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Communication

# Effect of Visitor Activities on Surface Soil Environmental Conditions and Aboveground Herbaceous Biomass in Ayder Natural Park

The effects of visitor activities on surface soil environmental conditions and aboveground herbaceous biomass in Ayder Natural Park, Turkey, were investigated. Soil properties and aboveground herbaceous biomass were identified and characterized as heavily trafficked site (HTS), moderately trafficked sites (MTS) and control (non-trafficked site) in grassland in a forest gap. Some soil properties were measured on 60 pits at 0–5 and 5–10 cm soil depths. The intensity of visitor activities had a negative impact on both surface soil properties and the aboveground herbaceous plant biomass and root mass in the study area in Ayder. The soil bulk density and soil penetration resistance increased from 0.94 to 1.47 g $cm^{-3}$ and 0.55 to 1.65 MPa, respectively, saturated hydraulic conductivity decreased from 77.98 to 8.85 mm $h^{-1}$, and soil organic matter decreased from 6.71 to 1.77% in moderately and heavily trafficked sites, respectively, at 0–5 cm soil depth. The soil properties were degraded at both the surface layer and the subsurface layer and the greatest degradation was measured in the heavily trafficked site followed by the moderately trafficked site. There was a strong negative linear relationship between soil degradation and aboveground herbaceous plant biomass, which decreased by 50.05 and 78.19% in moderately and heavily trafficked sites, respectively.

**Keywords:** Aboveground herbaceous biomass; Environmental conditions; Saturated hydraulic conductivity; Soil bulk density; Surface Soil

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## 1 Introduction

The provision of opportunities for public enjoyment is an important part of the Turkish National Park Service's mission. However, recreational activities and other uses may be allowed in parks only to the extent where they can take place without causing impairment or deterioration of the park's resources, values, and purposes. Soil systems are not static, but are subject to natural changes, that include both directional and cyclic changes. Changes can occur over time scales ranging from days to millennia. The impacts of human activity are superimposed on natural changes and their significance must be evaluated in the light of natural changes. The assessment of the sensitivity of the soil landscape to further change must also include the natural variability in both space and time [1]. Recreational activities have a significant effect on damaging the physical and hydrophysical properties of surface soils. Currently, the demand of recreational diversity in protected areas has been increasing rapidly and this makes planning and protection of the environment difficult [2]. The effects of human trampling on vegetation communities have been widely reported [3], e.g., species richness (estimated via capture-recapture methods) have decreased significantly with the increasing intensity of trampling in maritime high grassland regions [4].

Damage of the protective vegetation cover affects soil development, and consequently, soil is more exposed to wind and water erosion. These impacts are growing because of the large increases in the number of hill walkers in recent decades [5]. The intensive recreational use of grassland in forest gap soils leads to soil compaction and increased bulk densities in the areas involved. An important consequence of increased bulk density is a diminished capacity of the soil to retain water, with increased losses by surface runoff [6]. Ball games and other activities may wear out a reasonable stretch of grassland and damage the topsoil structure [7]. Soil is compacted when pore space is reduced and bulk density increases [8, 9]. Therefore, any process that reduces pore space causes soil compaction. The major cause of soil compaction is the traffic over the fields [10, 11]. Human trampling, camping equipments, livestock, and car parking are all known to compact soil [12]. The extent of compaction depends on many factors, including soil physical conditions, soil texture, weight and design of the load on soil, camping equipment, and the number of trips made over the same area [13]. The physical properties of soil are negatively impacted during trafficking, and the results can persist for many years, e.g., the limiting of plant productivity [14]. The impact is greatest in the surface layer [15, 16]. As a consequence of compaction, soil infiltrability and permeability are reduced [15, 17]. Similarly, if the compaction is accom-

