SERİ SERIES SERIE SÉRIE	A	CİLT VOLUME BAND TOME	53	SAYI NUMBER HEFT FASCICULE	1	2003

İSTANBUL ÜNİVERSİTESİ

ORMAN FAKÜLTESİ

D E R G İ S İ

REVIEW OF THE FACULTY OF FORESTRY,
UNIVERSITY OF ISTANBUL

ZEITSCHRIFT DER FORSTLICHEN FAKULTÄT
DER UNIVERSITÄT ISTANBUL

REVUE DE LA FACULTÉ FORESTIÈRE
DE L'UNIVERSITÉ D'ISTANBUL

SELECTED PHYSICAL PROPERTIES OF HEAVILY TRAMPLED SOILS ON LIVESTOCK TRAILS

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Abstract

The experiment investigated how selected physical soil properties were affected by trampling on compacted livestock trails. Two adjacent sites with similar ecological conditions were choosen as the study area. The control site consisted of an ungrazed exclosure. The other site was a heavily grazed range site with compacted trails. The range site has been grazed heavily by sheep and water buffalo, while the exclosure has been protected from grazing for decades. The experiment used a completely randomized design with three replications for each treatment. Data were analyzed using analyses of variance. Soil core samples were collected from 36 soil profiles at the 0-10 cm depth in each treatment site. The soil samples were examined for soil texture, percentages of fine (<2 mm) and coarse (between 2-5 mm, and >5 mm) soil fractions, percentage of root mass, dispersion ratio, particle density, bulk density, total porosity, saturated hydraulic conductivity, saturation capacity, moisture equivalent, pH, electrical conductivity, and organic matter. Additionally, soil compaction was determined using a pocket penetrometer at the soil surface of each soil profile before the collection of samples. Heavy trampling reduced saturation capacity, saturated hydraulic conductivity, moisture content at the field capacity, and porosity but increased soil bulk density and compaction on the trails.

Keywords: Trampling, soil compaction, grazing, livestock trails.

1. INTRODUCTION

It is well known that severe trampling by grazing animals has negative effects on the physical parameters of range soils (BUSY/GIFFORD 1981; MAPFUMO et al. 2000). However, depending on grazing systems and site conditions, the effect of trampling varies between experiments and between various soil parameters (JOHNSTON et al. 1971; DORMAAR et al. 1994). The common point in the majority of these studies was that soil bulk density increased as an indicator for soil compaction under intensive grazing conditions (DORMAAR/WILLMS 2000). Numerous studies indicated that severe trampling compacted soils and therefore reduced infiltration rates and increased the amount of soil that was lost due to runoff (CURRIE 1975; WARREN et al. 1986; KRZIC et al. 2000). In contrast, perhaps due to a difference in grazing systems, some studies found no difference

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Yayın Komisyonuna Sunulduğu Tarih: 13.02.2002

in some soil properties, such as soil compaction and infiltration rates, between various grazing intensities (SKOVLIN et al. 1976; TAKAR et al. 1990). Increased bulk density, especially in top soil, may cause lower porosity and lower water holding capacity in the soils (MAPFUMO et al. 2000). Heavy continuous grazing or intensive rotational grazing systems can create many compacted trails on rangelands (WALKER/HEITSCHMIDT 1986; ANDREW 1988). These trails have lower infiltration rates which can in turn lead to higher runoff and cause soil erosion on heavily grazed rangelands. Trails may be the best location on rangelands to determine the effects of intensive trampling on soil parameters. Therefore, the objective of this study was to determine how selected soil parameters differ in the heavily compacted trails from those in the exclosure.

2. MATERIAL AND METHODS

2.1 Study area

The study site is located about 13 km northwest of Istanbul, Turkey (Long. E:28° 54´; Lat. N: 41° 11´). The range site was mainly dominated by gramineous species such as Bermuda grass (Cydonon dactylon (L.) Pers.) and perennial ryegrass (Lolium perenne L.), and forb species such as common dandelion (Taraxacum officinale Wiggers), common plantain (Plantago major L.), thyme species (Thymus sp.), and English daisy (Bellis perennis L.). The exclosure site, in addition to these species, was dominated by orchard grass (Dactylis glomerata L.), and legumes, forbs, and woody species such as red clover (Trifolium pratense L.), white clover (Trifolium repens L.), woodland strawberry (Fragaria vesca L.), heather (Erica arborea L.), hornbeam (Carpinus betulus L.), oak (Quercus sp.), and beech (Fagus orientalis Lips.). Historically, the range site has been heavily grazed by sheep and water buffalo, though the timing and duration of the grazing are not well known. The exclosure has been protected from grazing for decades. According to the Thorntwaite method, the climate of the area is humid, mesothermal oceanic with a moderate water deficit in the summer. Average annual precipitation is about 1094 mm and falls mainly from October to April. The soils are generally shallow to moderately deep, gravelly, sandy, loamy clay in the surface horizons and clay in the sub-soil. Elevation averages about 75 m at the sea level. Slope in the area is approximately 20 percent, and the general topography is not steep.

