Recebido em: 17/03/2016. Aceito em: 26/08/2016

Revista
Ciência, Tecnologia & Ambiente

How the change of land use affects soil attribute?

Raquel Stucchi Boschi[1]*, Laura Fernanda Simões da Silva[1], Maria Leonor R.C. Lopes-Assad[2], Miguel Cooper[1]

[1]University of São Paulo/ESALQ – Dept. of Soil Science, C.P. 09 – 13418- 900 – Piracicaba, SP – Brazil.
[2]Center of Agricultural Sciences, Federal University of São Carlos, Rodovia Anhanguera, Km 174, Araras, São Paulo, Brazil.
*Corresponding author: raboschi@gmail.com

RESUMO

O futuro do Bioma Amazônia depende da capacidade dos seus ecossistemas de suportar as perturbações causadas pelo uso da terra e pelas mudanças climáticas. A compreensão de como solos se comportam sob diferentes usos é essencial para a adoção de sistemas alternativos para uma agricultura sustentável. O objetivo deste estudo foi compreender quais atributos do solo são mais afetados pela mudança do uso de floresta (F) para pastagem (P). Os dados de solo foram obtidos a partir da caracterização detalhada de duas topossequências na Amazônia Oriental. A área de estudo está localizada em Nova Ipixuna (Pará, Brasil), uma região com uma concentração de assentamentos agroextrativistas. Os atributos avaliados foram: tipo de estrutura do solo, teor de matéria orgânica (OM), granulometria, densidade do solo (Bd), capacidade de troca catiônica (CEC), pH e porosidade. A análise dos dados permitiu compreender os principais atributos responsáveis pela diferenciação de um solo sob P de um sob F. O tipo de estrutura, pH, mesoporosidade, CEC e a Bd foram os principais atributos afetados pela mudança do uso da terra. Os atributos do solo que diferenciam F de P podem ser considerados como os mais afetados pelas mudanças de uso do solo, confirmando a hipótese da pesquisa. O conhecimento adquirido pode auxiliar na definição de sistemas de produção sustentáveis em áreas de agricultura familiar.

Palavras-chave: degradação do solo, floresta, pastagem, sistema agroextrativista, Amazônia

ABSTRACT

The future of the Amazon Biome depends on the ability of its ecosystems to withstand the perturbations caused by land use and climatic changes. The understanding of how soils functions under different uses is essential to the adoption of alternative systems for a sustainable agricultural. The objective of this study was to comprehend the soil attributes which are most affected by the change of use from forest (F) to pasture (P). The soil data were acquired from the detailed characterization of two toposequences in Eastern Amazonia. The study area is located in Nova Ipixuna (Pará, Brazil) a region with a concentration of agroextractivist settlements. The evaluated attribute were: soil structure type, organic matter content (OM), particle size distribution, bulk density (Bd), cation exchange capacity (CEC), pH and porosity. The exploratory analysis allowed us to better understand the main attributes responsible for the differentiation of soil under P from one under F. The structure type, pH, mesoporosity, CEC and the Bd were the main attributes affected for the land use differentiation. The soil attributes which differentiate forest from pasture can be considered as those most affected by land use changes, confirming the hypothesis of the research. The knowledge acquired may assist in the definition of sustainable production systems in areas of family agriculture.

Keywords: Soil degradation, forest, pasture, agroextractivist systems, Amazonia

INTRODUCTION

The introduction of pastures in the Amazon Biome has been identified as the main responsible cause of large-scale deforestation and severe damages to the landscape (Ferraz et al., 2005, Grimaldi et al., 2014). Many studies have been carried out to evaluate the impacts of changes in land use in the Brazilian Amazon. (Maia et al., 2009, Carvalho et al., 2010, Zimmermann et al., 2010).

Soil structure is a dynamic soil property, responsive to a large number of environmental, anthropic and biological variables and can be significantly modified through management practices (Bronick and Lal., 2005). This property has a large influence on the soil water dynamic, gas exchange, soil organic matter and mineral nutrient dynamics, soil microbial biomass, diversity and activity, and the susceptibility of the soil to erosion (Bronick and Lal., 2005).

