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SOIL ORGANIC CARBON CHANGES DUE TO UNPAVED-DIRT TRACKS: A CASE STUDY IN KHENTII PROVINCE

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Abstract: Unpaved-dirt roads have several negative impacts on the environment; one of them is increased wind and water erosion. Soil erosion has four stages (detachment, breakdown, transport/redistribution and deposition of sediments), and the soil organic carbon (SOC) is influenced during all stages. Erosion process removes the light organic fraction of a low density of < 1.8 mg/m3. The main objective of this study was to determine how much organic carbon lost from soil when it's changed to a dirt road in different natural zones in the case of Khentii province. Also, the changes in soils main physical and chemical properties were examined. To do this, we took 2 samples (one from the road, and another one from adjacent to the road in order to compare) from 6 sites. A total of 12 soil bulk samples were taken from 10 cm and analyzed. According to laboratory results, the average SOC loss was 18.4% at the unpaved-dirt road in Khentii province. However, in forest road, SOC was 45.3% higher than the control sample.

Keywords: Soil organic carbon, soil erosion, unpaved-dirt track.

Introduction

Mongolia is a sparsely populated, landlocked country which has seen an economic growth spurt since the 1990s. This rapid growth in the economy has led to a growth in the number of vehicles, which far exceeded the growth of the capacity for road construction. According to Mongolian Statistical Information Service, vehicle number increased about 15 times, from 36.674 to 536.399 between 1987 and 2017 in Mongolia. It is available to see the improved auto road (paved, gravel and improved soil road) information from statistic database, but unpaved-dirt road length and area data are still rare. In 2010, The Mongolian road network has about 45 000 km of dirt roads and about 2000 km of gravel roads in its approximately 49 500 km network (Onon, 2010). Besides the scarcity of paved roads, there is practically no restriction to either vehicular movement or vehicle speeds. Also, repeated usage of tracks makes old track unsuitable for driving due to the formation of potholes and corrugations in the soil. This process is facilitated by snowmelt, rainfall, and sub-soil permafrost-thawing. Consequently, a parallel track is generated (Keshkamat et al., 2011).

The impacts of off-road vehicles have been well documented (Webb & Wilshire 1983) and one of them is increased wind and water erosion. The degree of erosion experienced in an area exposed to off-road vehicles use is affected by two main factors. First, increased water erosion is partially attributable to decreased infiltration rates due to compaction. Second, off-road vehicles destroy surface stabilizers, making soils more susceptible to erosion (Hinkley et al., 1983). The soil organic carbon (SOC) pool is influenced during all four stages (detachment, breakdown, transport/redistribution and deposition of sediments) of soil erosion. Being a selective process, erosion preferentially removes the light organic fraction of a low density of < 1.8 Mg/m^3 (Lal, 2003).Soil organic matter in eroded sediments is easily mineralized and 20–30% of the displaced SOC may be emitted into the atmosphere (Jacinthe & Lal, 2001). Therefore, the total ecosystem carbon pool is lower in eroded than in uneroded landscapes, and the rate of mineralization of soil organic matter is more in sediments than in original soil (Lal, 2003).

Over 360 small settlements which are connected by unpaved-dirt tracks in Mongolia and these tracks become much wider near settlements. In other words, multiple roads within a small location create an overlapping influence-zone larger than a single large road (Sanderson et al., 2002). For instance, road density is 4.61 km per 1 km^2 near the center of Tsogttsetsii soum which is located near the mining areas (Batkhishig et al., 2017).

In Mongolia, several types of researches about the impacts of unpaved-dirt roads have been conducted, such as vegetation recovery and soil erosion. For example, Byambaa & Muryama (2012) examined changes in vegetation cover, soil physical and chemical properties, and morphology shape in 4 different dirt roads (1-in use, 2-restored, 3-in restoration, 4- unused for a road). Their results indicated that soil chemical properties (organic content, pH) need a longer time than physical properties (bulk density, moisture, and infiltration) to restore. Vegetation recovery in the tracks of an abandoned dirt road can affect the surrounding vegetation through colonization be an expansion of low-palatability clonal species (Toshihiko et al.,2013; Shen et al., 2006). Another interesting study was conducted in Southern Mongolia; Davaadorj (2017) used field experiment simulating off-road track driving to measure soil quality changes and to compare them to conditions before the experiment. After 50 operations, 300 t/ha soil was eroded from the surface (0-10 cm) soil.

