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PHYSICAL AND CHEMICAL PARAMETERS OF AN ULTISOLS CULTIVATED WITH PASTURE IN DIFFERENT DEGRADATION STAGES

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ABSTRACT

Soil degradation is an important global issue because of its adverse impact on agronomic productivity, the environment, and its effect on food security and the quality of life. Productivity impacts of soil degradation are due to a decline in soil quality on site where degradation occurs (e.g. erosion) and off site where sediments are deposited. The present study aimed to identify possible signs of soil degradation in a rural property in a region of the State of São Paulo in Brazil. Deformed and undisturbed soil samples were collected in the 0.00-0.10 and 0.10-0.20 m layers in order to evaluate the physical parameters: macroporosity, microporosity, density, resistance to penetration and infiltration of soil and chemicals: organic matter, phosphorus, pH and base saturation. The results showed that the area under cultivated pasture presented the best parameters, indicating that the incorrect soil management results in soil degradation. The main indicators of soil quality were macroporosity and soil water infiltration. For the chemical attributes, the characterization did not detect changes in the studied areas. The relationship between soil physical and chemical properties was positive.

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INTRODUCTION

Soil degradation is the process of soil depletion by loss of nutrients, leaving you infertile or low concentrations of nutrients, which impairs or prevents the agricultural practices. The definition of soil degradation is associated with the own soil quality setting, i.e., as the quality determining characteristics of the soil are changed negatively establishes a degradation process. The soil degradation process involves the reduction of the potential renewable resources by a combination of processes acting on the soil. These may be natural erosion processes, some other soil formation invasion, or a natural plant or animal pests. It can also occur by human activities directly on the ground or indirectly because of adverse climate change induced by man. In Brazil, from the 1950s began the so-called "Green Revolution", due to population growth and the consequent need to increase productivity of food. From this decade there has been a great loss of forests and native fields, which are replaced by areas of pastures and crops, which use chemical fertilizers, pesticides and agricultural mechanization. With the constant use of these techniques, there was soil degradation in several regions, thus reducing the productivity sought. Among the causes that lead to soil degradation include soil erosion, surface compaction, organic matter reduction, porosity, water infiltration and water storage in the soil. In addition, the use of chemical fertilizers and pesticides result in the contamination of surface and subsurface water leading to degradation of water resources and the deposition of large amounts of sediment in rivers (Schwanke, 2013). Prager et al., (2011) reports that soil degradation is not only an ecological problem but also an institutional problem which needs to be addressed from a multidisciplinary perspective. Such a framework should consider environmental conditions, farming practices impacting on soil conservation, different types of actors, policies, institutions and governance structures. Agricultural systems that associate monoculture with inadequate soil preparation equipment result in rapid soil degradation. The same occurs in pastures under an extensive management regime. The use of more rustic forages, such as those of the Brachiaria genus, has alleviated the problem of degradation, but over time, even these forages have not been well developed in these soils, since the consumption of the green mass by the animal, the lack of nutrients, soil acidification, loss of organic matter and soil compaction decrease pasture efficiency. The adoption of soil management systems considered conservationists, such as no-tillage, have been presented as a viable alternative to ensure the sustainability of agricultural land use. The selection of the species to be used in the recovery of degraded areas is fundamental to obtain positive results. In the initial stages of restoration, the primary objective is the rehabilitation of ecosystem function and services. This means that it is often impossible to rehabilitate the original structure of an ecosystem at an early stage, and the mitigation of impacting agents is urgently required through immediate soil cover (Rovedder & Eltz, 2008). With the improvement in soil quality, the productivity of the pastures increases and it is possible to intensify their use with a higher rate of animal stocking (Lugão et al., 2003). On the other hand, a better-quality pasture allows to intensify its use with a higher stocking rate, which entails the physical quality of the superficial layer of the soil. In rural areas, soil degradation occurs mainly through deforestation or unsustainable cropping, irrigation or grazing practices, which, in turn, stems from the socioeconomic conditions in which the people live, possibly altering the physical and chemicals parameters of the system (Imeson, 2012). The chemical degradation of the soil results in the decrease of its fertility caused by the reduction of the contents and the quality of the organic matter and the reduction of the levels of macro and micronutrients (Bonini et al., 2015). Commonly, there is an increase in manganese and aluminum levels due to the reduction of pH and these parameters are important indicators of soil quality. In recent years the public and scientific concern about soil degradation in Brazil by monitoring physical, chemical, biological parameters and soil nanoparticles as indicators of quality has been growing continuously (Bonini et al., 2015; Costa et al., 2014; Monreal et al., 2016). Therefore, the objective of this paper was to evaluate the physical and chemical parameters of an Ultisols cultivated with pasture at different stages of degradation, in the region of the State of São Paulo in Brazil.

