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The Effect of Forest Road Construction on Soil Organic Carbon Stock in Mountainous Catchment in Northern Iran

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Abstract

The main objective of this study was to investigate the effect of forest road construction on the Soil Organic Carbon Stock (SOCS) in Ziarat Catchment. Therefore, soil samples were collected from five land use types including road construction, cultivated area, channel bank, pasture and forest land and soil organic carbon concentration and bulk density were measured in the samples and SOCS were calculated. The results showed that the forest road construction reduce SOCS. SOC stock was greatest in the forest land use and the total SOC stock under different land uses varied in order forest, pasture, cultivate, channel bank and road construction with 143, 136, 128, 36 and 29 Mg ha^{-1}, respectively ($p < 0.001$). Therefore, these results can be useful as a scientific basis for selecting the proper soil erosion control methods as a simple and low-cost approach to mitigate the SOC loss.

Keywords:
Forest road, Organic carbon stock, Ziarat Catchment, Different land uses, Soil erosion

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INTRODUCTION

The forest ecosystem is one of the several ecosystems being considered for storing additional carbon since it is unique in containing large above- and below-ground stocks of carbon (Johnson and Kern, 2002). Although 40% of soil carbon is found beneath forests, carbon is accumulated in forest soils (especially in mountainous areas) (Lal, 2005; Peltoniemi *et al.*, 2007). Variations in soil OC stocks are related to a number of natural factors (e.g. climate, parent material, landscape position) and human-induced factors (e.g. land use type, management intensity) (Mou *et al*., 2005; Somaratne *et al.*, 2005; Tan *et al*., 2004). Of these factors, land use is the most sensitive to human disturbance. Monitoring the SOC for different land uses is essential for estimating the SOC distribution and stock (Fang *et al.*, 2012). Road construction removes the forest vegetation, disturbs forest floor, and damages soil structure, which dramatically increases the sediment yield (Demir and Hasdemir, 2005). In order to protect forest areas from land use change, it is necessary to quantify forest productivity and to consider among forest benefits not only the production of wood (for biofuel or timber), resins or cellulose, but also the provision of environmental services like carbon storage, aquifer recharge, soil and surface water conservation, etc. (Peña-Ramírez *et al*., 2009). Several studies have estimated the differences in the SOC in relation to vegetation and topography, land use, and climate. Kucuker *et al.* (2015) evaluated the impact of land use change on the soil carbon stock in the Karasu region of Turkey, and estimated average carbon stocks at the depth of 0–1 m to be 12.36 and 12.12 kg/m^2 in forested and agricultural soils, respectively. (Korkanç, 2014) In an investigation on the effects of a forestation on soil organic carbon and other soil properties, Korkanç (2014) found that these values were significantly higher than the values for the bare land soils (0.54%). For all types of land use, the amount of the SOC in the soils decreased with depth. The amount of carbon sequestrated in Black Pine, Cedar and bare land sites at the depths of 0–10 cm and 10–20 cm were 18.20 t/ha and 16.33 t/ha, 23.54 t/ha and 12.38 t/ha and 11.2 t/ha and 7.22 t/ha, respectively. The objective of this study was to investigate the effect of road construction (Figure 1) on carbon stock rate in Ziarat catchment in Golestan province in Iran.

MATERIALS AND METHODS

The study area was Ziarat catchment (54°23' to 54 31'N and 36°36' to 36°43' E) which is located in the 10 km Southern of Gorgan, part of Gharesoo Drainage Basin, Golestan Province, Iran (Figure 1). The drainage area of the catchment is 77 km^2. Ziarat catchment has a mountainous topography and is covered with forest with minimum and maximum altitudes of 703 m and 3020 m above the sea level, respectively. The long-term (2002-2012) mean annual precipitation is 531 mm in the region where it mostly occurs in late autumn and winter.

Sampling and data collection

According to land use, five sites were sampled including forest, arable lands, pasture, road and

Figure 1: An example of a damaged road verges in Ziarat catchment.