Dirt roads are a source of emission of wind-eroded dust because of their low vegetation cover (Gillette and Adams 1983; Goossens and Buck 2009a, b) and the Mongolian steppe is assumed a major source of dust emission in Asia (Zhang et al., 2008; Shinoda et al., 2011). Wind-blown dust is sometimes transported long distances and causes human disease in downwind countries such as Korea, Taiwan, and Japan (Kwon et al., 2002; Yang et al., 2005; Hashizume et al., 2010).

Therefore, unpaved-dirt road and its impacts need to be assessed objectively and quantitatively from many aspects. Importance of soil degradation in general and that of soil erosion in particular on C dynamics and possible emissions of GHGs cannot be overemphasized. In this study, we will determine how much organic carbon lost from soil when it’s changed to a dirt road in different natural zones in case of Khentii province.

Method

Sampling location

The study was conducted on the Khentii province, one of the 21 provinces of Mongolia, located in the east of the country, and has 18 soums and 5 villages. The study site covered an area of 80 thousand square kilometers and is conterminous with the southern border of Russia. The Khentii province has a variety of topography, with elevation ranging from 1680-2800 meters above sea level. The northwest of the province is covered by the eastern part of the Khentii Mountains, towards the southeast the landscape changes into the eastern Mongolian steppe plains and is located between Eurasian coniferous forest taiga and Central Asian arid steppe. According to natural zones classification by Dash (2005), forest steppe, meadow steppe, steppe, dry steppes, and taiga are dominant natural zones in Khentii (Figure 1).

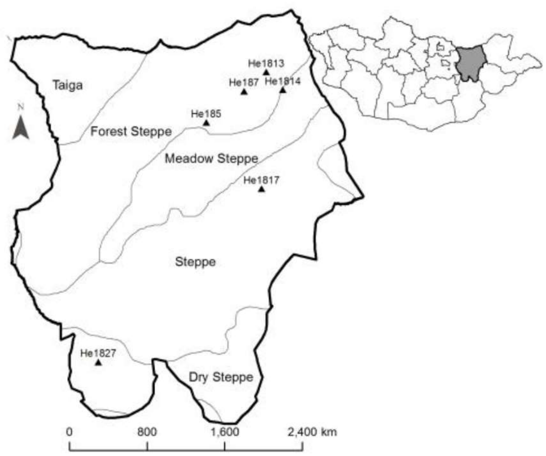

Figure 1. Map of Khentii province showing the natural zones (Dash, 2005), sampling location and ID of samples

The soils within the province are mainly Kastanozem and Chernozem. The climate is humid-cold in summer, and extremely cold in winter, with a mean annual rainfall of 200-500 mm (National Atlas, 2009).

In 2018, a total of 3758 vehicles were passed the technical inspection in this province.

Sampling method

Six sampling sites were selected from dominant natural zones in the province (Meadow steppe-He1814, Steppe-He1817, Dry steppe-He 1827, Forest steppe- He185, He187, and He1813), and fieldwork was conducted in 2018. One site is selected from every natural zone except the Forest steppe, because we also want to find out that is there any impact of land use difference on organic carbon changes due to unpaved-dirt track. Therefore, we sampled in 3 different land use type (He185-Pasture, regular track, He187-Near soum center, He1813-Forest track) in Forest steppe zone.

We took 2 samples from every sampling site, one from the road, and another one from adjacent to the road in order to compare. A total of 12 soil bulk samples were taken from 10 cm. A steel core with a known diameter and length used to collect soil samples. All samples were returned to the soil laboratory of Institute of Geography and Geoecology, air dried, gently disaggregated, and passed through the 2 mm sieve.

$$SOC = SOM(\%) \div 1.724 \quad (1)$$

The Walkley-Black method was used to measure organic content (SOM) and Van Bemmelen factor of 1.724 used to calculate soil organic carbon (SOC).

Results

Figure 2 shows PCA (Principal Component analysis) biplot of all samples main physical and chemical properties, analyzed on correlation matrix with the first two principal components explain 70.5% of the variance. In this circumstance, we will use this plot to see changes in samples main properties at every site.

