Comparing soil compaction under different grazing systems with a virgin forest soil to determine optimal stocking rates

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Abstract. The understanding of how soil physical properties respond to differing grazing practices may help explain the main causes of pasture degradation. Soil compaction has been shown to be a main degradation form of soil and the knowledge of techniques to quantify and rectify this are necessary to maintain optimal yields. This research aims to measure the rupture lines of red yellow latossol under differing pasture grazing practices compared to cropping and a natural forest. With this information it is aimed to calculate the correction factor for stocking rates and traffic of tillage tools. The differing soil management practices examined was, pasture grazed by sheep, and dairy cattle, a maize crop in no tillage cover-crop system and a natural forest. To quantify the soil physical changes, the direct shear test was used, which calculated the resultant force of a load. The resultant forces of the natural forest were compared against pasture systems and crop system, and a correction factor for stocking rates was calculated. The samples of Red yellow Latossol were equilibrated in the matrix potential (ψ): -6 kPa. In the shear test, the normal stress used was the 450kPa. The correction factor (CF) indicates whether the soil has structural degradation compared to natural forest. Values less than 1 indicated soil degradation. The pastures grazed by sheep and dairy cattle had values observed to be less than 1, excessive loads at high soil moisture may be attributed to this soil structural deformation. For these systems, grazing management and stocking rates should be corrected. The correction factor gives an indication of the magnitude of management change that is required (*i.e.* the stocking rate decreased). The crop area was found to have no soil strength issues, using the stress test.

Keywords: Soil degradation, pasture management, crop management, shear strength, red yellow latossol.

Introduction

Decreasing pasture production can be due to several factors. In this paper we argue that soil compaction, caused by animal trampling, is a major cause of degradation. Soil moisture is one of the principal controlling factors of compaction (Pires 2007). Soil compaction occurs due to the application of external pressure to the soil surface resulting in a reduction of air filled porosity of the soil. It can occur either by animal trampling or by heavy farm machinery (Rocha *et al*. 2007). There are several techniques to quantify soil compaction. We focus on the shear strength method in this study to determine the amount of soil compaction under differing land management practices.

All forces involved in the dynamic process of soil compaction are related and correlated with bulk density, penetration resistance, porosity, and weathering degree (Rocha *et al*. 2002). Soil shear strength is the maximum shear stress the soil can stand without rupturing, or the soil shear stress on the surface where the rupture occurs, expressed in the Coulomb equation: $\sigma = c + \sigma n \, tg\phi$ (Ramamurphy 2001), where σ is the maximum shear stress supported by the soil; σn is the normal stress the failure surface is subjected to; *c* is the cohesion intercept or apparent cohesion of the soil; ϕ is the soil internal friction angle (angle formed by the normal strength with the strength the soil bulk is subjected to). This equation defines the rupture line as the limit line of soil strength, that is, any shear stress on this line will result in soil rupture (Rocha 2003). Carvalho *et al*. (2010) using the soil shear strength technique, calculated the ratio between natural forest and trampling areas, concluded that this ratio could be used to assist in assessing soil structure alterations. Values below 1 indicate a soil structural alteration in (compaction) has occurred. Since natural forests can be considered to have virgin soils, this correction factor gives an indication of the magnitude of management change that is required (*i.e.* the stocking rate decreased) based on the amount of compaction.

Methods

This study was carried out at two experimental farms, the Federal University of Jequitinhonha and Mucuri, the soils can be described as a dystrophic Red Yellow Latossol (LVAd) (Brazilian Soil Classification System) analogous to a Oxisol in Soil Taxonomy (USDA). The areas under study comprised of pastures grazed separately by sheep and dairy cattle, a maize crop under zero tillage and a natural forest as the control. From each management system, 32 undisturbed soil samples were collected randomly from the surface layer (0–3 cm) (32 samples x 4 management systems).

The sheep pasture was *Panicum maximum* cv. Tanzania, 4 ha in size and grazed by 30 animals. The dairy cattle pasture was *Brachiaria brizantha* cv. MG-5 Vitória, 6 ha in size and had a stocking rate of 4 animal units/ha. The maize was a cover-crop over a *Brachiaria ruziziensis* pasture with a no-tillage system and was 2 ha in size. Lastly, the natural forest is an Atlantic Forest residue.

32 intact soil cores were taken to the Soil Physics Laboratories of the Federal University at Jequitinhonha and Mucuri and saturated and equilibrated at a tension of -6 kPa (field capacity), on a pressure plate apparatus (Richards 1965). After the soil cores had equilibrated, the samples were tested for shear strength tests according to Rocha *et al*. (2007) and using a ELE International (Digital Shear Machine, 26-112-9901X0089). Horizontal displacement speed was set at 2 mm/min and normal stress of 194, 304, 415, and 526 kPa was applied (Pires 2007).

Straight lines of strength were drawn after the application of the normal stress (x) and determination of the maximum shear stress (y) and the resultant force in each management system was calculated. Statistical comparisons between the rupture lines, *i.e*., between the straight line equations, were carried out according to Snedecor and Cochran (1989).

Of the rupture lines obtained by the direct shear test, the shear stress was calculated for a normal stress of 450 kPa, which, according to Betterige *et al*. (1999), is the common pressure applied by animals to soil. Once the normal and shear stress was known, the resulting tension was calculated according to Pythagoras's Theorem in which: σr = resulting tension (kPa), τ = shear stress (kPa) σn = normal stress (kPa) (see Fig. 1).