MATERIALS AND METHODS

The study was conducted in an area in Quintana city, State of São Paulo (latitude 22º04'21" south and a longitude 50º18'27" west, altitude 595 meters). The mean annual rainfall in the region is 1,225 mm, temperature 26°C and relative humidity between 70 and 80%. The soil was an Ultisols, according to the soil taxonomy (Soil Survey Staff, 2010), Acrisols (WRB, 2006), or Argissolo Red Yellow medium to sandy texture in the Brazilian Soil Classification System (EMBRAPA, 2013). The study area is cultivated with Brachiaria brizantha cv BRS Piatã grass since 1997 with the following management, every two years peanuts (Arachis hypogaea L.) is cultivated in a conventional system (plowing and harvesting) and liming with limestone Dolomite, in order to raise base saturation to 70% and also to supply calcium and magnesium. The mineral fertilization was not carried out, the nutrients supplied the plants come from the cultural remains. This cultivation of a Fabaceae family crop every two years in an area cultivated with grass belonging to the Poaceae family, benefits the soil by having different root systems. The Poaceae, in turn, adapts easily to the different edaphoclimatic conditions, becoming fundamental in the revitalization of the soil, protection and recovery of these areas. In addition, the Fabaceae family is endowed with great environmental and economic potential due to its ability to fix nitrogen and, in intercropping pastures, supply this nutrient to the grasses to which they are associated, maintaining pasture productivity and providing sustainability of the production systems to a reduced cost, offering less damage to the environment (Werner et al., 2001). The grazing method used is the continuous stocking rate and variable stocking rate, using Nelore cows. The experimental method was completely randomized with 3 treatments and 10 replicates in three types of areas: (a) Degraded area, with presence of gullies; (b) Pasture cultived area and (c) Area degradation beginning. In all areas, the same management (soil correction, animal stocking, soil preparation) was carried out, in which soil correction was carried out at the time of soil preparation for peanut planting. In May 2017, the following soil physical properties were assessed: soil bulk density (SBD) by the volumetric ring method; total porosity by measuring soil saturation (total volume of water-filled soil pores); macroporosity (MA) using the tension table and a water column of 6 kPa and microporosity (MI) which was calculated from the difference between soil total porosity (SPT) and microporosity. All evaluations were performed according to methodologies described by Donagema et al. (2011). Soil Penetration Resistance (SPR) was determined by a penetrolog FALKER and soil moisture on a mass basis (Donagema et al., 2011). For the analysis, according to their specific characteristics, disturbed and non-disturbed soil samples were collected from two depths: 0.00–0.10 and 0.10–0.20 m. The water infiltration rate in the soil was determined with Mini Disk infiltrator, according to Zhang (1997). Chemical analysis of soil was performed before implantation of the experiment and after 361 days. According to the methodology described by Raij et al. (2001) were evaluated the levels of phosphorus (P) by the extraction method with ion exchange resin. The content of organic matter (OM) was determined by colorimetric method and pH in calcium chloride was calculated the amounts of base saturation (BS%). The data were analyzed by analysis of variance and Tukey test to compare the means at 5% of significance, using the SIVAR computer program (Ferreira, 2011).

RESULTS AND DISCUSSION

The data of mechanical resistance to root penetration and soil water content are presented in Figure 1 (a) and (b). For penetration resistance, the data found are below 2.0 MPa which is the limit proposed by Canarache (1990) for the plant not to suffer losses in its development and productivity. The data obtained in this work differ from those reported by Bonini & Alves (2012) in degraded areas cultivated with Brachiaria and treated with limestone, gypsum and green manures, where values higher than those recommended by Canarache (1990) were obtained. In the integrated systems of production, which are known as soil conservation systems, values similar to the present one were found, noting that the use of grasses favors a recovery of soil quality, mainly in the superficial layer (0.00-0.10m). The soil water content in the three studied areas was similar and is in agreement with the results described by De Gennaro et al. (2014), who reported different types of soil management and verified that soil water content did not interfere in the soil mechanical resistance to penetration. Soil water content interferes with soil adhesion and cohesion forces, so very humid soil underestimates penetration resistance and very dry soil overestimates this property. It is recommended to determine resistance in the field when the soil has water near its field capacity (Bonini & Alves, 2012). Table 1 shows the data obtained in relation to soil porosity (macro, micro and total) and soil density. Only the macroporosity in the 0.00-0.10 m layer was significant the Tukey test at 5% probability.