Braz et al. (2013) reported changes in physical attributes of a Typic Hapludox soil as a function of the conversion from forest to pasture, proving that land use change has impacts on the soil. They collected fifteen samples, at 0 to 0.2 m depth, under *Brachiaria* grass (*Brachiaria brizantha* Hochst Stapf. cv. Marandu), which had been established for 8, 13 and 15 years, and from an adjacent forest remnant. They concluded that Bd and Ca^{2+} concentration were increased by land use conversion from forest to pasture, regardless of the period of grazing after conversion. Further, they observed that the forest soil was more acidic than the pasture soils.

A comparison of forest and pasture soils by Moraes et al. (1996) also revealed an increase in bulk density, pH and CEC, especially in Ca^{2+}, when land use was changed from forest to pasture. In this case, the study area was in the state of Rondonia, in the southwestern part of the Brazilian Amazon basin and two chronosequences were examined so that the effects of pasture age could be investigated.

Chauvel et al. (1999) have highlighted two mechanisms responsible for soil compaction due to the conversion of land use from forest to pasture. The first is the direct effects of the machinery used for the conversion and to manage the pasture, and to the continuous soil compaction by the hooves of the grazing animals. The second is linked to the reductions in the abundance and the diversity of the soil macrofauna which result from the conversion. A discussion of the main mechanisms by which soil macrofaunal communities impact on soil structure can be found in Bottinelli et al. (2015).

The objective of this study was to comprehend the soil attributes which are most affected by the change of use from forest to pasture. The soil data were acquired from the detailed characterization of two toposequences in Eastern Amazonia.

MATERIAL AND METHODS

Study area

The study area is located in the Praialta Piranheira Agroextractivist Settlement Project, within the municipality of Nova Ipixuna, State of Pará, Brazil. The area is defined by the geographical coordinates 04º 45' 00" to 04º 58' 11" S and 49º 15' 02" to 49º 25' 21" W. The local climate type is Aw, according to the Köppen’s classification. The average annual precipitation is 1700 mm, with a clearly pronounced dry season extending from June-July to October-November. The average relative humidity is around 80%, the average daytime temperature is around 27 ºC, with minima and maxima of 21 and 32 ºC, respectively.

We selected two toposequences, representative of the predominant soils found in the settlement; one is under forest (F), the other is under pasture (P). The extractive activities occurring within the forest area, F, were the collection of Brazil nuts (*Bertholletia excelsa* Humb. & Bonpl.), andiroba almonds and oil (*Carapa guianensis* Aubl.), native cupuaçu fruit (*Theobroma grandiflorum* Schum.) and açaí berries (*Euterpe oleracea* Mart.).

The pasture area had been left fallow for six years and during this period, it had not been cleared by fire, nor used for periodic grazing. During the first 10 years the area was managed with under-grazing (4 to 8 head of cattle), and every 3 years the area was submitted to burning for pasture renovation and new seeding. Fire was used the last time in 2006, since then remaining fallow with sporadic use of the pasture by neighboring cattle raisers.

The bidimensional geometric distribution of the soils in the two toposequences was performed by Oliveira (2014), according to the methodology proposed by Boulet et al. (1982). The profiles from F were labelled as F1, F2 and F3, from upslope to downslope, those from P as P1, P2 e P3, again from top to bottom (Figure 1).

In profiles F1, F2, F3, P1 and P2, the soils were classified as Argissolo Amarelo distrófico saprolítico argiloso cascalhento (Brazilian System of Soil Classification- SiBCS; Santos et al., 2013). According to international classification systems these soils are classified as Typic Haplustults (Soil Taxonomy, 1999) and Haplic Acrisols (clayic) (IUSS Working Group WRB, 2006). The soil of profile P3 was classified as Argissolo Amarelo distrófico epirredóxico argiloso cascalhento (Brazilian System of Soil Classification – SiBCS; Santos et al., 2013); Typic Haplustults (Soil Taxonomy, 1999); and Haplic Acrisols (clayic) (IUSS Working Group WRB, 2006), due to the occurrence of mottling from redox processes (Oliveira, 2014).

