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Impacts of soil stabilization treatments on reducing soil loss and runoff in cutslope of forest roads in Hyrcanian forests

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ABSTRACT

Cutslopes are the most important source of sediment among other parts of forest roads network. A significant amount of runoff and sediment is observed in Hyrcanian forests because of the fine-textured soil. This study investigated the effectiveness of three treatments of jute cover (JC), mulch cover (MC) and bare cutslope as control plots (CP) under the natural rainfall condition. Two months investigation on two new and old roads with silty-clay cutslopes was done. Correlation between some of soil properties, soil loss and runoff showed that the sediment concentration was increased with increasing in soil bulk density. Runoff volume showed a significant negative correlation with the percentage of organic matter and a positive correlation with the plastic limit. With runoff volume increasing, sediment concentration and soil loss were significantly increased. Analysis of the results showed that in both new and old roads, the treatment of JC is superior. This treatment has reduced soil loss by 9.68 times compared to CP treatment. The treatment of JC compared to the MC on a new cutslope and an old one has reduced soil loss by 2.77 and 2.54 times. Also, JC have reduced soil loss by 2.67 times compared to the MC. The total cost per square meter of JC is US $ 0.21 and this amount is equivalent to $ 0.26 for the MC. According to the results, it is suggested that soil protection and bioengineering designs should be focused on the use of JC.

1. Introduction

Forest roads are the essential component of forestry and forest management. Any operations in forests are unimaginable without well-designed forest roads (Lotfalian and Parsakhoo, 2012). Changes in natural slopes and vegetation by creating the cutslopes, fillslopes and soil compaction of roads surface, cause disruptions in the hydrological behavior and physical properties of soils, which would lead to occurrence of runoff and soil loss (Tague and Band, 2001; Aust et al., 2011). This issue in turn would make forest roads as one of the main source of sediment into streams networks of a watershed. Researches results have shown that the greatest volume of soil loss is observed in the first years after the road construction and vehicles traffic (Arnáez et al., 2004). Soil loss is a phenomenon that impacts stability of fillslopes, and durability and stability of technical buildings (Kidd et al., 2014).

The road trenches are divided into two distinct groups: (A) cutslope as a result of cutting a natural soil that is compacted and (B) fillslope as a result of creating embankment. Cutslopes has steep slopes than the natural slope and are often very poor in vegetative cover in the early years of construction (Jordán-López et al., 2009). Fillslopes are covered by the local plant species in a short time. These plants are capable of protecting the underlying soil as an insulator against geomorphologic processes that cause soil erosion (Gimeno-García et al., 2007). This has led to study the reduction of soil loss rate by conducting soil bioengineering and vegetation restoration on cutslopes in this study.

Preventing soil loss is considered as an important goal in the management and conservation of natural resources. A common method for soil conservation is the use of mulch. In the past, mulch was referred as covering the soil surface with organic material such as straw, plant leaves and sometimes animal manures and similar materials. Recently, it is referred to other natural or synthetic materials that could create a distinct and extensive layer on the ground and could protect the soil against wind and rain (Rafahi, 2006). The mulch can prevent soil erosion, reduce weeding, conserve soil moisture, and increase temperature of the soil. In order to control erosion in forest areas, natural mulch should be used that are indigenous vegetation. However, using exotic materials like agricultural straw or chemical mulches such as polymers and polyacrylamide, which have a long durability, do not play a role in soil enrichment after their loss and would pollute the environment, thus damage the natural habitats (Robichaud et al., 2010). A suitable material for substitution is wood products in forest. The residual slash is one of the wood products that are used as mulch for erosion control in