2.2 Sample collection

Soil compaction due to trampling takes place mostly in the surface soil layer (HEITSCMIDT/STUTH 1993). The depth of this layer is normally 5 cm, though it can reach 15 cm (HEADY 1975). Therefore, soil samples were collected at 0-10 cm depth for this experiment to investigate effects of trampling on the selected soil parameters. Although historical grazing periods, stocking rates and the frequency of use of the trails by livestock were unknown, trails that had no plants growing on them and had bare ground were assumed to be heavily trampled. Soil samples were taken from these types of trails. Soil profiles were dug on randomly distrubuted trails consisting of only bare ground on the range site and were dug on randomly selected locations on the exclosure. Before undisturbed core samples (85 mm diameter and 65 mm height) were taken at 0-10 cm depth of each soil profile, soil compaction was determined using a pocket penetrometer at the soil surface of each profile. Saturated hydraulic conductivity of the samples was determined according to the Darcy Law and modified Equation (ÖZYUVACI 1976). Saturation capacities of the soils were determined on saturated core samples as described by Balcı (1964). The core samples were then dried at 105 °C in an oven, weighed, and bulk densities were calculated as outlined by Page-Dumroese et al. (1995). Soil texture was determined as per the Bouyoucos hydrometer method (PIPER 1950); soil fractions over 2 mm (between 2-5 mm and >5 mm) as described by Page-

Dumroese et al. (1995); dispersion ratio as outlined by Baver (1961); particle density using picnometer method as outlined by Black et al. (1965); total porosity using equation described by Balcı (1973b); moisture equivalent as described by Özyuvacı (1976); soil pH using a Metrhom Herisan E 520 type pH meter as outlined by Gülçür (1974); electrical conductivity using Electronic Switgear-London, MC-1 type (BALCI 1973a); and organic matter as outlined by Walkley and Black method (JACKSON 1958). Root mass was determined on oven-dried core samples. After the roots were washed and dried, root mass was calculated on the oven-dried core samples as a percentage of total soil weights in the cores.

2.3 Statistical analysis

The experiment was a completely randomized design with three replications. The soil core samples were the experimental units. The soil core samples were collected from 36 soil profiles for each treatment. Data were analyzed by analysis of variance (HICKS 1993).

3. RESULTS AND DISCUSSION

Percentages of the soil fractions did not show significant difference between treatments (Table 1). Even though the amount of root mass was higher in the soils from the trails than the soils found in the exclosure, the difference between the two treatments was not statistically significant. This can be attributed to the dominant vegetation types on the sites. The range site was dominated by shallow-rooted herbaceous vegetation; the exclosure was dominated by these species as well as by woody species. Since the soil samples were collected at the 0-10 cm depth, the root content of core samples from both treatment sites included only shallow-rooted herbaceous vegetation. The soil texture was not similar in both sites and the proportions of sand, silt, and clay in the soil texture differed significantly between two treatments (P<0.001) (Table 1). This may be the result of sand that had been lost from compacted trails.

Table 1: Mean Values of Selected Soil Properties From Trails and Exclosure

Tablo 1: Patika ve Korunmuş Alandaki Toprakların Bazı Fiziksel Özelliklerine Ait Ortalamalar