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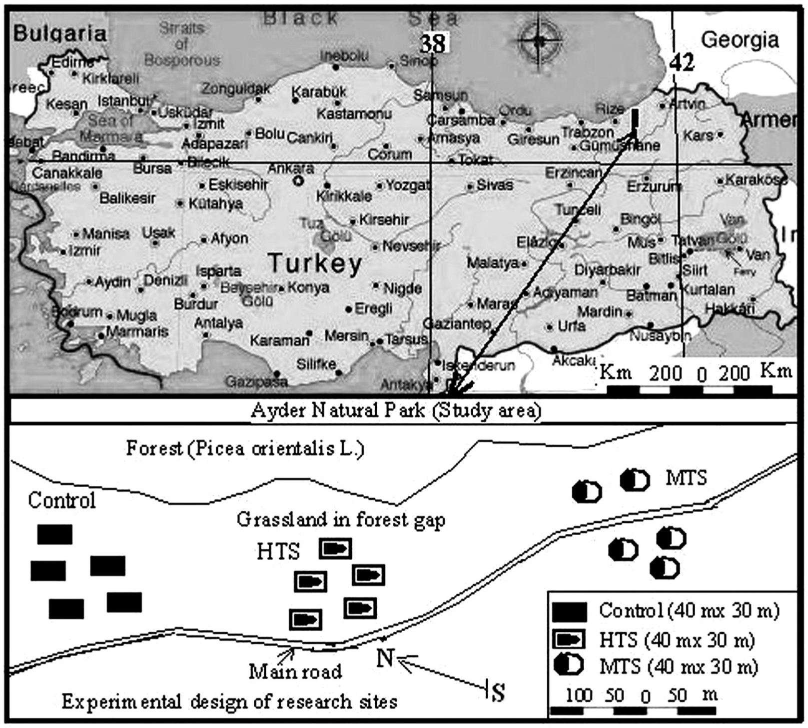


**Figure 1.** Location of the study area and experimental sites in Ayder.

plished with proper moisture control, the movement of capillary water is minimized [18, 19]. The minimized capillarity reduces the tendency in the soil to take up water and its shearing resistance. When the moisture content is less than optimum, the soil is more difficult to compact. Beyond the optimum value, most soils are not dense under a given effort since the water interferes with the close packing of the soil particles. The relationship between soil compaction and water content is usually included in models predicting soil compaction [20]. Trafficking causes a progressive decrease in soil volume, and consequently, a decrease in total pore space. The optimal conditions for compaction often occur at water content near the field capacity [21]. The analysis of effects of compaction on water retention of grassland in forest gap soils is often limited to the comparison of water contents at specific levels of pressure or differences among them, e.g., the macropores, micropores, field capacity, air-filled porosity, and available water holding capacity.

The impact of visitor activities on surface soils in protected areas has been a concern in developed countries for more than 30 years and a lot of research has been performed to quantify the effect of compaction on soil, and to manage grassland to minimize soil compaction in recreational areas. There is a lot of research concerning the effect of visitor activities on surface soil environmental conditions in many part of the world. However, the studies undertaken concerning this subject in Turkey are insufficient. The aim of this study is to evaluate the effect of the activities of visitors on the physical and hydro-physical properties of surface soils and aboveground herbaceous plant biomass in Ayder Natural Park in Rize, Turkey.

## 2 Materials and Methods

### 2.1 Site Description and History

The study area is located in Ayder, a site close to Çamlihemsin town, in the northeast of Turkey, Rize. (lat. 40°57′14″ – 40°57′30″ N, and longit. 41°06′15″ – 41°06′24″ E, altitude 1250 m above sea level), as shown in Fig. 1.

Since there was no meteorological station in the study area, the nearest meteorological stations in Pazar and Çamlihemsin were taken into account. The climate is humid, with an annual average rainfall of 1350 mm with a minimum in spring (250 mm), and maximum in autumn (680 mm) and the mean annual temperature is 8.2°C in the meteorological station, which is located 17 km away at a similar altitude [22, 23]. The altitude ranges between 1190 and 1285 m, and the slope of the study area is moderate, i.e., 18 ± 2%. The soils are classified as brown forest soils according to the International Soil Classification System (ISCS) [22, 24], and are derived from granite bedrock. The rock mass is extensively intrusive disrupted, and parent material is granite [25]. The study area mainly consists of *Lolium perenne* (L.), and *Poa nemoralis* (L.), *Poa pratensis* (L.), *Trifolium repens* (L.), *Taraxacum sp.*, *Alchemilla sp.*, *Plantago sp.*, *Carex sp.*, and *Geranium arundinacea* (Kunth). Ayder and its environment have a different topography, rich and abundant vegetation, clean and fresh air and is located 7 km away from Çamlihemsin County. For these reasons, people who live in the north east of the Black sea region have a major interest in recreational activities in this area.