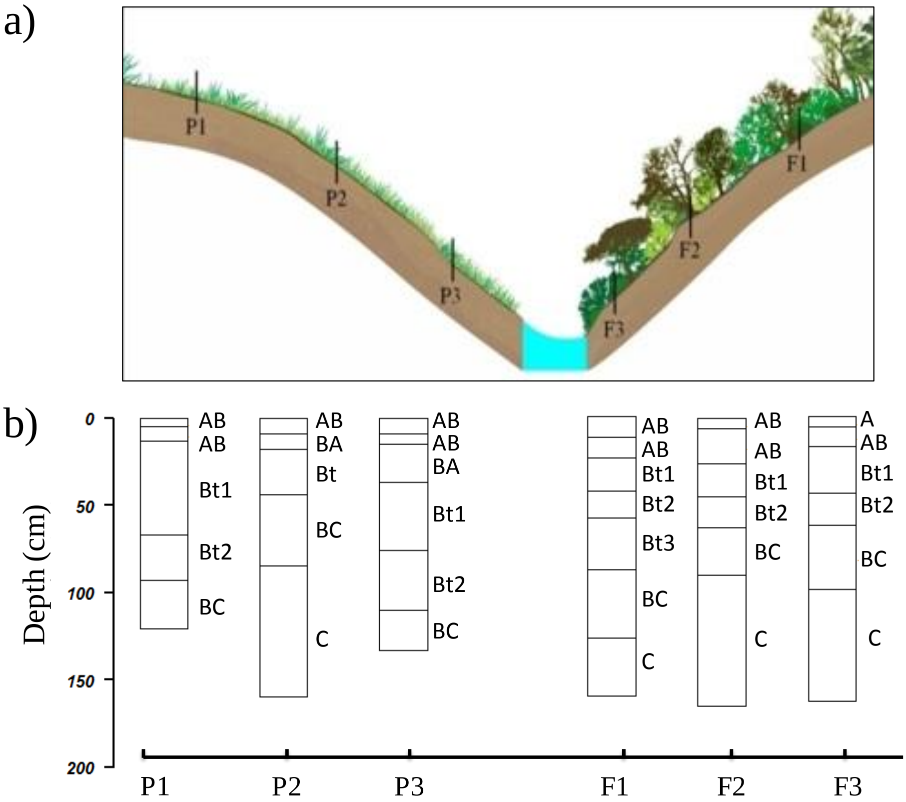

Figure 1. Schematic illustration of the forest and pasture toposequences indicating the location of the analyzed profiles in the Praialta Piranheira Agroextractivist Settlement Project, Nova Ipixuna, Pará State, Brazil (a) (Source: Oliveira, 2014). Horizon sequences in the profiles (b).

Methods to determine the soil attributes

For each horizon of the six profiles, disturbed and undisturbed samples were collected to determine the following attributes: pH (in water); CEC (capacity of exchangeable cations) (EMBRAPA, 1997); organic carbon (OC) (Walkley and Black, 1934); particle size distribution (hydrometer method) (Gee and Or, 2002); bulk density (Bd) by the volumetric ring method (Grossman and Reinsch, 2002); and the pore size distribution (macro, meso and micro porosity) according to the methodology proposed by Libardi (2005). The data set used for comparisons comprised 35 horizons, of which 19 were situated in forest and 16 in pasture (Figure 1).

RESULTS AND DISCUSSION

The evaluation of single and combined attributes allowed understanding which attributes are most affected by land use change. The attributes that presented relevant difference between the uses were: Bd, pH, OM, CEC, total, macro, meso and microporosity (Figure 2).