Soil properties	Trails	Exclosure	F - Values
Sand (%)	63.67	75.44	64.67 ***
Silt (%)	16.46	10.37	53.17 ***
Clay (%)	19.87	14.19	32.89 ***
Soil fractions			
<2mm (%)	69.20	69.04	<0.01 N.S.
2-5 mm (%)	20.38	23.86	2.56 N.S.
>5 mm (%)	9.34	6.40	1.94 N.S.
Root mass (%)	1.08	0.70	1.78 N.S.
Dispersion ratio (%)	33.21	32.90	<0.01 N.S.
Particle density (gr/cm^3)	2.58	2.57	0.16 N.S.
Bulk density (gr/cm^3)	1.36	1.12	12.69 ***
Total porosity (%)	47.08	56.25	15.36 ***
Saturated hydraulic conductivity (cm/h)	1.60	44.30	17.69 ***
Saturation capacity (%)	28.67	40.78	11.83 ***
Moisture equivalent (%)	23.07	29.97	12.75 ***
pH	5.22	5.46	1.38 N.S.
Electrical conductivity (µmhos/cm)	84.42	70.42	1.37 N.S.
Organic matter (%)	4.84	5.21	0.35 N.S.
Compaction (kg/ cm^2)	3.62	1.18	43.45 ***

*** Means are significantly different at 0.001 level.

N.S. Means are not statistically significant (P>0.05).

Since trampling decreases infiltration rates in the soils (WARREN et al. 1986; WELTZ/WOOD 1986), it also increases runoff on the compacted soil surface and hence, loss of dispersed sand particles. Other soil parameters that were not significantly affected by trampling include pH, particle density, electrical conductivity, and dispersion ratio (Table 1). The pH values of both treatment sites were similar and acidic, and the electrical conductivity was low for both sites (Table 1). This may be expected due to the presence of the same parent material (Neocene formation) in both sites. In contrast to these results, the study conducted by Mapfumo et al. (2000) showed that grazing intensity influenced soil pH and electrical conductivity. Although higher organic matter was expected in the soils of the exclosure than those of the range site due to litter accumulation from ungrazed plants, organic matter did not differ significantly between treatments (Table 1). Urine and faeces that mix into the soil, especially on trails having the highest trampling frequencies, can increase the organic matter content of soils in the rangelands (HEADY 1975). Trampling by livestock compacted the soils as found by Krzic et al. (2000), and it was higher in the soils collected from the trails than soils from the exclosure ($P<0.001$) (Table 1). As expected, soil compaction resulted in higher bulk density, less total porosity, lower saturation capacity and moisture equivalent, and slower saturated hydraulic conductivity in the range site (Table 1). These soil parameters on the range site differed significantly from those of the exclosure ($P<0.001$). It was obvious that heavy trampling was dentrimental to soil hydrophysical properties related to water economy of the range soils (WARREN et al. 1986; CLARY/MEDIN 1990; KRZIC et al. 1999; MAPFUMO et al. 2000). The results indicate that heavy trampling on the trails had a mainly negative effect on soil parameters such as total porosity, bulk density, saturation capacity, saturated hydraulic conductivity as consequences of soil compaction. Compacted soils led to increased soil bulk density and decreased soil porosity. Trail compaction may increase under continuous heavy grazing and may lead to the low soil porosity and infiltration rates that lead to concentrated runoff, which can in turn cause soil and water loss. Grazing pressure on rangelands should be evenly distributed or intensive grazing systems should be avoided in order not to increase the number and size of trails. As seen in Table 1, all selected soil parameters in the trails of the range site were not significantly different from those of the exclosure. In this experiment, trails with bare ground were assumed to have been trampled heavily because they lacked growing plants and had compacted soils. Because the grazing history of the range site is unknown, because stocking rates and species of livestock (sheep and water buffalo) changed over time, and because no information was available about trampling frequencies of trails, these results should be evaluated with caution. If the trampling frequency of the trails, the grazing history, and the stocking rates of an area were known, better evaluation of soil parameters would be possible.

4. CONCLUSIONS

Many experiments have been conducted to determine the effects of severe grazing on physical properties of soils so far but their results varied depending on grazing intensity, frequency, and period. To demonstrate the effect of heavy grazing on physical properties of soils, soil samples were collected from trails despite unknown grazing history of the site. The conclusion from the data is that severe grazing was dentrimental for soil properties those directly related to water economy of the soils in the heavily trampled trails. When heavily trampled trails are concerned on grasslands, these places are the most vulnerable locations for soil loss by erosion due to lower infiltration rate and higher runoff as a result of soil compaction by grazing animals. Therefore, distribution of range animals is an important factor not to create many compacted trails. This problem can be prevented by the application of grazing systems on rangelands.