It was estimated that more than 500,000 people visited Ayder during 2006, and most of theses visited during July and August. The prevalent recreational activity, the Ayder culture, art and nature festival has been running since 1994, and nowadays, tourism is the main source of income for local inhabitants since the abandonment of traditional agriculture. As a consequence, there is strong social and economical pressure for tourism in protected areas.

The festival area is ca. 10 ha. and there is no accepted land use plan associated with it. Apart from the traditional Ayder festival, people can also enter the area free of charge and can camp in any part of the grassland in the forest gap and in addition, there is random light grazing on the grassland in forest gap.

 

## 2.2 Sampling

A preliminary study was conducted in the Ayder protected area to determine site use type and intensity, e.g., the variety and intensity of the activities of visitors, camping sites, the numbers and average size of tents, etc. For this purpose, a public survey concerning the recreational activities of visitors was carried out using visual observation in the midsummer of 2006. According to the visual observation and public survey, in the present study the research sites are categorized as: (a) "high" disturbance sites (heavily trafficked sites), which are located on the main festival area where a lot of activities, e.g., folk dances, ball games, skiing on grass, and light grazing, have been conducted since 1960, (b) "low" disturbance sites (moderately trafficked sites), which are outside the main festival area and have been used as camping areas since 1980, and (c) the control site, which is located in an adjacent area (closed to festival activities) in grassland in the forest gap (GFG).

The experimental design at each site was a randomized complete block with five replications. Soil samples were collected from control (closed festival activities), moderately trafficked (MTS), and heavily trafficked sites (HTS). Soil research on the festival site was conducted and monitored in August 2007 when the soil moisture was typically low. The four disturbed and four undisturbed soil samples were randomly taken at a soil depth of 0 to 5 cm and 5 to 10 cm in each plot in the GFG area. The undisturbed soil samples were taken by using a steel core sampler of a 98.18 $cm^3$ volume (5 cm in diameter and 5 cm in height). The field capacity (FC) was measured by subjecting saturated soil samples <2 mm to tensions of 1/3 bar. The permanent wilting point (PWP) was measured at 15 bar until equilibration in a pressure membrane and a pressure plate extractor. Plant available water (PAW) content was calculated from the difference between the field capacity and the permanent wilting point [26]. The bulk density, $D_b$, total porosity, and saturated hydraulic conductivity were determined in the undisturbed soil samples. The dry bulk density was determined by the core method [27, 28]. Particle density was determined by the pycnometer method. Total porosity, St, was calculated from Eq. (1):

$$[\mathrm{St}\ (\%) = (1 - D_b/D_p) \cdot 100] \quad (1)$$

where St is total pore spaces, $D_b$ is bulk density and $D_p$ is the soil particle density [29]. Soil organic matter (SOM) was determined according to the Walkey-Black procedure. Soil pH was determined in a 1:12.5 by volume of soil water mixture using an Orion 420 A pH meter [30]. The saturated hydraulic conductivity, $K_{sat}$, was measured by the falling-head method according to Klute and Dirksen [31]. The samples were saturated and then oven-dried at 105 ± 2°C to determine bulk density. The particle size distribution was determined by using disturbed soil samples sieved through a 2 mm sieve by the Bouyoucos hydrometer method [32]. Root masses (RM) were weighed after rinsing with distilled water and oven drying at 105°C for 24 h [33]. The soil penetration resistance (SPR) was measured to 40 cm depth [34]. Measurements were recorded at depth intervals of 5 cm, using a manual (hand-pushed) 13 mm diameter cone (30°) penetrometer, and 20 measurements were performed on each plot. The cumulative infiltration, Ic, in the field was determined using a single ring infiltrometer [35] having a cylinder of diameter 20 cm and a height of 20 cm, and 4 measurements were performed at a level surface in each plot. The site was prepared by removing all residues and any large clods (in tilled soils) that would interfere with achieving a level surface. The cylinder was pounded ca. 5 cm into the ground. The change in water depth of the cylinder was measured at time intervals of 5, 10, 15, 20, 30, 40, 60, 75, 90, 105 and 120 min.