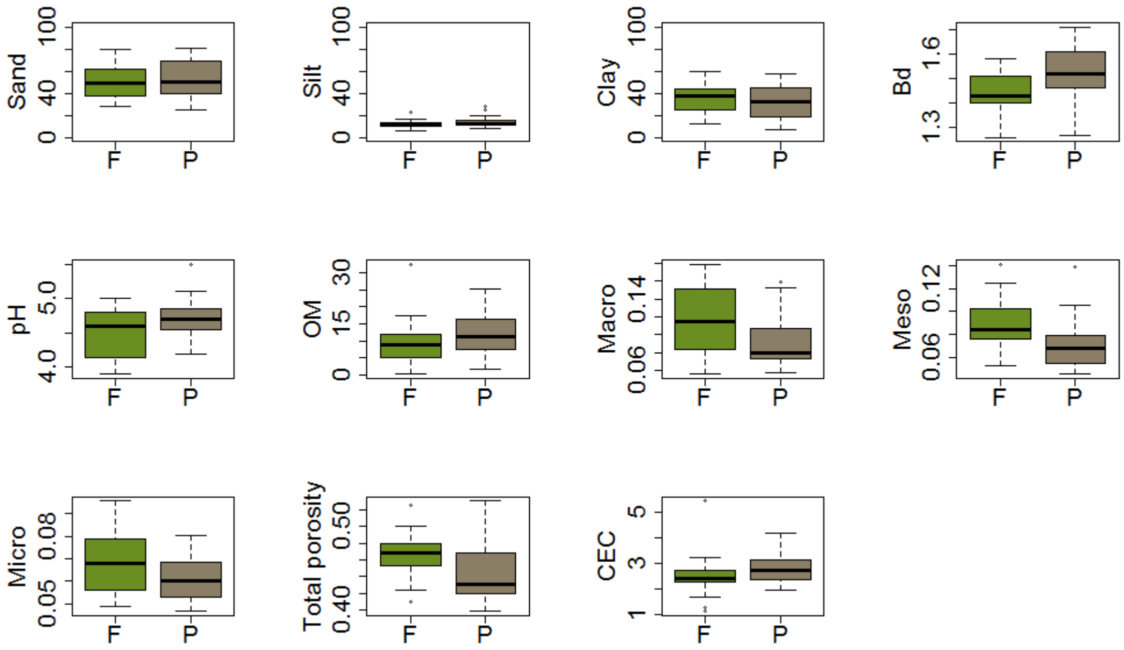

Figure 2. Boxplot of soil attributes.

The values of Bd were lower in F and the distribution was quite different from P. A similar behavior was observed for pH with lows values for F, however, F presented a wider range of values. OM was higher in P, but the highest values was observed in F (>30 kg kg^{-1}). In general, soil porosity was higher in F. Macroporosity present a uniform distribution in F while in P the values were concentrated around 0.07. P presented an extreme value of mesoporosity with most of the values around 0.065. The range of values of microporosity was also higher in F, suggesting a more heterogenic system. CEC was greater in P.

The analysis of combined attributes revealed some patterns (Figures 3 4). The patterns are highlighted in figures and namely as R1, R2 and R3. Values of pH below 4.1 define the R1 area in Figure 4 and characterize F. Higher values of pH in superficial horizons occurred for P (Figure 3, blue circles). The five horizons of F identified by R1 were also shallower horizons (horizons A and AB). Possible explanation is that the increased pH of the superficial soil horizons under pasture is a residual effect of the addition of ashes to the soil during the conversion (by felling and burning) from forest to pasture. Muller et al. (2004) also observed high values of pH for soils under pasture when compared to soils under forest.

Most of F subsurface horizons present pH higher than 4.1 and mesoporosity greater than 0.07 m^{3} m^{-3} (R2, Figure 3). Only six horizons of P, against 12 of F, presented this same condition, being three of them superficial (A). From an analysis of the morphological characterization of these horizons, Oliveira (2014) reported that horizon BC of P2 was permeated by ancient forest root channels and presented biopores filled with decomposing organic matter. For horizons AB and Bt1 of P3, an abundance of fine roots was observed. These specific morphological characteristics account for the higher quantity of mesopores (mesoporosity > 0.07 m^{3} m^{-3}) in these P horizons.