OTLAKLARDA, HAYVANLARIN GEÇİŞ YAPTIĞI AŞIRI DERECEDE ÇİĞNENMİŞ GÜZERGAHLARDA BAZI FİZİKSEL TOPRAK ÖZELLİKLERİNİN DEĞİŞİMİ

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Kısa Özet

Bu çalışma, otlak alanlarında hayvanların oluşturdukları patikalarda aşırı derecede sıkışma sonucu fiziksel toprak özelliklerinde meydana gelen değişimleri ortaya koymak amacıyla yapılmıştır. Toprak örnekleri; her bir alanı temsilen üç tekrarlı tamamen tesadüfi örnekleme deseninde, toplam 36 profilden olmak üzere aşırı derecede toprak sıkışmasını temsil etmesi açısından otlak alanlarındaki hayvanların devamlı yol olarak kullandıkları patikalarda ve otlatmanın söz konusu olmadığı korunmuş alanlarda açılan toprak profillerinin 0-10 cm'lik derinlik kademelerinden alınmıştır. Toprak örnekleri üzerinde kum, toz ve kil oranları, 2 mm'den büyük toprak fraksiyonları, kök oranı, dispersiyon oranı, tane yogunluğu, hacim ağırlığı, toplam boşluk hacmi, permeabilite, nem ekivalanı, maksimum su tutma kapasitesi, pH, elektriki iletkenlik ve organik madde oranı tespit edilmiştir. Ayrıca, her profil noktasında toprak yüzeyindeki sıkışma miktarı ölçülmüştür. Analiz sonuçları, düzensiz ve aşırı otlama faaliyetlerinden dolayı otlak alanlarında meydana gelen toprak sıkışması sonucunda; hacim ağırlığı, toplam boşluk hacmi, maksimum su tutma kapasitesi, nem ekivalanı, permeabilite ve kompaktlaşma gibi toprakların su ekonomisi ile ilgili özelliklerinin olumsuz yönde etkilendiğini ortaya koymuştur.

Anahtar Kelimeler: Çiğnenme, kompaktlaşma, otlatma, patika yolu.

1. GİRİŞ

Kontrolsüz havyan otlatmasının toprakların hidrolojik özellikleri üzerindeki olumsuz etkileri pek çok araştırmacı tarafından ortaya konulmuştur (BUSY/GIFFORD 1981; MAPFUMO et al. 2000). Bu araştırmalara göre, düzensiz ve aşırı otlatılan otlaklarda topraklar sıkışmakta ve bunun doğal sonucu olarak su tutma kapasitesi, geçirgenlik gibi toprağın su ekonomisini etkileyen fiziksel toprak özellikleri olumsuz yönde etkilenmektedir. Kontrolsüz otlatmanın yapıldığı otlak alanlarında, hayvanlar genellikle aynı geçiş güzergahlarını kullanmaktadır. Bu durum; otlak alanlarında aşırı sıkışmış, yüzeysel akışların toplanarak erozyona yol açabileceği alanların artmasına sebep olmaktadır (WALKER/HEITSCHMIDT 1986; ANDREW 1988). Bu araştırmanın amacı da düzensiz ve aşırı otlatmanın yapıldığı otlaklardaki hayvanların geçiş güzergahlarında bulunan aşırı sıkışmış toprakların fiziksel özelliklerinde meydana gelen değişimleri ortaya koymaktır.

2. MATERYAL VE METOTLAR

Çalışma alanı Alibeyköy Barajı Havzasında yer alan, benzer ekolojik özelliklere sahip birbirine komşu otlatmaya açık ve otlatmadan korunmuş iki farklı alanda yapılmıştır. Otlak alanında uzun yıllardır manda ve koyun otlaması yapılmakta buna karşılık bitişikteki alan ise otlatmadan korunmaktadır. Otlak alanında hakim vejetasyon daha çok gramine türlerinden, korunmuş alanın vejetasyonu ise otsu bitkiler yanında meşe, gürgen ve kayın gibi odunsu ve çalı türlerinden oluşmaktadır.