Aboveground herbaceous biomass was measured on four randomly selected areas of 1 · 1 m (1 $m^2$) in each site at the beginning of September 2007. The standing biomass was destructively sampled by clipping at the ground line and placing samples in paper bags. The biomass was dried to a constant mass in a force draft oven at 80°C for 48 h and then weighed [36]. The total biomass fresh weight per plot was recorded and the biomass moisture content for each plot was determined to obtain the total biomass dry matter (DM) per plot which was converted to Kg DM $ha^{-1}$.

## 2.3 Statistical Analysis

Statistical analysis was performed by analysis of variance (ANOVA), and the means were subjected to the Duncan test ($P < 0.05$) to obtain the main differences between the treatments (sites). The data were also subjected to correlation with SPSS software packages. The mean values found for all properties are shown in relevant tables.

# 3 Results and Discussion

## 3.1 Soil Texture, Water Characteristics, Bulk Density, Particle Density and Total Porosity

### 3.1.1 Soil Depth of 0–5 cm

The soil texture of the study area was sandy loam (SL), see Tab. 1. The value of mean sand was the highest in the control site followed by the MTS, and the HTS. The sand content slightly decreased in the MTS compared to the control site, and the mean clay content increased significantly ($p < 0.048$) in the HTS compared to the control site, Tab. 1.

The FC decreased in going from the control to the MTS to the HTS. The PAW was significantly lower ($p < 0.000$), while the PWP was moderately higher in the HTS than in the control site. Because of the traffic density, the SPR increased and the total porosity decreased on passing from control to MTS to HTS. The significant increase in bulk density and SPR, and significant decrease in total porosity possibly affected FC, PWP, and PAW values, see Tab. 1. Froehlich and McNab [15] reported that soil compaction has a variable effect on the water holding capacity of soils.

The average bulk density was the highest for the HTS followed by the MTS. The soil bulk density increased significantly ($p < 0.000$), and total porosity decreased significantly ($p < 0.005$) in the MTS and HTS.

A very strong relationship was found between soil bulk density and soil depth at both 5 cm and 10 cm, as shown in Eqs. (2–5):

$$y = 0.028x + 0.8,\ R^2 = 0.9999 \text{ for the control} \quad (2)$$

$$y = 0.034x + 1.1,\ R^2 = 0.9998 \text{ for the MTS} \quad (3)$$

$$y = 0.05x + 1.22,\ R^2 = 0.9998 \text{ for the HTS} \quad (4)$$

The bulk density and SPR increased with disturbed conditions, and accompanying clay content increase and sand fraction decrease. The bulk density and soil compaction are known to vary under the influence of particle size distributions in a soil layer [37, 38]. The presence of clay and sand correlated well with higher bulk

 

