applied to the soil changes the soil aggregate and distribution; compaction and shear stresses cause the soil particles to merge, increasing soil bulk density (Grace et al., 2006; Cambi et al., 2015). The most important effect of this reduced permeability of compacted soils is runoff, that reduces the soil water balance and often leads to soil erosion (Croke et al., 1999, 2001; Kozlowski, 1999; Cristan et al., 2016; Ashcroft et al., 2017).

Logging operations also cause wheel ruts, especially in wet soils and on steep trails where water can create gullies and erode the land (Christopher and Visser, 2007; Cambi et al., 2017). Skid trails, like forest roads, are thus a major source of sediments (Hartanto et al., 2003; Stuart and Edwards, 2006; Christopher and Visser, 2007; Hotta et al., 2007; Smith et al., 2011; Holz et al., 2015; Wagenbrenner et al., 2015). The loss of vegetation cover after forest harvesting also increases the volume of surface runoff and sediments (Hartanto et al., 2003; Brown et al., 2005; Moore and Wondzell, 2005; Wade et al., 2012; Webb et al., 2012; Ide et al., 2013; Holz et al., 2015). Hence, timber harvesting operations are considered as nonpoint source pollution (NPSP) (Wade et al., 2012; Cristan et al., 2016).

Various mulches (material such as straw, leaves, plastic film, or loose soil that is spread on the surface of the soil to protect the soil and plant roots) have also been applied to control and mitigate surface runoff and sediment after wildfires (Wagenbrenner et al., 2006; Robichaud et al., 2008, 2009, 2016; Dodson and Peterson, 2010; Prats et al., 2012; Santana et al., 2014; Díaz-Raviña et al., 2015; Vega et al., 2015). Agricultural straw, seeding herbaceous plant or shrub seed alone or in combination with other postwildfire rehabilitation activities, geotextiles, hydromulches and dry mulches made from forest materials (e.g., wood strands, wood chips, or wood shreds) have been tested and

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http://dx.doi.org/10.1016/j.ecoleng.2017.09.009
Received 2 April 2017; Received in revised form 10 September 2017; Accepted 13 September 2017
0925-8574/