Bulk density > 1.58 g cm^{-3} occurred just for P (Figure 4). Whereas values of CEC ≤ 2.3 cmol$_{c}$ kg^{-1} and Bd ≤ 1.58 g cm^{-3} characterize F (Figure 4). There have been other studies comparing soil attributes under pasture and adjacent forests remnants which point to the importance of Bd and CEC (Braz et al., 2013; Moraes et al., 1996).

We also could see that structure type was an important attribute in differentiating P and F (Figure 4 and Figure 5). For both uses, superficial horizons presented a granular structure (gr). Nonetheless, F presented a more homogeneous structure type across the horizons. The dominant structure type was subangular blocks (bs) for F (around 57% of horizons) while angular blocks (ba) and prismatic (pr) types appear just for P (Figure 5). Of the attributes used to verify the alteration in soils due to land use change, granulometry, Bd, CEC, structure type and pH can be easily determined in routine studies of soils. The mesoporosity requires the determination of the water retention curve from undisturbed soil samples, which is a demanding task.

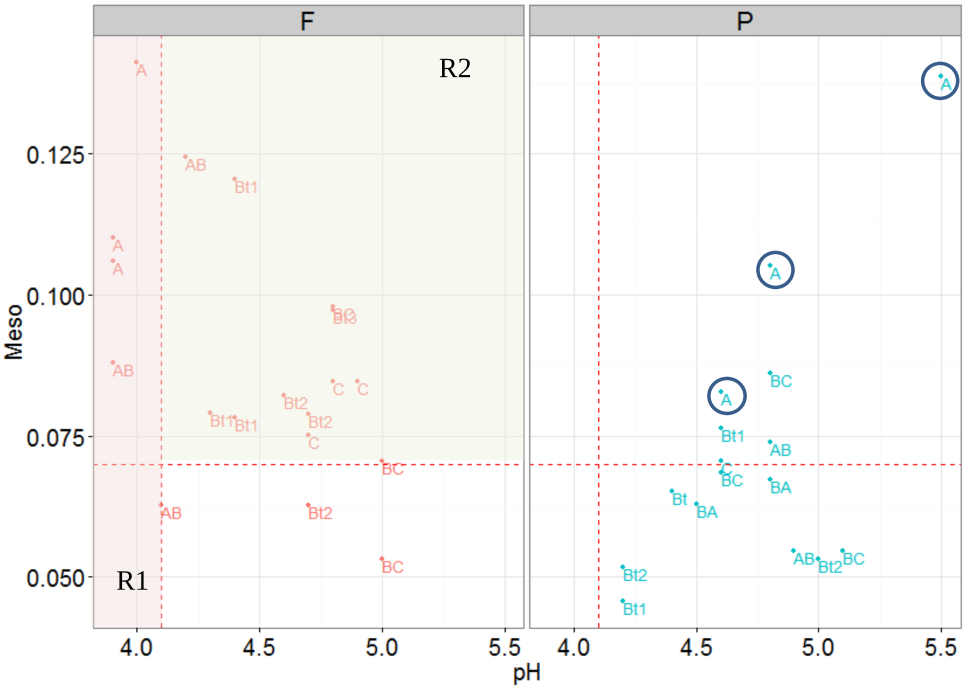

Figure 3. Mesoporosity (Meso) versus pH. R1: region 1; R2: region 2.