**Table 1**. Soil properties at 0 – 5 cm soil depth in the study area.

| Characteristics | Control (Non-trafficked) "NTS" | Moderately Trafficked Site "MTS" | Heavily Trafficked Site "HTS" |
|---|---|---|---|
| Sand (%) | 70.21[a)] | 67.35[a)] | 65.73[a)] |
| Clay (%) | 11.54[a)] | 14.15[a, b)] | 17.33[b)] |
| Silt (%) | 18.25[a)] | 18.50[a, b)] | 16.94[b)] |
| Soil texture class | Sl | Sl | Sl |
| Bulk density ($g\ cm^{-3}$) | 0.94[a)] | 1.27[b)] | 1.47[c)] |
| Particle density ($g\ cm^{-3}$) | 2.36[a)] | 2.39[a)] | 2.32[a)] |
| Total porosity (St), (%) | 60.17[c)] | 46.86[b)] | 36.64[a)] |
| Field capacity (FC), (% vol.) | 25.96[b)] | 22.55[a, b)] | 20.75[a)] |
| Permanent wilting point (PWP), (% vol.) | 10.18[a)] | 11.23[b)] | 13.25[c)] |
| Plant available water (PAW), (% vol.) | 15.78[c)] | 11.32[b)] | 7.50[a)] |
| Saturated hydraulic conductivity ($K_{sat}$), ($mm\ h^{-1}$) | 77.98[c)] | 19.50[b)] | 8.85[a)] |
| Cumulative infiltration (Ic), (mm) | 521[c)] | 316[b)] | 154[a)] |
| pH | 5.40[b)] | 4.71[ab] | 4.59[a)] |
| Soil organic matter (SOM), (%) | 6.71[c)] | 4.39[b)] | 1.77[a)] |
| Root mass (RM), ($g\ cm^{-3}$) | 1.55[c)] | 0.69[b)] | 0.35[a)] |
| Above ground biomass ($Kg\ ha^{-1}$) | 1958[c)] | 978[b)] | 427[a)] |
| Soil penetration resistance (SPR), (MPa) | 0.55[a)] | 1.13[b)] | 1.65[c)] |

a) $N$ = Number of samples ($N$ = 20).
b) Sl = Sandy loam.
c) Different letters after means indicate a significant difference between the means (Duncan Test, $P$ = 0.05).

**Table 2**. Soil properties at 5 – 10 cm soil depth in the study area.

| Characteristics | Control (Non-trafficked) "NTS" | Moderately Trafficked Site "MTS" | Heavily Trafficked Site "HTS" |
|---|---|---|---|
| Sand (%) | 68.77[a)] | 64.20[a)] | 61.77[a)] |
| Clay (%) | 11.79[a)] | 15.89[b)] | 20.15[c)] |
| Silt (%) | 19.44[a)] | 19.91[a)] | 18.08[a)] |
| Soil texture class | Sl | Sl | Sl |
| Bulk density ($g\ cm^{-3}$) | 1.08[a)] | 1.44[b)] | 1.72[c)] |
| Particle density ($g\ cm^{-3}$) | 2.43[a)] | 2.41[a)] | 2.47[a)] |
| Total porosity (St), (%) | 55.55[c)] | 40.25[b)] | 30.36[a)] |
| Field capacity (FC), (% vol.) | 22.77[a)] | 20.15[a)] | 18.80[a)] |
| Permanent wilting point (PWP), (% vol.) | 11.25[a)] | 13.85[a, b)] | 14.90[b)] |
| Plant available water (PAW), (% vol.) | 11.52[c)] | 6.30[b)] | 3.90[a)] |
| Saturated hydraulic conductivity ($K_{sat}$), ($mm\ h^{-1}$) | 51.67[c)] | 9.81[b)] | 2.90[a)] |
| pH | 5.50[b)] | 5.12[a, b)] | 4.81[a)] |
| Soil organic matter (SOM), (%) | 3.83[c)] | 2.05[b)] | 0.58[a)] |
| Root mass (RM), ($g\ cm^{-3}$) | 1.25[c)] | 0.62[b)] | 0.20[a)] |
| Soil penetration resistance (SPR), (MPa) | 0.88[a)] | 1.38[b] | 1.65[c)] |

a) $N$ = Number of samples ($N$ = 20).
b) Sl = Sandy loam.
c) Different letters after means indicate a significant difference between the means (Duncan Test, $P$ = 0.05).

density and SPR in the HTS. If the soil was wetter than field capacity, it was significantly compacted regardless of the traffic density number. Yüksek et al. [2] reported that during the festival season from 28 June to 1 July 2006, 8607 people and 2454 vehicles entered Kafkasör festival area, causing soil compaction.

### 3.1.2 Soil Depth of 5 – 10 cm

At a soil depth of 5 – 10 cm, the sand content slightly decreased while the silt content slightly increased in the MTS compared to the control site, and the mean clay content significantly increased in the MTS and HTS compared to the control site, see Tab. 2.