Table 1. Mean values for soil macroporosity (MA), soil microporosity (MI), soil total porosity (STP) and soil bulk density (SBD) for treatments and soil depths studied. Quintana - SP - Brazil. 2016

Treatments	MA	MI	STP	SBD
	$m^3 . m^{-3}$			$g\ dm^{-3}$
			0-0.10 m	
degraded area	9.45 b	24.31	33.76	1.58
cultivated pasture	15.93 a	27.60	43.53	1.48
area beginning degradation	10.37 b	25.98	36.35	1.58
F(5%)	83.968*	52.206^{NS}	3.682^{NS}	4.253^{NS}
VC (%)	5.56	4.70	5.51	3.15
			0.10-0.20 m	
degraded area	9.34	22.42	31.76	1.60
cultivated pasture	16.03	20.93	36.96	1.50
area beginning degradation	12.28	23.17	35.45	1.62
F(5%)	5.613^{NS}	0.661^{NS}	1.499^{NS}	2.536^{NS}
VC (%)	19.52	10.96	6.67	4.34

Mean values followed by the same letter do not differ statistically at the 5% level according to the Tukey test. *;- Significant at 5% probability. ^{NS} - not significant.

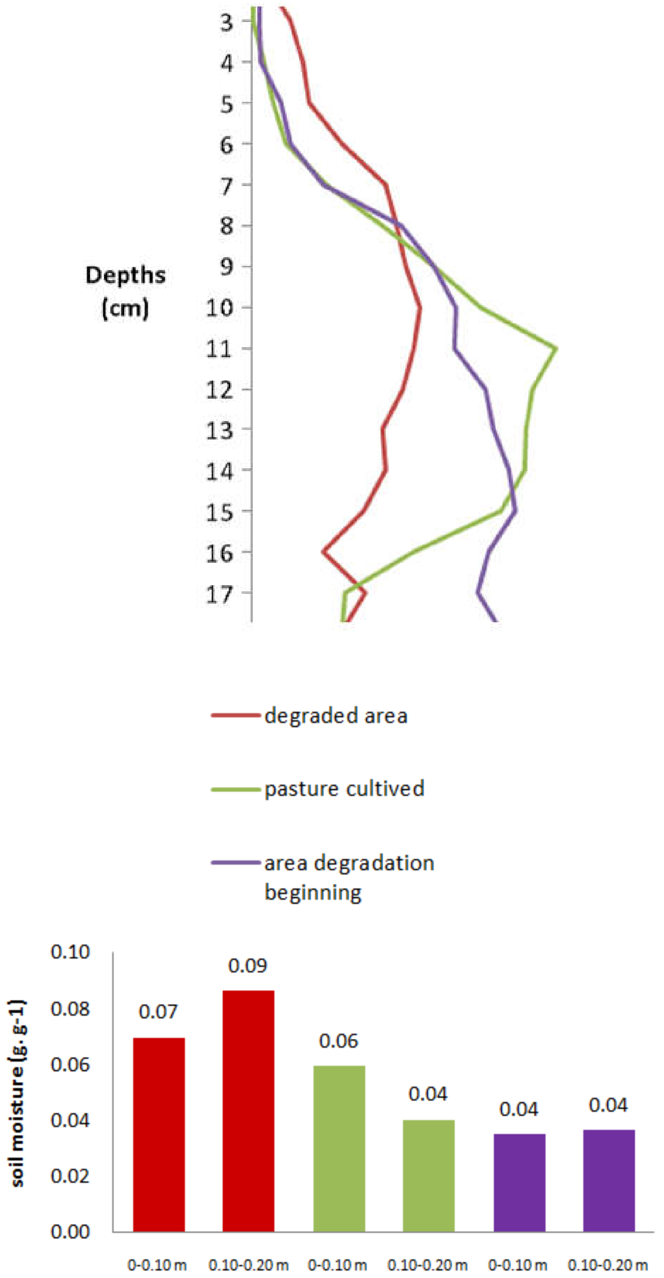
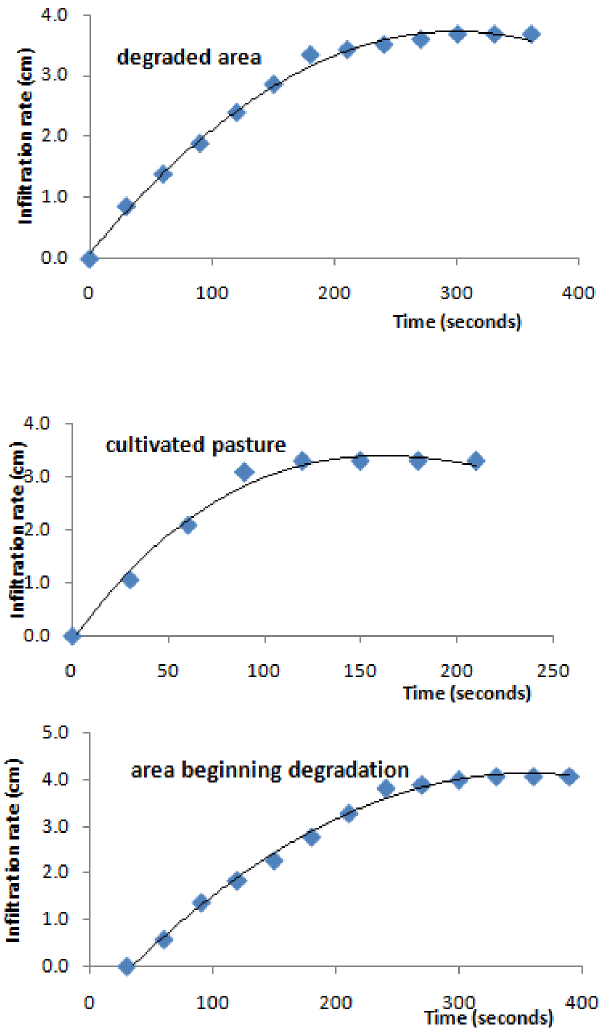