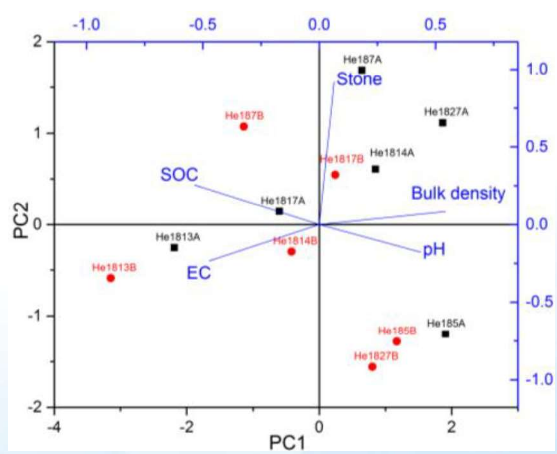

Figure 2. PCA biplot of soils main physical/chemical properties. • Pasture (control site) ■ Unpaved road

Bulk density of unpaved roads was higher than control samples at every site. Also, SOC had higher content in every control samples except He1813. EC (electrical conductivity) – salinity of soil had an increase at unpaved road samples from He1814 and He1817 sites. pH values did not show a significant difference.

Bulk density

According to PCA Biplot (Figure 2) of main soil physical/chemical properties, only bulk density had an increase at every site. Therefore, bulk density results consider separately (Figure 3).

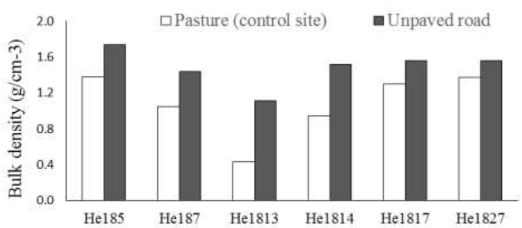

Figure 3. Changes in bulk density

At the unpaved road, bulk density was ranging from 1.11-1.74 g/cm3. In forest road, bulk density was the lowest in both road (0.43 g/cm^3) and control site (1.11 g/cm^3).

It can be seen that bulk density changes in He185 (forest steppe) and He187 (forest steppe) were relatively close, increased by 0.36 g/cm^3 and 0.39g/cm^3, respectively. Changes in He1817 (steppe) and He1827 (dry steppe) were exactly same at 1.56 g/cm^3. The largest variance occurred in forest road (He1813), increased approximately 2.5 times (Figure 4).

Soil Organic Carbon

Figure 4 compares all road samples with adjacent pastures (control site) SOC content and its changes estimated by percentages.

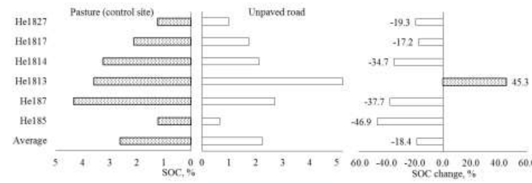

Figure 4. Soil organic carbon and its changes due to an unpaved road

Average SOC was 2.2% in the unpaved road, and 2.6% in the control site. In other words, 18.4% of SOC was lost from the upper 10 cm soil when it was changed to the unpaved-dirt road in all sites.

In Steppe (He1817) and Dry-steppe (He1827) zones, control soil samples had lower OC (2.11% and 1.24%, respectively) compare to other zones in Khentii province. Also, samples from the unpaved road in these zones had lower SOC content.

Samples from Forest steppe zone (He185, He187, and He1813) showed interesting results. Most significant SOC loss occurred at He185 (-46.9%). Also, He185 had the lowest SOC content (1.22%) in the pasture (control site). On the contrary, He187 had the highest SOC at 4.33%, however, it did not have the highest SOC content in the road. Samples from forest road (He1813) showed phenomenon result. In this site, SOC of the road was higher (45.3%) than the control site (Figure 4).

Discussion & Conclusion

From the results of 6 sites 12 samples, the average SOC loss was 18.4% at the unpaved-dirt road in Khentii province. A decrease of the soil organic carbon in the present study shows that soil erosions accelerated at unpaved roads and this is in agreement with previous studies (Davaadorj, 2017; Byambaa & Muryama, 2012). However, soil organic carbon of unpaved road had 45.3% higher than the control sample in forest site (He1813). This increase may have been caused by an enhancement of soil water retention potential and/or reduction in evapotranspiration in compacted soil. Compacting the soil compresses its macropores, thereby creating more micropores and increasing the soil's potential for water retention (Richard et al., 2001; Sillon et al., 2003). In addition, there is less wind to blow soil fine/light organic fractions and less sunlight to evaporate soil moisture in the forest.

Moreover, from the results of this study, we can assume that SOC loss is different in natural zones and land use types. Forest-steppe and Meadow steppe has high SOC. Therefore, the difference of SOC between unpaved road and control sample was also higher than dry-steppe and steppe zones. But, it needs to analyze more samples to get accurate information.

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