Geoderma 284 (2016) 103–112

Contents lists available at ScienceDirect

Geoderma

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

Effects of road construction on soil degradation and nutrient transport in Caspian Hyrcanian mixed forests

Saleh Yousefi [a,*], Hamidreza Moradi [a], Jan Boll [b], Sarah Schönbrodt-Stitt [c]

[a] Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Emam Reza Street, P.O. Box: 46417-76489, Noor, Iran
[b] Civil and Environmental Engineering, Washington State University, P.O. Box 645425, Pullman, WA 99164-5425, USA
[c] University of Tübingen, Department of Geosciences, Chair of Physical Geography and Soil Science, Tübingen, Germany

ARTICLE INFO

Article history:
Received 15 April 2016
Received in revised form 26 August 2016
Accepted 1 September 2016
Available online 7 September 2016

Keywords:
Forest soil
Forest road
Soil chemical properties
Soil erosion degradation and land degradation

ABSTRACT

Forest roads are the most essential projects in forest management. The aim of the present study was to investigate the effects of topographic factors on nutrient transport and degradation areas resulting from forest road construction in the Research and Educational Forest of Tarbiat Modares University in Iran. In this study erosion features around the forest road with a distance of 50 m from the road were documented using a Global Position System (GPS). Work units were determined by using slope, aspect and elevation maps. In addition, physical and chemical soil properties were determined in 19 work units for erosion regions, non-erosion regions and control regions. Results of correlation analysis between regional erosion features with distance to the road and number of erosion features show a significant correlation at the 99 percent level of confidence interval. Furthermore, there is a significant correlation between areal erosion features and elevation classes, slope, road age classes and aspect at the 99, 95, 95 and 95 percent significant level, respectively. Results of analysis of variance (ANOVA) show that areal erosion features at different elevation classes, slope, aspects and road age classes have a significant difference at the five, five, one and five percent level, respectively. Results of ANOVA for physical and chemical soil properties on erosion areas, non-erosion areas and control areas conveyed significant difference in pH, soil organic matter, silt, clay, nitrogen and phosphorus. These findings demonstrate the connectivity of soil properties when they are impacted by human activities.

1. Introduction

Soil is very important for the earth system and losing the soil is a big threat for many functions the system provides (Brevik et al., 2015; Decock et al., 2015). In addition, soil is a key component of the earth system as it controls hydrological and geochemical process including water erosion (Keesstra et al., 2016a, 2016b; Smith et al., 2015). Worldwide, soil erosion is a major environmental problem having serious ecological and socio-economic implications (Chen et al., 2011; Norris, 2008). Although soil erosion is a natural geomorphic process evident throughout Earth history (Breshears et al., 2003). Inappropriate land use and management have caused serious on-site and off-site effects (Cerdà et al., 2016; Hansbauer et al., 2008; Jimenez et al., 2013; Keesstra et al., 2016a, 2016b; Nanko et al., 2015; Navarro-Hevia et al., 2015; Palacio et al., 2014; Prosdocimi et al., 2016; Sadeghi et al., 2007; Wang et al., 2014; Yazdanpanah et al., 2016). According to Lal (2001), water erosion is the main driver of soil degradation. At the end of the 20th century, for instance, almost 67% of the worldwide approximately 16.4 million km^2 of degraded soil was linked to water erosion.

With the increase of employment of machines and technology development during the 20th century, human impacts on natural land strongly increased and also favored access to pristine areas of land as forested ecosystems. An example is road construction for the purposes of land reclamation and infrastructure connection (Cheng et al., 2015; Navarro-Hevia et al., 2015; Rose et al., 2014; Safari et al., 2016). Although roads are essential in forest management (i.e., timber harvesting, fire management, and disease control) and in conservation and recreational activities as stated by Brown et al. (2015) and Liu et al. (2014), they are primarily considered as connection pathways for logging and deforestation (Barber et al., 2014). As stated by Alves (2002), 90% of deforestation activities occur within <100 km distance from roads. According to the Lindquist et al. (2012), the worldwide net change of forest cover by deforestation from 2000 to 2010 was estimated to be approximately 5.2 million ha.

Forest roads further enhance the soil erosion potential by compacting the soil surface, removing the soil-protective vegetation cover and disturbing the forest floor during construction (Akay et al., 2008; Cao et al., 2015; Cerdà, 2007; Grace, 2000; Jimenez et al., 2013). In turn, infiltration is reduced and runoff potential increased, even for low-intensity rainfall events (Atucha et al., 2013; Pereira et al., 2015; Ziegler et al., 2009). Moreover, Cerdà (2007) reported that soil erosion

* Corresponding author.
E-mail address: saleh.yousefi@modares.ac.ir (S. Yousefi).

http://dx.doi.org/10.1016/j.geoderma.2016.09.002
0016-7061/

from bare road sides is 30 times greater than from vegetated road sides. Jordán and Martínez-Zavala (2008) reported runoff coefficients ranging from 46% to 85% for cut-off and slope-filled road beds. Runoff coefficients in non-disturbed forests are disparate by comparison. Zavala et al. (2009) reported a significant difference between runoff coefficients for forest roads (62.2%) and vegetated road sides (24%). Furthermore, Rijsdijk et al. (2007) stated the average runoff coefficient for forest roads (65%) is more than for undisturbed forest lands (7%).