Figure 1. (a) Soil penetration Resistence (MPa); (b) Soil Moisture ($g\ g^{-1}$)

According to Bauer et al. (2012), macroporosity values should be above 0.10 m3 m-3, which occurred in the cultivated pasture area, showing that the physical characteristics are conserved. For the area of degraded soil, a value lower than 0.10 m3 m-3 was obtained and for the area at the beginning of degradation the value was very close to the ideal one. Bonini et al. (2015) reported that the use of soil conservation techniques results in soil macroporosity greater than the limit recommended by the literature. Soil management modifies macroporosity and soil density, which does not occur with microporosity. The total porosity is also not used as an indicator of quality, because the distribution of pore size is important to know the proper management. In this work, it is noticed that the porosity and the soil density are reflections of the results of the macroporosity, therefore, it is noticed that the cultivated soil has the greater macroporosity and total porosity of the soil and lower density of the soil. The infiltration of water in the soil is presented in the graphs of Figure 2. It is observed that the water infiltration time in degraded areas is higher (Fig. 2 (a) and (c)).

It was verified that in the area of cultivated pasture there is a higher rate of infiltration of water in the soil (Fig. 2 (b)) and the degraded areas the values were smaller and similar. Brandão et al. (2012) reported that soils with sandy texture have an average infiltration value that can range from 38.1 to 111.8 mm/h. This range is too long and can lead to conflicts in the results. Therefore, what can be affirmed is that the higher the rate of water infiltration in the soil, the less chance of this area to suffer erosion due to mass displacement. According to Klein (2014), the adopted management systems also interfere in the infiltration rate in the soil. Table 2 shows the Pearson correlations for the physical (MA, MI, SBD, SPR, IR) and chemical (P, OM and BS%) parameters. The parameters that resulted in better adjustments in the 0.00-0.10 m layer were: organic matter with macroporosity; soil penetration resistance to with microporosity; base saturation with soil bulk density, organic matter and phosphorus. In the 0.10-0.20 m layer: base saturation with macroporosity; soil bulk density with soil penetration resistance, phosphorus and organic matter; soil penetration resistance with phosphorus and organic matter; organic matter with phosphorus. These positive correlations suggest behavior of the cerrado soils, agreeing with Bonini & Alves (2012), who described some characteristics of this type of soil, such as: pH, phosphorus and organic matter at low