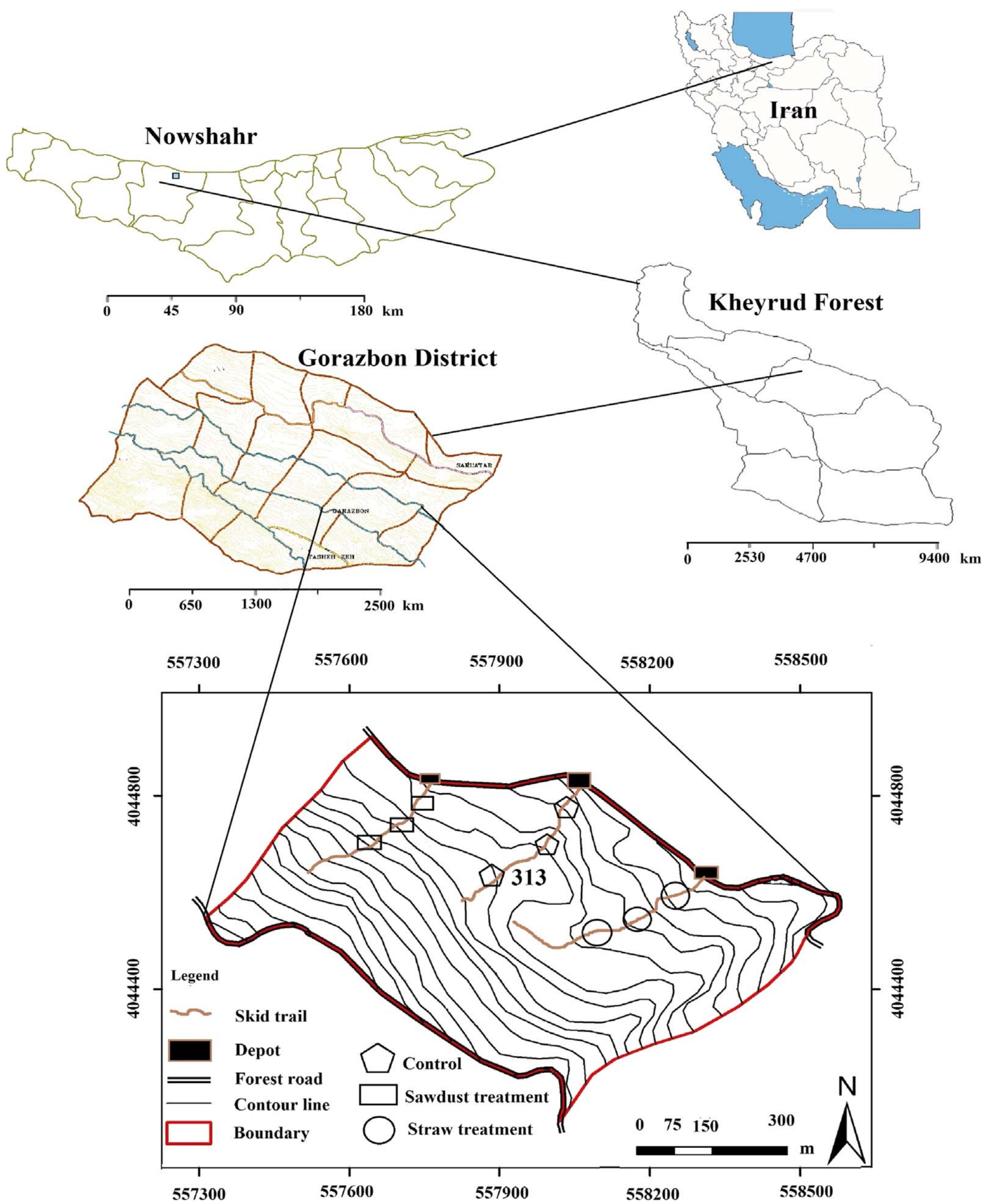

Fig. 1. Layout of the skid trail treatments plots in Gorazbon District in the Hyrcanian forest.

in some cases applied as postfire hillside treatments in the several studies (Peppin et al., 2010; Robichaud et al., 2013; Prats et al., 2014; Vega et al., 2014; Sadeghi et al., 2015; Wagenbrenner et al., 2015; Fernández and Vega, 2016a,b). Although neither the types of effects nor the intensities of the disturbance of wildfires are comparable to those of ground-based logging, but in each case, removing the litter layer and increasing soil compaction eventually leads to decreased water permeability and increased runoff and sediment. In a study of postfire salvage logging, Wagenbrenner et al. (2015) found that sediment production from burned soils in skidder trail plots was 10–100 times greater than in the undisturbed control plots.

Forestry best management practices (BMPs), including operations such as log landings, skid trails, stream crossings, and site preparation (Cristan et al., 2016), have helped decrease surface runoff and sediment in streams and rivers (Stuart and Edwards, 2006; Wade et al., 2012; Sawyers et al., 2012). Amending skid trails with slash (Wagenbrenner et al., 2015), adding fiber to skid roads (Grushecky et al., 2009), mulching just after a fire (Wade, 2010; Fernandez and Vega, 2016a,bFernandez and Vega, 2016a,b), scattering slash and litter (Fernandez et al., 2004; McIver and McNeil, 2006), rapidly applying mulch (Sadeghi et al., 2015; Prats et al., 2016a,b), using BMPs techniques (Wade, 2010; Nolan et al., 2015; Cristan et al., 2016), and installing waterbars and/or applying slash, mulch, or a combination of mulching and seeding (Cristan et al., 2016) have been recommended.

Additionally, Sawyers et al. (2012) evaluated the erosion control effectiveness of five overland skid trail closure techniques and found that combining water bar installation with seeding and mulching was most effective for reducing erosion (3.29 Mg ha^{-1} yr^{-1}), followed by water bar plus mulching with hardwood slash (5.08 Mg ha^{-1} yr^{-1}). When Wade et al. (2012) examined five BMPs for bladed skid trail closures to control erosion in the Piedmont region of Virginia in the United States, the water bar was the most effective at controlling erosion (137.7 t of sediment ha^{-1} yr^{-1}). Wear et al. (2013) applied skid trail stream crossing BMP including slash, mulch, grass seed, silt fence and mulch plus grass seed. Results showed that the most effective methods for reducing the amount of sediment entering the stream was the slash treatment (62.7% reduction), followed by the mulch treatment (15.8% reduction), and finally the mulch + silt fence treatment (10.5%