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Effects of Livestock Trampling on Soil Physical Properties and Vegetation Cover (Case Study: Lar Rangeland, Iran)

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ABSTRACT

Soil physical properties play an important role in vegetation growth on rangelands as a result of the effects they have on the development of root systems. The goal of this research was to investigate the trampling effect of livestock grazing on soil physical properties (moisture, bulk density, infiltration rate and mechanical resistance) and vegetation cover. The experiment was conducted on three rangeland condition areas - the reference area, a moderately grazed area and a heavily grazed area - in the Lar rangelands (84 km northeast of Tehran) during the grazing season of 2000 and 2001. Soil moisture was reduced from both the reference area and the heavily grazed area throughout the grazing season to depths of 0-15 and 15-30 cm. Soil bulk density increased during the grazing season, being lowest in the reference area and highest in the heavily grazed area. Throughout the grazing season, bulk density was higher in the top soil layer (0-15 cm) compared to underlying layer (15-30 cm) at all areas. The reference area had the highest soil porosity, compared to the moderately grazed and heavily grazed areas. As the grazing season progressed, soil porosity declined at all areas for both soil depths. Soil infiltration rate was reduced and mechanical resistance increased at all the experimental areas as the grazing period progressed. The proportion of grass to total vegetation composition was greatest for the reference area and represented only 1% in the heavily grazed area. The total vegetation cover was 7% by the end of the grazing season for the heavily grazed area.

Key Words: Livestock grazing; Trampling; Soil moisture; Soil physical properties; Vegetation cover

INTRODUCTION

Soil physical properties play an important role in the establishment and growth of rangeland plants. Soil bulk density, mechanical resistance, porosity and infiltration rate are all affected by soil texture as well as by rangeland management practices. Soil chemical properties are also indirectly affected by the above factors. The interaction between soil physical, chemical and biological properties and the climate determines the type and kind of vegetation, its regenerative capacity and the carrying capacity of rangelands.

Trampling by livestock results in compaction of the soil surface and this affects soil infiltration. In most cases, the current rangeland condition is the result of past management practices (Ferrero, 1991). The destructive effects of high intensity grazing on the physical properties of soil have been reported by many researchers (Severson & Debano, 1991; Sun & Liddle, 1993). The severity of these impacts can be evaluated by assessing rangeland and soil conditions (Curtis & Wright, 1993).

The organic matter content of soil stabilizes soil structure and improves water infiltration rate. Intensive grazing reduces soil organic matter, which results in the compaction of the soil surface layer, causing increased surface runoff (Faizol *et al*., 1995). McCalla (1984) and Thurow (1986) showed that the vegetation biomass plays an important role in the soil infiltration rate in grasslands. The effects of different grazing periods on soil infiltration rate in rangelands have been investigated by Weltz and Wood (1986). These authors determined that the infiltration rate of water infiltrated into the soil following episodic grazing of pasture in a short duration grazing system was significantly less than the infiltration rate prior to the grazing period. It was concluded that this is because of a severe reduction in vegetation cover and the expansion of the area of bare soil during long-term grazing.

Intensive grazing in rangelands is the major problem of most rangeland areas in Iran. In order to understand the soil response to different stocking rates and its effect on rangeland vegetation dynamics, this study was conducted in the mountainous Lar rangelands of Iran.

MATERIALS AND METHODS

The Lar watershed has an area of approximately 73000 hectares and is located 84 km northeast of Tehran, Iran (51°04´- 51°32´E and 35°48´- 36°04´N). It is a mountainous region and is the highest elevation watershed in Iran at 2400 m above sea level. The area is characterized by deep valleys and an erratic distribution of precipitation. The climate is a temperate semi-arid one with an average annual precipitation of 330 mm and a mean annual temperature of 12°C (1970-2000). Most of the annual precipitation occur during winter (December-February) and spring (March-May) comprising 42.6 and 29.7% of the annual total, respectively. The mean annual wind velocity at 10 m above ground level is 8.2 m s^{-1}.

The textures of the dominant soils are mostly sandy loam with calcareous parent materials. The soil profile is not well developed, there is a shallow surface A horizon of 10-15 cm depth and a B horizon 15-20 cm thick. Plant growth is not limited by the pH or EC in the soils; the only limitation is the high proportion of sand and gravel in the soil texture.