The FC value slightly decreased in the MTS, while the PWP increased significantly ($p < 0.04$) in the HTS compared to the control site. The PAW value decreased significantly ($p < 0.000$) in the MTS and HTS, see Tab. 2. Sand content, FC and PAW decreased with soil depth, while clay and PWP increased in all sampling sites in the study area. Compaction and lower SOM content may have a negative impact on the water and air status of the soils in the MTS and HTS. According to Hudson [39], soil high in organic matter (OM) content has significantly higher available water content (AWC) than soils of similar texture that contain less OM. In addition, there was a significant positive correlation between soil OM content and estimated AWC in all textural groups, i. e., sand, silt loam and silty clay loam. As OM increased, the soil at the FC had an increased amount of held water at the PWP, which resulted in an increase of AWC. The soil bulk density increased significantly ($p < 0.000$) and the total porosity decreased significantly ($p < 0.002$) in the MTS and HTS, see Tab. 2. The main reason for the increase in soil bulk density was the variety and density of the activities of the visitors over the study area. Folk dance, car parking, walking, camping, ball games and other visitor activities increased the bulk density and caused soil compaction. Troeh and Thompson [7] reported that ball games and other activities might wear out a good region of grassland and damage the topsoil structure. Soil compacts when pore space is reduced and bulk density is increased [8, 9]. Therefore, any process that reduces pore space causes soil compaction.

## 3.2 Soil Organic Matter, pH, Root Mass and Aboveground Biomass

### 3.2.1 Soil Depth of 0 – 5 cm

The SOM content decreased in MTS and HTS, and it was significantly ($p$ < 0.006) lower than that of control site. The root mass (RM) decreased in MTS and HTS, and it was significantly ($p$ < 0.002) lower than that of control site. The aboveground biomass decreased in MTS and HTS, and it was significantly ($p$ < 0.000) lower than that of control site. The significant increase in bulk density and SPR, and significant decrease in total porosity and PAW possibly affected root and plant growth. Therefore, aboveground biomass decreased significantly in trafficking sites (MTS and HTS), Tab. 1.

### 3.2.2 Soil Depth of 5 – 10 cm

The SOM decreased in both the MTS and HTS and it was significantly ($p$ < 0.000) lower than that of control site. The mean pH was slightly lower in the MTS, but the difference was not statistically significant. The RM decreased in both the MTS and HTS and it was significantly lower ($p$ < 0.003) than that of control site, see Tab. 2.

A very strong negative relationship was found between SOM and soil depth, at both 5 cm and 10 cm, Eqs. (5 – 7):

$$y = -0.576x+9.59,\ R^2 = 0.9999 \text{ for control} \quad (5)$$

$$y = -0.468x+ 6.73,\ R^2 = 0.9997 \text{ for MTS} \quad (6)$$

$$y = -0.238x +2.96,\ R^2 = 0.9999 \text{ for HTS} \quad (7)$$

It is well known that vegetative residuals are one of the major sources of SOM. The intensity and density of the activities of visitors damage surface soil properties and decrease the herbaceous cover. Different studies have shown that removing aboveground biomass practices affect SOM and pH levels [40]. Jim [41] studied the impact of camping on vegetation and soil in a Hong Kong country park. It was seen that trampling resulted in loss of vegetation cover, and a reduction in plant height and root biomass. The species composition shifted in response to increasing usage towards domination by a few trampling-resistant grasses (monocots) at the expense of sensitive woody dicots. The loss of vegetation and litter cover contributed to soil compaction, increased the bulk density, penetration resistance and bare soil cover, and decreased the void ratio and SOM content, which led to the reduction of water storage capability.

## 3.3 Saturated Hydraulic Conductivity, Cumulative Infiltration and Soil Penetration Resistance

### 3.3.1 Soil Depth of 0 – 5 cm

The value of $K_{sat}$ decreased in the MTS and HTS and was significantly lower ($p$ < 0.000) than that of the control site. The SPR increased in the MTS and HTS and was significantly higher ($p$ < 0.011) than that of control site, see Tab. 1. The values of cumulative infiltration, Ic, were significantly lower at the trafficked sites compared to the control site. A very strong relationship was found between the cumulative infiltration and square of time, see Fig. 2.