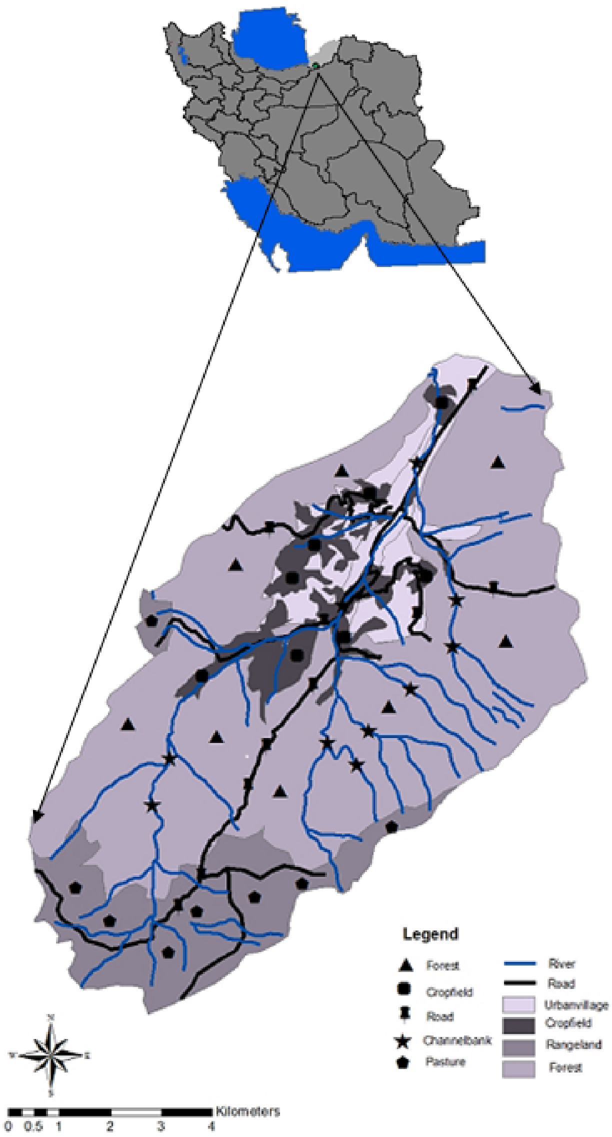

Figure 2: Soil sampling site - Ziarat catchment- Iran

channel bank from which 8, 8, 8, 10 and 9 representative samples were collected at different locations within the Ziarat catchment, respectively (Figure 2). Sampling sites were selected so that similar land forms (slope, aspect and elevation) or uniform topographic positions were selected in all sites. The samples were collected by taking a representative sample from the top soil layer (0–5 cm). In each sampling site, five subsamples were collected over an area of approximately 100 m^2 which were mixed into a single composite sample.

Soil bulk density was measured on 6 cm long and 6 cm diameter stainless steel cores. Samples were air-dried and sieved (<2 mm) for organic C concentrations measurement.

The organic C content was measured by the Walkley-Black method (Skjemstad and Baldock, 2008). The SOC and stocks were calculated based on the following formula (Yu *et al.,* 2007):

$$SOCD=(1-\theta_i\%)\times \rho_i \times C_i \times T_i/100$$

where, SOCS (Mg ha^{-1}) is soil organic carbon stock, θ_i is gravel content (>2 mm) in horizon *i* (%), ρ_i is soil bulk density in horizon *i* (Mg m^{-3}), *Ci* is the concentration of organic carbon or total nitrogen in horizon *i* (g kg^{-1}), *Ti* is the thickness of horizon *i* (cm), and *n* is the number of horizons involved.

Statistical analyses

Data were examined using the Kolmogorov-Smirnov test for normality and the Levene test for

Table 1: Descriptive statistics of SOCS in different land use types

Land use	No. of samples	SOCS (Mg ha^{-1})		
		Mean	SD	SE
Total	43	94.3	21.3	5.30
Road	9	29	20.7	7.30
Channel bank	10	36.5	20.8	6.20
Forest	8	142	28.8	10.2
Pasture	8	136	19.3	6.80
Cultivate	8	128	23.7	13.4

Table 2: One way ANOVA for the effects of land use types on SOC

Effect	df	SS	MS	F	p-value
Intercept	4	112468	28117	53	0.000
Land use	38	19810	521	4	0.000
Total	43	10185			

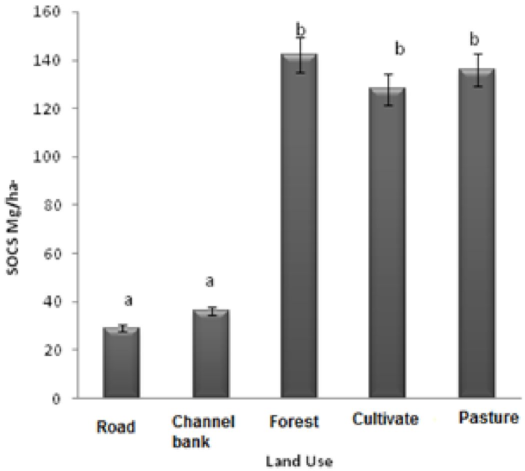

Figure 3: SOCS in different land use units are significantly different at 1% level.

homogeneity of variance. These statistical analyses were followed by one-way ANOVA (F-test) and unequal N Tukey HSD, post-hoc tests for the identification of significant differences among treatments (Nosrati, 2013). Statistical analyses were carried out using SPSS.16 Software Package.

RESULTS

Comparison of organic carbon stored in the analysis of variance showed a significant difference in soil organic carbon storage in road and channel bank with other land uses. But there was no significant difference in the other land uses of the forest, pasture and agriculture (Table 1). There are maximum range SOCS in forest land 142 (Mg ha^{-1}) and minimum of it in road construction 29 (Mg ha^{-1}). SOCS in roads and channel banks are less than other land uses. Moreover the results of one way ANOVA showed that SOCS are significantly different in land use types (Table 2 and Figure 3).

DISCUSSION

The results of this investigation suggest that damaged road verges can represent an important primary source of soil erosion. Very few studies have been done on the effect of road construction in soil organic carbon stock. Pearson *et al.*, (2014) studied carbon emissions from tropical forest degradation caused by logging and found that logging infrastructure factors for three countries varied by almost a four-fold factor between the lowest and highest value. In all cases, roads and desks dominated total infrastructure emission of SOC representing 96% of emission in RO Congo, 70% in Indonesia and 83% in Guyana. Our purpose of this study was to study the effect of forest road in organic carbon stocks in Ziarat basin, Iran. So, SOC was investigated in five land uses and results showed that there were difference in SOC rates among forest road, channel banks and some land uses.

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