The primary grass species represented in the area are *Agropyrum intermedium, Bromus tomentellus, Agropyron spp., Oryzopsis spp., Poa bulbosa, Melica persica, Festuca ovina* and *Dactylis glomerata.* Shrubs are mainly represented by *Onobrychis cornut*, *Astragalus spp.* and *Thymus kotscyanus Carex spp.* is common as is *Ferula sp*.

Sheep have been herded in the Lar rangeland by nomads for meat and milk production for over a hundred years. Continuous stocking is practiced extensively from May through to September (the grazing season) every year. Watering points are available in different parts of the rangeland as natural springs and streams. Mean stocking rate varies in different parts of the rangeland according to the biomass and water supply available as well as the permission obtained by different tribes from the government authorities. The mean stocking rate on most of the area in a normal season is one sheep per hectare during the grazing season (late May to late September). However, the number of the sheep grazing in different parts of the rangeland differs according to the area allocated to each tribe.

Sampling procedure. The watershed was sub-divided into three sub-sample areas according to grazing history and condition: a reference area (control) has been exempted of livestock grazing for 30 years (1970-2000). Stocking rate for the moderately and heavily grazed areas were 1 and >3 sheep hectare, respectively, for 30 years. Sub-sample areas have similar climatic conditions, topography soil texture and parent materials. Data were recorded in a single representative area of 5 hectares for each range condition category during the grazing season (late May to late September) in 2000 and 2001.

Each representative sampling area of five hectares was sub-divided in to five national strata of 1 ha each according to the slope gradient from top to bottom, and numbered from 1 to 5. Data were collected from five replicates (one in each stratum).

Soil physical properties such as bulk density, porosity, mechanical resistance, the infiltration rate and the soil moisture level were measured on a monthly basis from the beginning to the end of the grazing season (5 months). Five soil samples (one from each stratum) were taken by cores of 8 cm diameter and 15 cm long and were immediately placed in sealed containers. Soil samples were weighed and then dried in an oven at 75ºC for 48 h and then re-weighed. The soil moisture content was calculated on the basis of soil dry weight. Each sample represented one replication. All the measurements were carried out at two soil depths, of 0-15 and 15-30 cm. To measure the mechanical resistance of the soil, an ELE penetrometre was used. After calibrating instrument, ten random readings were recorded at both soil depths for each sampling area (two readings for each soil depth per *stratum*). The infiltration rate was measured using a double ring method at the start (late May) and the end of the grazing season (late September).

Vegetation cover was measured at all three areas (reference, moderately grazed and heavily grazed areas). The percentage of vegetation cover and its components were measured, as well as bare ground, at the beginning and end of the grazing season. Transects were 50 m long and 10 quadrates were recorded for each (Daubenmire, 1959). Five transects were set up in each sampling area (one per strata) and ten quadrates were randomly assigned per transect to measure the % vegetation cover as well as the frequency of individual species and vegetation groups (grasses, forbs & shrubs). All the measurements were repeated for two years (2000 & 2001).

The treatments were arranged as split-split plots where the reference moderately grazed and heavily grazed areas were considered as the main plots; the time of sampling (at monthly intervals) was allocated to sub-plots (split plots in time) and the depth of sampling to sub-sub plots. Data were analyzed using a Complete Randomized Block Design with five replications. To eliminate the effect of the year, a compound analysis of variance was run for the two years using MStatC statistical software.

RESULTS

Soil moisture varied by year, grazing treatments, grazing period, soil depth and their interactions (Tables I, II & III). The mean soil moisture content was significantly higher in all three grazing treatments in 2000 compared with 2001 and in both years, it decreased with stocking rate, although lessened in 2001, which was a drier year (Table III). Across years was a trend decreasing soil moisture at both of the measured depths as the grazing season proceeded until September when soil moisture increased (Table II). Soil moisture was constantly and significantly greater in the deeper soil layer, again until the last sampling period (Table II).

Across all treatments soil bulk density was higher in 2000 compared to 2001 (Table I). Bulk density increased significantly as a function of stocking rate (Table I) and as a function of time across the grazing season (Table II). Soil bulk density in the surface 15 cm was consistently greater than the underlying layer (Table II).

The infiltration rate decreased from early in the grazing season (late May) to the end of the grazing season. At all the experimental areas, the infiltration rate for the first 5 min of water application was a lot higher than for the remainder of the measuring period (90 min). Measured over time, the infiltration rate decreased gradually (Table IV).