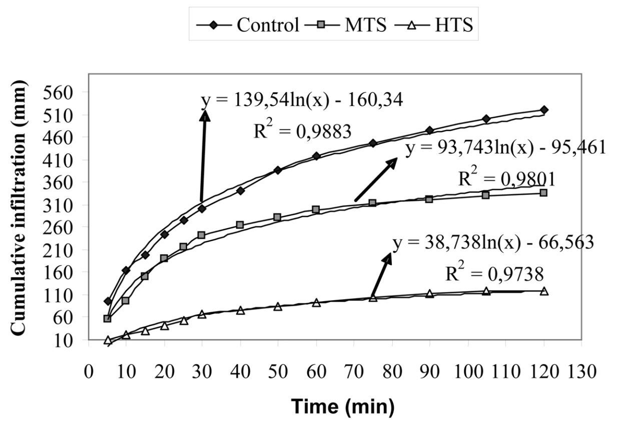


**Figure 2.** Cumulative infiltration (mm) in control, MTS and HTS in the study area.

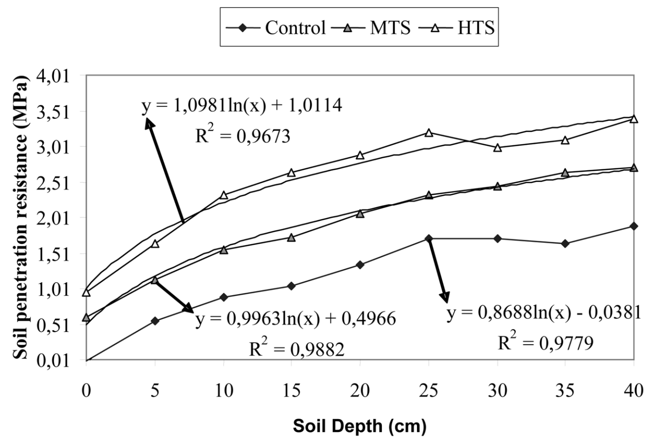


**Figure 3.** Soil penetration resistance (MPa) in control, MTS and HTS in the study area.

### 3.3.2 Soil Depth of 5 – 10 cm

The value of $K_{sat}$ decreased in the MTS and HTS, and was significantly lower ($p$ < 0.000) than that of the control site. The value of $K_{sat}$ was highest for the control followed by the MTS and HTS, see Tab. 2. The mean $K_{sat}$ value decreased linearly with soil depth in all sampling sites more than in the control site. Thus, $K_{sat}$ decreased on increasing the intensity of visitor activities. The increased bulk density and SPR, and decreased SOM reduced the capacity of the soil to take up water, and hence, decreased $K_{sat}$ and infiltration. The intensity of visitor activities compact the soil to considerable depths and significant changes occurred in soil strength and $K_{sat}$ because of the traffic. When the trampling effects of visitors are considered, the mean SPR increased by 22.12%, and 46.66% in the MTS and HTS, respectively, at 10 cm soil depth. The SPR linearly increased with depth in both the control and MTS sites, see Fig. 3.

# 4 Conclusions

In this research, the impact of long term activities on the surface soil properties in the study area was studied. Visitor activities had a negative impact on the surface soil physical and hydro-physical properties, aboveground herbaceous plant biomass, and root mass. The impact was greatest in the heavily trafficked sites and, to a lesser degree, in moderately trafficked sites. A principal challenge of protected area management is determining what action(s) will be most effective in avoiding or minimizing visitor impact. The principles of management in the Ayder protected area must be revised, and the use of this area without a long-term plan must be stopped as soon as possible. An acceptable land use plan must be applied in the study area in Ayder. Visitor activities should be classified and the most suitable places must be planned for each recreational activity. Some alternative places could be planned to suit each type of visitor activity. When areas of activity are destroyed, they should be closed to visitors for rehabilitation work.

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