An animal moving about the pasture or heavy both machinery (*e.g.* a tractor with tillage equipment) causes shear stress and normal stress (Rocha 2007, Fig. 1). On this basis, the resulting tension (compaction) was calculated for each management system and the ratio between the measured compaction of the forest soil (σrM)/ compaction of each management studied (σrm). This ratio was denoted as the correction factor (CF).

Based on this correction factor it is possible to evaluate changes to soil structure between a natural forest and a grazed area. A value below 1 indicate a structural alteration, indicating soil compaction, as the natural forest can be considered the soil use where the original structure is preserved. This correction factor can be used to assist management in determining amongst other factors stocking rate (animal unit/ha). It is worth mentioning that this ratio is necessary to determine the need for amelioration (*e.g.* sub soiling and scarification) which could reverse the effects of compaction. This correction factor may also be too used to measure the effectiveness of a range of soil management methods to reduce soil compaction.

Results and discussion

Rupture lines of LVAd that where submitted to different tension of water retention of -6 kPa show a high coefficient of determination for all treatments, demonstrating a good fitting of the mathematical model (Fig. 2).

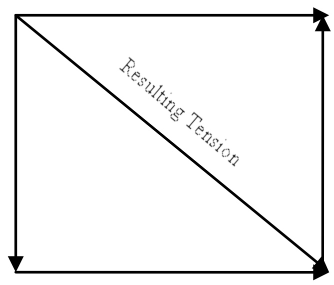

Figure 1. Scheme of tension distribution in the direct shear test (Carvahlo *et al.* 2010)

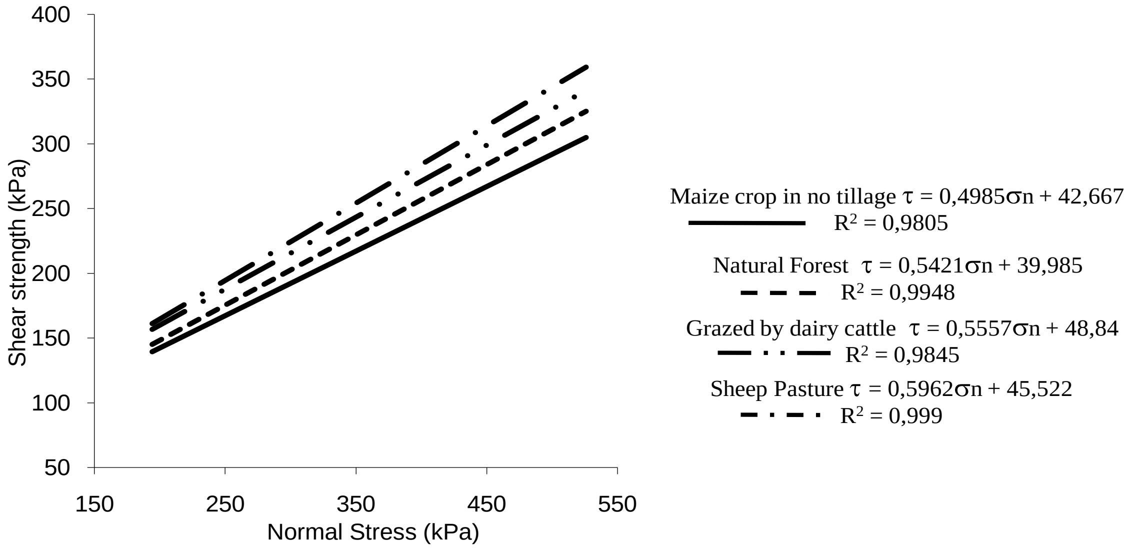

Figure 2. Shear rupture lines of an LVAd submitted to different managements, with samples at a water tension of -6 kPa.

Table 1. Correction factor for the different managements

Management	CF
Maize crop in no tillage	1.01
Grazed by dairy cattle	0.98
Sheep Pasture	0.96

The rupture lines of LVAd soil for all managements differed statistically according by Snedecor and Cochran (1989), indicating that a different soil structural component was found for the different managements in this study. The maize crop had a lower soil shear strength than the native forest. The lower shear strength may be caused by the physical disturbance of the soil and the *B. ruziziensis* maybe improving soil structure, and decreasing the soil strength. It can be observed that the natural forest showed low shear strength values, indicating this soil is in a undisturbed condition, with no machine traffic and no animal trampling (Fig. 2). The pasture grazed by sheep and dairy cattle, presented higher shear strength values, possibly indicating animal hoof trampling as the principal cause.

The correction factors indicate that pastures grazed by dairy cattle and sheep are more likely to have soil structural problems (Table1). To address the decline in structure the stocking rate could be corrected by multiplying the values by the CF. The soil under the sheep pasture presented the lowest value for CF (0.96), followed by soil under grazed by cattle (0.98). The maize crop under zero tillage was the management system that presented the least amount of compaction, because the CF value is greater than 1.

Conclusion

The maize crop no tillage system was the management that had the soil shear strength that was similar to the natural forest. The CF factor was lowest under the sheep pasture management system, indicating potential soil compaction problems. For the pastures grazed by sheep and dairy cattle it, may be necessary to correct the stocking rate or grazing management. While CF factor gives an indication of the magnitude of change that is required to adjust soil strength, further experiments are required to determine whether a change in stocking rate or grazing management result in changes in soil strength, due to the hysteresis processes of degradation and repair in the soil.

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