The mechanical resistance of the soil in 2000 was 10% less than in 2001 (Fig. 1); as the soil moisture content increased, the soil mechanical resistance decreased. There was no significant difference between the mechanical resistance in the reference area and the moderately grazed

Table I. Soil moisture, bulk density and soil mechanical resistance under different long term grazing intensities in 2000 and 2001 at Lar rangelands, northeast of Tehran, Iran

	Soil physical properties		
	Soil moisture%	Bulk density g/cm^3	Soil mechanical resistance KPa
Year			
2000	6.3 a	1.52 a	690 a
2001	5.2 b	1.37 b	765 b
Grazing treatments			
Ungrazed reference area	6.0 a	1.39 a	710 a
Moderately grazed area	5.5 b	1.45 b	690 a
Heavily grazed area	5.2 b	1.50 c	780 b
Grazing period			
May	7.0 a	1.31 a	
June	6.5 b	1.39 b	
July	5.8 c	1.52 c	
August	5.0 d	1.54 d	
September	6.0 c	1.59 e	
Soil depth (cm)			
0-15	5.0 a	1.42 a	
15-30	6.5 b	1.45 a	

Within columns for each parameter and treatment, means with the same letter are not significantly different at p<0.05 .

Table II. Soil moisture and bulk density during the grazing period in 2000 and 2001 at Lar rangelands, northeast of Tehran, Iran

Soil property		Grazing Period				
		May	June	July	August	September
Depth (cm)	Soil moisture %					
0-15		6.0 c	5.6 c	4.1 e	4.0 e	6.3 c
15-30		8.3 a	8.0 b	6.9 c	5.0 d	6.2 c
Year	Bulk density g/cm^3					
2000		1.37 a	1.51 b	1.55 b	1.61 c	1.64 c
2001		1.22 d	1.23 d	1.45 c	1.47 bc	1.51 b

Within columns and rows for each parameter and treatment, means with the same letter are not significantly different at p<0.05.

Table III. Soil moisture under different long term grazing intensities for 2000 and 2001 for the Lar rangelands in northeast of Tehran, Iran

	Grazing areas		
	Ungrazed reference area	Moderately grazed area	Heavily grazed area
Depth (cm)		%	
0-15	5.5 c	4.5 d	4.3 d
15-30	7.3 a	6.5 b	6.0 c
Year		%	
2000	7.4 a	6.0 b	5.5 c
2001	5.1 c	5.0 cd	4.9 d

Within columns and rows for each parameter and treatment, means with the same letter are not significant at p<0.05.

area (Fig. 1). However, there was a significant difference in the heavily grazed area observed compared with the other two areas.

The average vegetation cover in the un-grazed treatment was 67.2% in late May of, which more than half (37.6%) was associated with the cool season grasses, while

Table IV. Infiltration rate (mm min^{-1}) of rangeland under different long term grazing intensities (reference area, moderately grazed area and heavily grazed area) in 2000 and 2001 for the Lar rangelands in northeast of Tehran, Iran

	Grazing period											
	May						September					
	Measuring time min.						Measuring time min					
	1	5	10	30	60	90	1	5	10	30	60	90
Grazing treatment	Infiltration rate (mm min.$^{-1}$)						Infiltration rate (mm min.$^{-1}$)					
Ungrazed reference area	19a	7c	4d	3.5d	3d	2.5d	11a	6c	4d	3.5d	2.5e	2f
Moderately grazed area	12b	3.5d	2.5d	2e	2e	2e	9.5b	5.8c	3.5d	2.5e	2f	2f
Heavily grazed area	11b	3.5d	3d	1.5e	1ef	0.5f	9.5b	4d	2.9e	2f	1.8f	1.5g

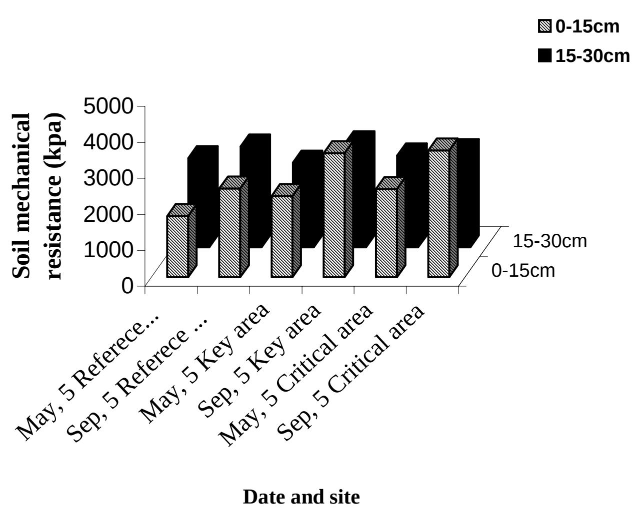
Within columns and rows for each parameter and treatment, means with the same letter are not significant at p<0.05.