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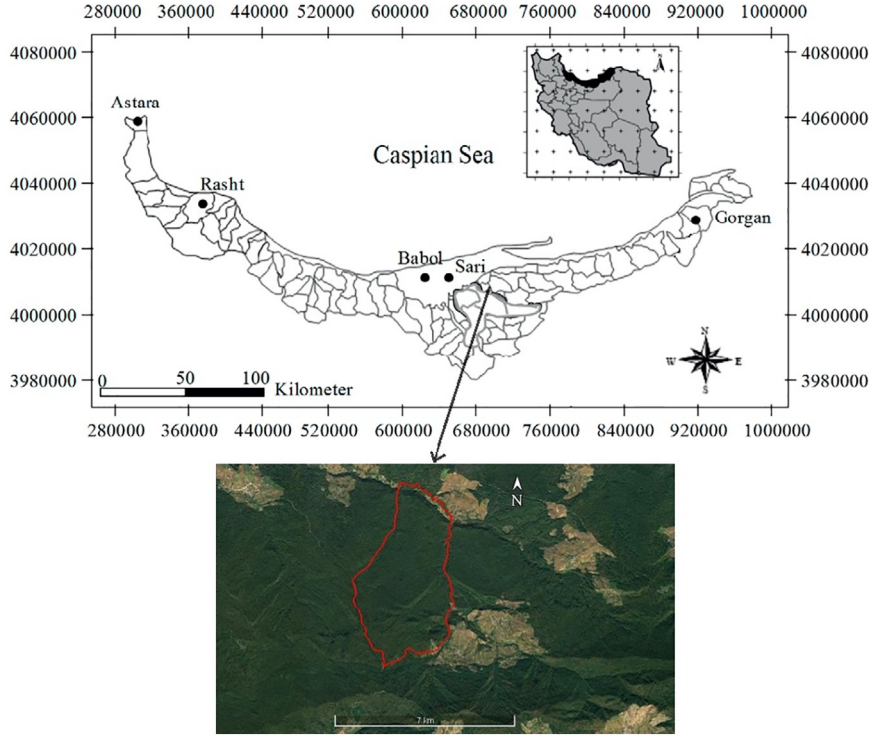

Fig. 1. Study area in Hyrcanian forests.

Fig. 2. Photos of old (a) and new (b) forest roads.

forest areas.

Arnáez et al. (2004) conducted a study on roads in Spain and found that more sediment concentration was generated in the first few minutes after running the rainfall simulator. The highest amount of sediment (161 g m^{-2}) was generated on the cutslopes, which were 16 and 11 times greater than fillslopes and road surface, respectively. Using the rainfall simulation tests, Cerdà (2007) measured the amount of soil loss or erosion on cutslopes over 5 areas in Valencia, Spain. He reported that the amount of soil erosion on the newly constructed trenches without vegetation was 30 times more than covered old cutslopes. De Oña et al. (2009) examined the effects of the use of sludge and compost on reduction of erosion rate of cutslopes in Gador in Almería, a province southern Spain. They used sludge and compost separately and in combination on cutslopes. The results showed that the separate use of sludge and compost could reduce the amount of soil loss by 35%; while in the combination case the erosion rate was reduced by 63 to 93%. Robichaud et al. (2010) studied the effects of conservation practices such as mulching with wood chips, seeding with native species and tree trunk barrier (LEB) on runoff and soil erosion in the east coast of Korea three years after the 2002 fire. The results showed that mulching with wood chips had greatly reduced the runoff and sediment; while seeding or LEB did not reduce the runoff. By using a rain gauge field, Kavian et al. (2010) studied the effect of soil properties on runoff and soil erosion in some parts of Hyrcanian forest. The results showed that soil organic matter content and sand percentage had a negative correlation coefficient; while previous soil moisture and bulk density had a positive correlation with the amount of runoff. In addition, the rate of soil erosion had a negative correlation with the amount of organic matter and a positive correlation with previous soil moisture. Li et al. (2011) tested the effect of mulch and grass cover with three treatments (grass cover, grass mulch and bare soil) on the runoff and soil loss on gradient lands in southern China over 5 years. The results showed that the surface runoff and erosion in plots with grass cover and grass mulch was lower; on the contrary they were high in the control plot. Lou et al. (2013) tested the effect of three types of geotextile on the runoff and soil loss on roads trenches in Beijing, China by using simulated rainfall test. The three types of treatment were the straw mats, non-woven fabrics and shadow network. All three treatments compared to the control (bare slopes) had a significant relationship with reduced soil loss and runoff. Shao et al. (2014) in a study using a rainfall simulator, studied the effect of vegetation on runoff, sediment and soil shear strength on roads trenches in China. The results indicated that the soil erosion on cutslopes was more than fillslopes. Totally, the treatments of grass and grass-shrubs were more appropriate and cost-effective in

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