	Water infiltration rate in soil (mm/h)
(a)	64.99 b
(b)	100.21 a
(c)	64.12 b

Figure 2. Infiltration rate and water infiltration rate in soil for the treatments studied: (a) degraded area; (b) cultivated pasture (c) area beginning degradation

Table 2. Pearson correlation for the physical (MA, MI, SBD, SPR, IR) and chemical (P, OM and BS%) parameters, in the treatments and soil layers studied. Quintana - SP - Brazil. 2016

	MA	MI	SBD	SPR	IR	P	OM
			0.00-0.10 m				
MA	-						
MI	-0.93	-					
SBD	-0.13	-0.25	-				
SPR	-0.95	0.76	0.43	-			
IR	0.26	0.12	-0.99	-0.55	-		
P	0.86	-0.99	0.39	-0.66	-0.26	-	
OM	0.96	-1.00	0.16	-0.82	-0.02	0.97	-
BS%	-0.41	0.04	0.96	0.67	-0.99	0.11	-0.13
			0.10-0.20 m				
MA	-						
MI	0.16	-					
SBD	-0.43	-0.96	-				
RP	-0.21	-1.00	0.97	-			
IR	-1.00	-0.10	0.37	0.14	-		
P	0.28	-0.90	0.74	0.88	-0.35	-	
OM	-0.04	-0.99	0.92	0.99	-0.02	0.94	-
BS%	0.98	0.36	-0.60	-0.39	-0.97	0.09	-0.24

Table 3. Mean values for phosphorus (P), organic matter (OM) and base saturation (BS%) for treatments and soil depths studied. Quintana - SP - Brazil. 2016

Treatments	P	OM	pH	BS
	(mg dm^{-3})	(g dm^{-3})		(%)
	0.00-0.10 m			
degraded area	2	8	5.0	57
cultivated pasture	4	9	4.7	43
area degradation beginning	9	10	5.3	55
	0.10-0.20 m			
degraded area	2	8	4.9	59
cultivated pasture	3	9	4.7	43
area degradation beginning	7	10	5.1	55

levels, resulting in a fragile soil. Soils with this characteristic must be specially treated so as not to evolve into irreversible degradation. The macroporosity of the soil had a positive correlation with the organic matter and this behavior is explained by the fact that the greater the quantity of organic matter, the greater will be the supply of ions that will be the cementing agents of the soil, with this greater the structuring and formation of Macropores in soil. The positive correlation between organic matter and phosphorus results from the process of mineralization of organic matter, one of the main ways of providing this nutrient to crops. The chemical parameters of the soil are shown in Table 3. According to Raij (2001), the average phosphorus content should range from 13 to 30 mg dm-3; the organic matter content from 16 to 30 g dm-3 and the pH should be around 5.5. Table 3 shows that pH corresponds to that described, although the values of phosphorus and organic matter are lower than the recommended values. The correlation of the phosphorus with the organic matter was consistent in the two layers of soil studied, showing that the low phosphorus levels are reflections of the low organic matter content in the soil. These evaluations show that to recover the soil chemically in tropical areas, a greater contribution of plant cover is required.

Conclusion

The attributes macroporosity and infiltration of water in the soil were good indicators of the physical quality, as opposed to the soil bulk density. For the chemical parameters, the characterization did not detect changes in the studied areas. There was good correlation between the physical and chemical parameters studied, the best correlations occurred between soil density/base saturation and macroporosity/organic matter. These relationships observed in the research allow us to conclude that proper soil management is essential to maintain its physical and chemical quality, since corrective actions for degraded areas with the soil characteristics of this region are practically unfeasible to present a high cost. On the other hand, the recovery of degraded areas is less costly, since they require less investment in the recovery and can also be used during the recovery process, if a controlled use is made. Considering the areas of pasture with soil in good condition, it was possible to observe that the producer seeks to correct the soil periodically and rotates the pastures in a systemic way to ensure that the area remains in good conditions of use.

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