Sıkışma daha çok üst toprakta (HEITSCHMIDT/STUTH 1993), yaklaşık olarak 5-15 cm arasında meydana geldiğinden; bu araştırmada toprak örnekleri 0-10 cm derinlik kademesinden alınmıştır. Otlak alanında hayvanların geçiş güzergahlarından, korunmuş alanda ise tesadüfi örneklemeyle seçilmiş alanlarda açılan profillerin 0-10 cm derinlik kademesinden çapı 85 mm ve yüksekliği de 65 mm olan çelik silindirlerle hacim ağırlığı örnekleri ve doğal yapısı bozulmuş torba örnekleri alınmıştır. Üç tekrarlı olmak üzere her bir alanda toplam 36 toprak profili kazılmıştır. Laboratuvarda örnekler üzerinde toprakların tekstür, toprak fraksiyonu ve kök yüzdeleri, dispersiyon oranı, tane yoğunluğu ve hacim ağırlığı, toplam boşluk hacmi, geçirgenlik, maksimum su tutma kapasitesi, nem ekivalanı, pH ve elektriki iletkenlik değerleri ölçülmüştür. Ayrıca, arazide her bir toprak profilinin yüzeyinde cep penetrometresi kullanılmak suretiyle kompaktlaşma değerleri ölçülmüştür. Elde edilen veriler varyans analizine tabi tutulmuştur.

3. SONUÇ VE TARTIŞMA

Elde edilen verilere göre, hayvanların geçiş güzergahlarında yer alan aşırı biçimde sıkışmış olan toprakların fiziksel özelliklerinin çoğu, özellikle su ekonomisi ile doğrudan ilişkili olan (toprakların geçirgenliği, su tutma kapasitesi, kompaktlaşması, hacim ağırlığı, toplam boşluk hacmi gibi) toprak özellikleri olumsuz yönde etkilenmiştir (Tablo 2). Otlak alanı ile korunmuş alan sadece toprak fraksiyonlarının miktarı, toprak içerisindeki kök miktarı, toprakların tane yoğunluğu, dispersiyon oranı, organik madde miktarı, pH ve elektriki iletkenlik değerleri bakımından önemli farklılık göstermemiştir (Tablo 2). Otlak alanlarında toprak sıkışmasından kaynaklanan benzeri olumsuz etkileri azaltmanın en kolay yolu otlak amenajmanı ilkelerine uyulmasıdır. Düzenli bir otlatma ile

Tablo 2: Patika ve Korunmuş Alandaki Toprakların Bazı Fiziksel Özelliklerine Ait Ortalamalar

Toprak özellikleri	Patika	Korunmuş alan	F - Değerleri
Kum (%)	63.67	75.44	64.67 ***
Tozt (%)	16.46	10.37	53.17 ***
Kil (%)	19.87	14.19	32.89 ***
Toprak fraksiyonları			
<2mm (%)	69.20	69.04	<0.01 N.S.
2-5 mm (%)	20.38	23.86	2.56 N.S.
>5 mm (%)	9.34	6.40	1.94 N.S.
Kök bioması (%)	1.08	0.70	1.78 N.S.
Dispersiyon oranı (%)	33.21	32.90	<0.01 N.S.
Tane yoğunluğu (gr/cm^3)	2.58	2.57	0.16 N.S.
Hacim ağırlığı (gr/cm^3)	1.36	1.12	12.69 ***
Toplam boşluk hacmi (%)	47.08	56.25	15.36 ***
Permeabilite (cm/h)	1.60	44.30	17.69 ***
Maksimum su tutma kapasitesi (%)	28.67	40.78	11.83 ***
Nem ekivalanı (%)	23.07	29.97	12.75 ***
pH	5.22	5.46	1.38 N.S.
Elektriki iletkenlik (µmhos/cm)	84.42	70.42	1.37 N.S.
Organik madde (%)	4.84	5.21	0.35 N.S.
Kompaktlaşma (kg/ cm^2)	3.62	1.18	43.45 ***

*** Korunmuş alan ve patikalardaki topraklara ait ortalamalar 0.001 düzeyinde önemli farklılık göstermiştir.
NS Korunmuş alan ve patikalardaki topraklara ait ortalamalar önemli farklılıklar göstermemiştir (P>0.05).

otlaklarda otlayan hayvanlar kontrol altına alınarak düzenli bir dağılım yapmaları sağlanabilir. Bu da otlak alanlarında belirli noktaların sürekli kullanılarak sıkışmasına engel olur. Böylece, otlak alanlarında hem besin maddesi döngüsünde dengesizlikler azaltılabilir hem de toprakların sıkışması sonucunda artan yüzeysel akışın sebep olduğu toprak kaybı engellenebilir.

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