Table V. Vegetation composition (percentage) of rangeland under different long term grazing intensities (un-grazed area, moderately grazed area and heavily grazed area) in 2000 and 2001 at Lar rangelands, northeast of Tehran, Iran

	Vegetation Composition Grazing Period								
	May					September			
Treatment	Grass	Forbs	Litter	Bare ground	%	Grass	Forbs	Litter	Bare ground
Ungrazed reference	37.6ab	29.6b	25.1b	7.7c		9.5c	9.6c	73.6a	7.3c
Moderately grazed	16.5b	38.8ab	19.9b	24.8b		1.0c	28.2b	10.5c	60.3a
Heavily grazed	1.0c	16.3b	7c	77.7a		1.0c	3.6c	3.3c	92.6a

Within columns and rows for each parameter and treatment, means with the same letter are not significant at p<0.05.

Fig. 1. Mean soil mechanical resistance in different sites and at different soil depths measured at the start (May) and the end (September) of the grazing seasons of 2000 and 2001.



the rest was comprised of forbs. By the end of the grazing period, the grass component of the vegetation cover in all areas had decreased significantly (Table V). The percentage of bare ground in the moderately grazed and heavily grazed areas in early May was 24.8 and 77.5%, respectively and this increased to 60.3 and 92.6% by the end of the grazing season. The increase was statistically significant in the moderately grazed treatment, but not in the heavily grazed treatment.

DISCUSSION

Lower precipitation during the grazing season in 2001 compared to the similar period in 2000 produced a non-significant difference in soil moisture levels between the different experimental areas. The higher organic matter in the reference area (3.9%) and moderately grazed area (3%) compared to the heavily grazed area (1.7%) helps to explain the ability of these soils to retain more moisture during the grazing season of 2000. The adverse impact of early and intensive grazing management on the organic matter content of the soil was described by Naeth *et al.* (1991). They also noted that heavy grazing reduces vegetation cover and breaks down dry litter. This accelerating, the decomposition process and ultimately reducing soil organic matter content. As the leaf area decreases the evaporation rate from the soil surface increases. There exists a significant relationship between increased livestock trampling, decreased soil infiltration and increased soil compaction, although it is not a linear one (Naeth & Chanasyk, 1995).

Soil moisture content in the lower soil layer (15-30 cm) was higher than in the topsoil and followed a decreasing trend from the reference area, through the moderately grazed area to the heavily grazed area for both depths. The low organic matter content, in addition to the sandy soil texture in the moderately grazed area, caused a non-significant difference in moisture content in topsoil between the heavily grazed and moderately grazed areas. The increased exposure of the surface to solar radiation as vegetation was removed. The compaction from livestock trampling likely contributed to the lower soil moisture content of the upper soil layer compared to the underlying soil layer. This occurred despite the higher organic matter in the topsoil. These results are compatible with the findings of Mapfumo *et al.* (2000).

The trend of decrease soil moisture through the grazing season was slower (0.7% per month) in the top soil (0-15 cm) than in the underlying layer of 15-30 cm (1.2%). The higher organic matter content in the upper layer of the soil profile illustrates well its better moisture holding capacity (Naeth & Chanasyk, 1995).

Soil bulk density was more severely affected by trampling in the heavily grazed area. Soil compaction in this area increased not only because of the high trampling intensity but also because of the lower organic matter content in the topsoil. As the soil moisture lessened during the grazing period, the rate of increase in the bulk density decreased (Table I). No significant difference was observed in bulk density since late July (when the soil moisture reached the lowest level) to the end of the grazing period as was reported also by Roundy *et al*. (1992).