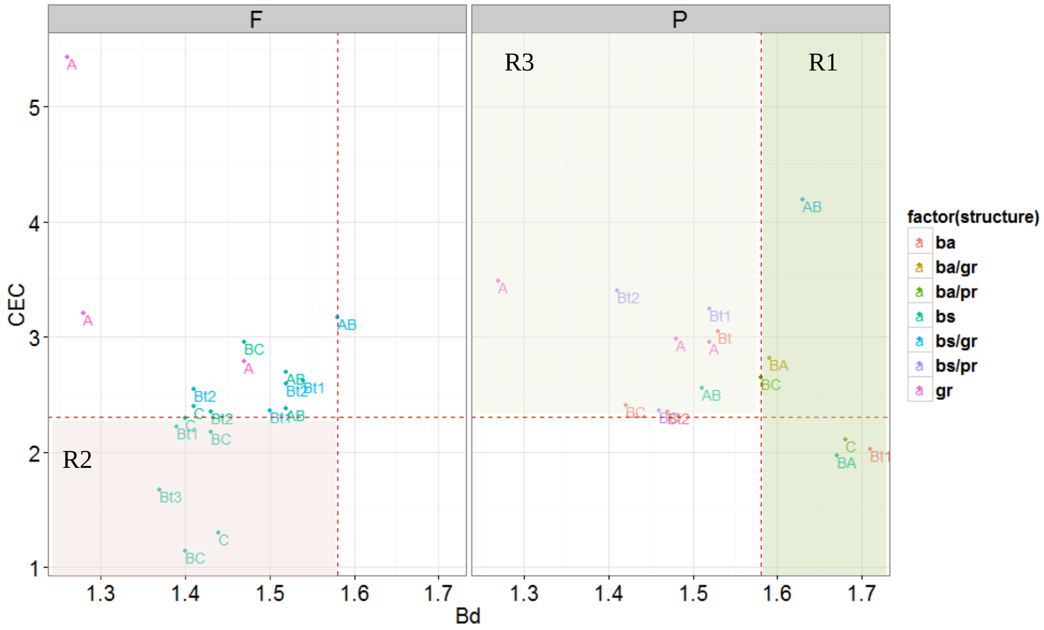

Figure 4. Cation exchange capacity (CEC) versus bulk density (Bd). The color represent type of structure. granular structure (gr); subangular blocks (bs); angular blocks (ba); prismatic (pr). R1: region 1; R2: region 2; R3: region 3.

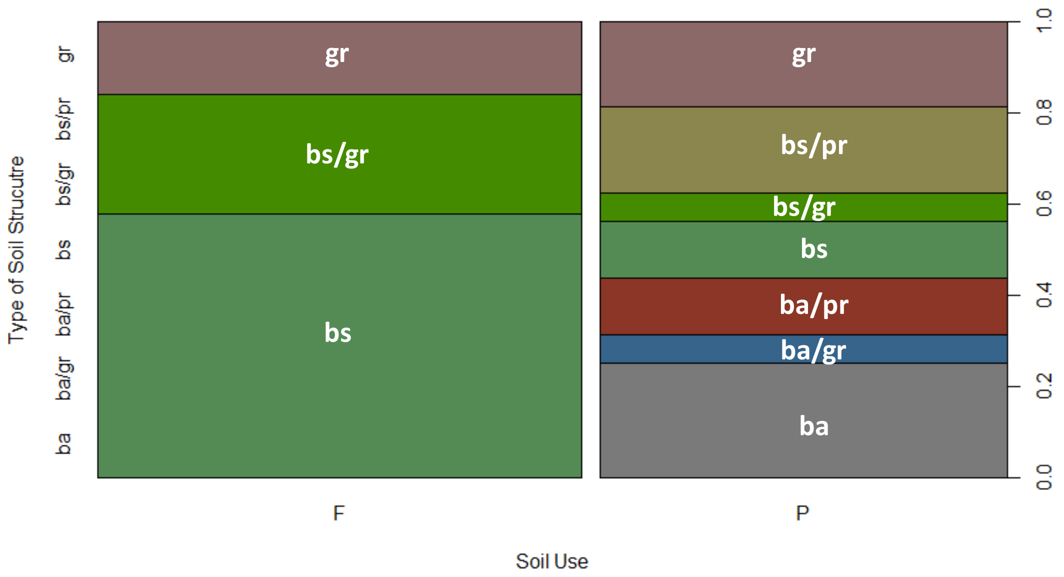

Figure 5. Proportion of soil horizon in each soil use (F, Forest; P, pasture). granular structure (gr); subangular blocks (bs); angular blocks (ba); prismatic (pr).