As stated by Sun and McNulty (1998), construction activities such as road building can cause extreme short-term soil erosion ranging from 20 to 500 t ha^{-1} a^{-1}, and can further enhance runoff that contributes to increased soil erosion in the long-term. In contrast, soil erosion rates by water in undisturbed forests in mountainous regions are distinctly less and vary between 1 and 5 t ha^{-1} a^{-1} (Patric, 1976). Hillslope surface flow and subsurface flow produced by cutting the slopes are observed to join road surface runoff above compacted ground and create conditions for increased road erosion by water (Brown et al., 2015; Seutloali and Beckedahl, 2015; Wemple and Jones, 2003). This is especially true for humid climates and steep reliefs with high intensity rainfall as one of the most intrinsic factors affecting water erosion. Thus, road construction facilitates this type of erosion (Cerdà, 2007; Demir and Hasdemir, 2005; Merz et al., 2006).

Abdi et al. (2009) reported that annually thousands of kilometers of forest roads are being constructed and thousands of cubic meters of trees are being cut. Consequently, millions of cubic meters of soil are lost by water erosion in the form of sheet erosion (Arnáez et al., 2004; Atucha et al., 2013), inter-rill erosion (Cao et al., 2015; Clarke and Walsh, 2006; Inbar et al., 2014), gully erosion (Makanzu Imwangana et al., 2014; Reid et al., 2010), and landslides (Clarke and Walsh, 2006; Haigh et al., 1988; Imaizumi and Sidle, 2012; Sidle et al., 2006). High-

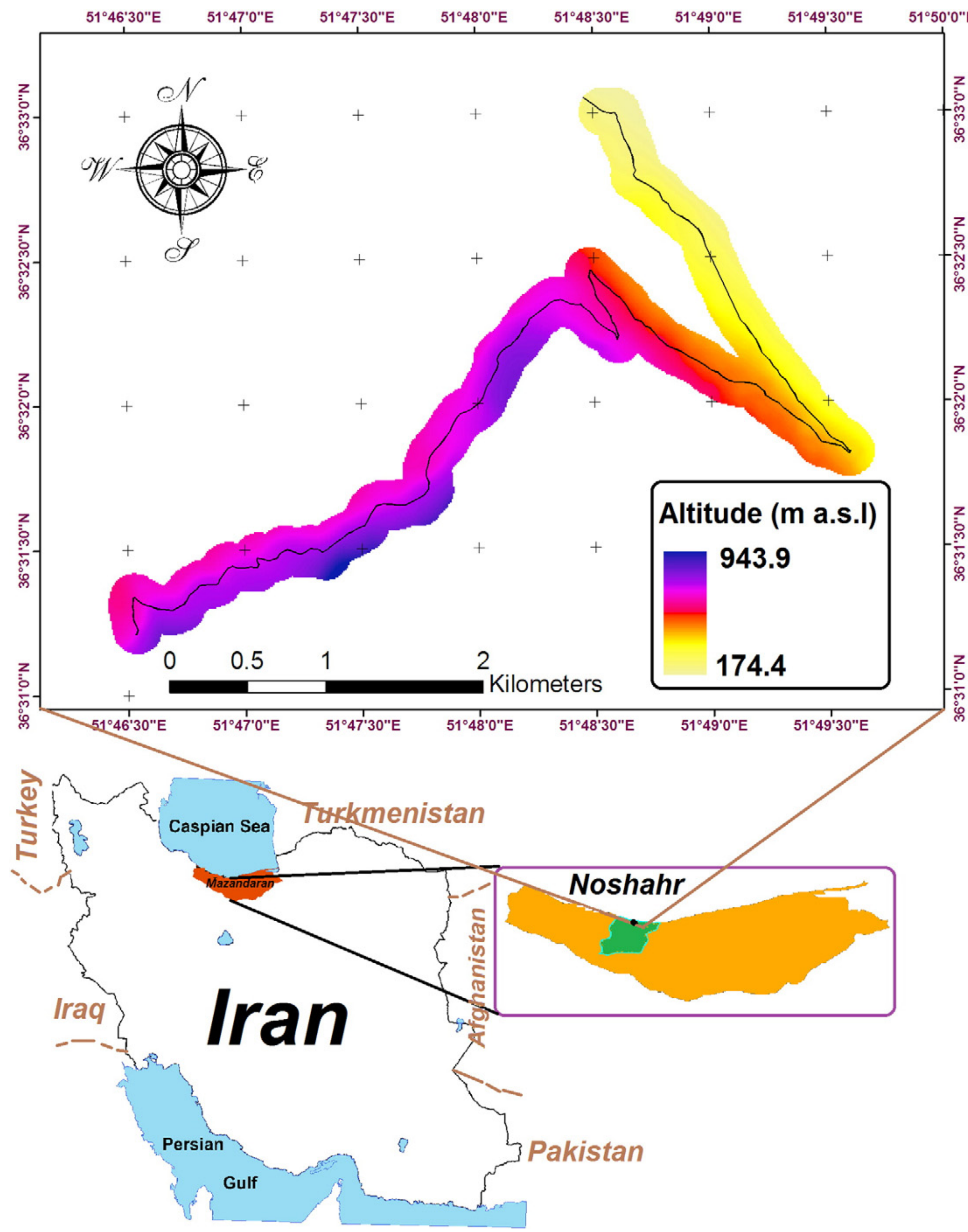

Fig. 1. Geographical location of the study area near Noshar city in the north of Iran.