Soil bulk density increased throughout the grazing season for all the areas (Table I). There was a 25% increase in soil bulk density in the heavily grazed area from the beginning (1.25 kg m^{-3}) to the end of the grazing period (1.65 kg m^{-3}). Over the same time period, the moderately grazed area and reference area had a slightly lower increase of only 19 and 17% or bulk densities of 1.6 and 1.5 kg m^{-3}, respectively. This reaction to trampling indicates the greater vulnerability of the soil in the heavily grazed area to compaction because of its low organic matter content and less stable soil structure (Mapfumo *et al*., 2000)**.** The higher soil bulk density at the 15-30 cm depth could be because of a hardpan layer, which has been created in the lower soil layer due to long term heavy trampling in the area (Table II). The higher soil porosity suggests a better soil structure, implying better water infiltration and higher soil moisture holding capacity. Soil with these characteristics supports a better vegetation cover. A high intensity of trampling decreases soil organic matter levels, and this ultimately reduces soil porosity (McCalla *et al*., 1984). The soil characteristics observed in the heavily grazed area leave the soil extremely vulnerable to wind and water erosion.

The disturbed topsoil structure as a result of the effects from trampling by grazing animals is a primary reason for lower water infiltration. The water infiltration rate within the first five min is a measure of the topsoil's ability to absorb and infiltrate precipitation (Chaichi, 1995). In late May, the soil water infiltration rate for the first five min in the moderately grazed area was reduced by 67% (from 12 mm min^{-1} to 4 mm min^{-1}). A 60% reduction in soil infiltration was recorded over a similar time period in late September. This can be explained by long-term soil compaction from trampling livestock that had deteriorated the soil's elastic capabilities. The severe shortage of vegetation cover has a direct impact on the lack of litter and organic matter in the soils of the heavily grazed area. A 30% reduction was observed in the infiltration rate when compared with the reference area at the beginning of the grazing season. This is indicative of the results of the destructive effects of heavy trampling pressure on soil structure and its ability to store and preserve soil moisture in both the heavily grazed and moderately grazed areas (Warren, *et al*., 1986; Naeth, *et al*., 1990; Naeth, *et al*., 1991).

The soil mechanical resistance followed an increasing trend with the length of the grazing period. This trend was reduced in 2001 because it was a drier year (Table I). Mechanical resistance for 2000, with its higher amounts of soil moisture, was 20% greater during the grazing period. This indicates the enhancing effect of moisture on soil mechanical resistance. Despite a non-significant difference in soil mechanical resistance between the reference area and the moderately grazed area during the grazing period, a significant increase was observed in the heavily grazed area. This was due to a shortage of organic matter and the removal of silt and clay as a result of erosion in the heavily grazed area. The lower organic matter content in the heavily grazed area best explains the higher mechanical resistance at this area (Fig. 1).

The limited vegetation cover of the heavily grazed area comprised mainly *Exilirion* sp., *Onobrichs* sp., *Astragalus* sp., and *Cousinia* sp., none of, which are desirable, high quality, palatable rangeland plants. The vegetation cover of grasses at the beginning of the grazing season was less than 1% in the heavily grazed area (Table II). At the same time, only 16% of the vegetation cover was occupied by forbs. Forb coverage was reduced to only 4% by the end of the grazing season because of the absence of more palatable or desirable alternative plants for sheep to graze. This resulted in an increase in the amount of bare ground at the end of the grazing season. The soil of the heavily grazed and moderately grazed areas is highly vulnerable to wind and water erosion, comprising 93 and 60.3% bare soil, respectively. This demonstrates the potential for destruction of rangeland production because of a long period of severe trampling in heavily grazed and moderately grazed areas.

Long-term trampling pressure, especially in areas with limited amounts of vegetation coverage, can create a layer of hardpan in the sub-soil layer of rangeland areas. This phenomenon is accelerated by a reduction in surface vegetation cover. The lack of vegetation cover, along with the shortage of litter being deposited on the soil surface, not only makes it more vulnerable to wind and water erosion but also accelerates the formation of the hardpan layer. The hardpan layer, in turn, acts as a barrier to proper seed germination and root expansion of the young seedlings (Samson *et al*., 2002).

To improve the vegetation cover in the moderately grazed area, the rangeland area needs to have restricted grazing by livestock for at least three years before it is managed with a more moderate stocking density that is in accordance with the rangeland's capacity to produce. In the heavily grazed area, the vegetation cover needs to be improved by the seeding and establishment of high quality rangeland plants which needs to be totally prohibited from grazing livestock long enough for plants to become well established and reproduce through natural regeneration.

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