The analysis of combining attributes allowed us to identify which soil attributes from a set of 11 are the most affected by converting forest to pasture. Of the six studied profiles, five present the same soil classification, so that from a pedological standpoint they could be considered equal. Profile P6 (Argissolo Amarelo distrófico epirredóxico argiloso cascalhento) differed from the other five only at the fourth categorization level of the Brazilian Soil Classification System (Santos et al., 2013). Consequently, the soil attributes which differentiate forest from pasture can be considered as those most affected by land use changes. In this study, the main attributes affected by land use conversion from forest to pasture were pH, structure type, mesoporosity, CEC and Bd. Similar results were obtained by Müller et al. (2004) and Braz et al. (2013). They observed that changing soil use from forest to pasture changed pH and Bd.

The study of patterns in data can assist in the definition of which soil attributes to sample to detect the impacts, positive or negative, arising from changes in land use. Additionally, the analysis allowed the understanding of which soil attributes were affected by land use and the interaction that may exist between them.

Given the dynamics adopted by the farmers in substituting forest by pastures and the increasing pressure of diverse segments of society in favor of the adoption of sustainable production systems in Amazonia, it is extremely important to understanding of which soil attributes were affected by land use and the interaction that may exist between them.

CONCLUSIONS

In this study, pH, structure type, mesoporosity, CEC and bulk density were the most important attributes of the differentiation of soils under pasture from soils under forest by combining attributes.

The soil attributes which differentiate forest from pasture can be considered as those most affected by land use changes, confirming the hypothesis of the research.

ACKNOWLEDGEMENTS

To FAPESP for the financing of this project, through grant 2012/14767-9. To CNPq for financial support. To Agrisus for financial support of the trips to the field site.

REFERENCES

BOTTINELLI, N., JOUQUET, P., CAPOWIEZ, Y., PODWOJEWSKI, P., GRIMALDI, M. and PENG, X., 2015. Why is the influence of soil macrofauna on soil structure only considered by soil ecologists? *Soil and Tillage Research*, vol. 146, pp. 118–124. http://dx.doi.10.1016/j.still.2014.01.007.

BOULET, R., HUMBEL, F.X. AND LUCAS, Y., 1982. *Analyse structurale et cartographie en pédologie:* II. Une méthode d'analyse prenant en compte l'organisation tridimensionnelle des couvertures pédologiques. Cahier ORSTOM, série Pedologie, vol. XIX, no. 4, pp. 323-339.

BRAZ, A.M. DE S., FERNANDES, A.R. and ALLEONI, L.R.F., 2013. Soil Attributes After The Conversion From

Forest To Pasture In Amazon. *Land Degradation & Development*, vol. 24, pp. 33–38. http://dx.doi.10.1002/ldr.1100.

BRONICK, C.J. and LAL, R., 2005. Soil structure and management: a review. *Geoderma*, vol. 124, pp. 3 –22. doi:10.1016/j.geoderma.2004.03.005.

CARVALHO, J.L.N., CERRI, C.E.P., CERRI, C.C., FEIGL, B.J., PICCOLO, M.C., GODINHO, V.P. and HERPIN, U., 2007. Changes of chemical properties in an oxisol after clearing of native Cerrado vegetation for agricultural use in Vilhena, Rondonia State, Brazil. *Soil and Tillage Research*, vol. 96, pp. 95–102. http://dx.doi.10.1016/j.still.2007.04.001.

CHAUVEL, A., GRIMALDI, M., BARROS, E., BLANCHART, E., DESJARDINS, T., SARRAZIN, M. and LAVELLE, P., 1999. Pasture damage by an Amazonian earthworm. *Nature*, v. 398, pp. 32–33. http://dx.doi.10.1038/17946.

EMBRAPA., 1997. *Manual de métodos de análise de solo*. 2. ed. Rio de Janeiro: Serviço Nacional de Levantamento e Conservação de Solos. 212 p.

FERRAZ, S.F. DE B., VETTORAZZI, C.A., THEOBALD, D.M. and BALLESTER, M.V.R., 2005. Landscape dynamics of Amazonian deforestation between 1984 and 2002 in central Rondônia, Brazil: assessment and future scenarios. *Forest Ecology Management*, vol. 204, pp. 69–85. http://dx.doi.10.1016/j.foreco.2004.07.073.

GEE, G. and OR, D., 2002 Particle-size analysis. In: DANE, J.H.; TOPP, C., orgs. *Methods of soil analysis*: *Physical methods*. Madison: SSSA, pp. 255-293.

GRIMALDI, M., OSZWALD, J., DOLEDEC, S., HURTADO, M.D.P, MIRANDA, I.S., SARTRE, X.A., ASSIS, W.S., CASTANEDA, E., DESJARDINS, T., DUBES, F., GUEVARA, E., GOND, V., LIMA, T.T.S., MARICHAL, R., MICHELOTTI, F., MITJA, D., NORONHA, N.C., OLIVEIRA, M.N.D, RAMIREZ, B., RODRIGUEZ, G., SARRAZIN, M., JUNIOR, M.L.S., COSTA, L.G.S., SOUZA, S.L., VELASQUEZ, E. and LAVELLE, P., 2014. Ecosystem services of regulation and support in Amazonian pioneer fronts: Searching for landscape drivers. *Landscape Ecology*, vol. 29, pp. 311–328. http://dx.doi.10.1007/s10980-013-9981-y.

GROSSMAN, R.B. and REINSCH, T.G., 2002. Bulk density and linear extensibility. In: DICK, W.A. (Ed.) *Methods of soil analysis: Physical methods*. Madison: SSSA, p.201-228.

IUSS WORKING GROUP WRB, 2006. *World Reference Base for Soil Resources 2006*. World Soil Resources Reports No. 103. (FAO: Rome).

LIBARDI, P.L., 2005. *Dinâmica da água no solo*. São Paulo: Editora da Universidade de São Paulo. 335p.

MAIA, S.M.F., OGLE, S.M., CERRI, C.E.P. and CERRI, C.C., 2009. Effect of grassland management on soil carbon sequestration in Rondônia and Mato Grosso states, Brazil. *Geoderma*, vol. 149, pp. 84–91. http://dx.doi.10.1016/j.geoderma.2008.11.023.

MORAES, J.F.L. DE, VOLKOFF, B., CERRI, C.C. and BERNOUX, M., 1996. Soil properties under Amazon forest and changes due to pasture installation in Rondonia, Brazil. *Geoderma*, vol. 70, pp. 63–81. http://dx.doi.10.1016/0016-7061(95)00072-0.

MÜLLER, M.M.., GUIMARÃES, M.., DESJARDINS, T. and MITJA, D., 2004. The relationship between pasture degradation and soil properties in the Brazilian amazon: a case study. *Agriculture, Ecosystems & Environment*, vol. 103, pp. 279–288. http://dx.doi.10.1016/j.agee.2003.12.003.

OLIVEIRA, M.N.D., 2014. *Funcionamento físico-hídrico do solo em duas topossequências sob floresta e pastagem em sistema agroextrativista na Amazônia Oriental*. Piracicaba: Universidade de São Paulo (Esalq). 169p. Tese de Doutorado em Ciências do Solo e Nutrição de Plantas.

SANTOS, H.G., JACOMINE, P.K.T., ANJOS, L.H.C., OLIVEIRA, V.A., LUMBRERAS, J.F., COELHO, M.R., ALMEIDA, J.A., CUNHA, T.J.F. and OLIVEIRA, J.B., 2013. *Sistema Brasileiro de Classificação de Solos*. 3ed. Embrapa. Brasília, DF, Brazil.

SOIL SURVEY STAFF., 1999. *Soil Taxonomy:* a basic system of soil classification for making and interpreting soil surveys. 2nd edition. Washington: USDA. 886 p. Agriculture Handbook No. 436.

WALKLEY, A., and BLACK, I. A., 1934. An examination of Degtjareff method for determining organic carbon in soils: Effect of variation in digestion condition and inorganic soil constituents. *Soil Science*, vol. 37, pp. 29-38.

ZIMMERMANN, B., PAPRITZ, A. and ELSENBEER, H., 2010. Asymmetric response to disturbance and recovery: Changes of soil permeability under forest–pasture–forest transitions. *Geoderma*, vol. 159, pp. 209–215. http://dx.doi.10.1016/j.geoderma.2010.07.013.