**Original Research Article**

# Granulometry and stability of aggregates in different land uses in the Santa Catarina Plateau of Southern, Brazil

**Abstract:** The aim of the present work was to determine the granulometry and stability of aggregates in different types of land use in the Santa Catarina Plateau of southern, Brazil. The research was conducted on Capão Alto, Santa Catarina, Brazil. The land use types selected were natural forest (NF), stand pinus (PP), crop-livestock integration (CLI), and burned natural rangeland (BR). The definition of the collection points in the field was performed by means of a random sample survey, with nine sampling points by type of use. The stability of aggregates in water, expressed by the mean geometric diameter of aggregates (MGD), was performed after separation of the larger aggregates in smaller aggregates by a set of sieves with 8 and 4.76 mm. Subsequently, these aggregates were fractionated by means of a set of sieves of 4.76; 2.00; 1.00; and 0.25 mm by means of shaking submerged in water. The levels of sand, silt and clay presented differences between the types of land use. MGD ranges from 4.43 to 5.70 mm in NF; from 4.06 to 5.81 mm in PP; from 3.00 to 5,45 mm in CLI; e 4.35 to 5.57 mm in BR. In general, the results showed that MGD varied little in the different types of use, and in all treatments there was a trend of decreasing soil MGD with increasing depth.

**Key words:** Soil quality; Forest; Pinus; Crop-livestock integration; Burned natural rangeland.

## 1. Introduction

The degradation of the physical properties of the soil is one of the main processes responsible for the loss of its quality [1]. Soil cultivation changes its properties, especially when compared to the natural condition of fields or forests. Such changes are more pronounced in systems with intensive preparation, which are manifested in the stability of the aggregates, influencing the infiltration of water, soil erosion and plant development [2]. The stability of aggregates depends, mainly, of soil texture, of its mineralogy, the content and type of organic matter and the soil moisture [3].

The texture of the soil, that is, the distribution of the size of the solid particles, comprising the fractions sand, silt and clay, is an intrinsic property of the soil, dependent on the characteristics of the originating material and the natural agents of formation [4]. Of the many factors that affect soil water retention and its availability to plants, the main one is the granulometry, because it determines the proportions of pores in different sizes. As for erosion, the coarse sand and the clay are the fractions that offer greater resistance. By virtue of its diameter, the sands have a larger mass, which hinders the action of water, while the clays, due to its cohesion, especially when combined organic matter form stable aggregates, which also offer resistance to water action [5].

The soil structure is one of the most important attributes from the agricultural point of view, because it is related to the availability of air and water to the roots of plants, with the supply of nutrients, with the resistance to mechanical penetration of the soil, and with the development of the root system. Because of that, the maintenance of a good state of aggregation and stability, and consequently, of a good structure, is an essential condition to guarantee high productivities [6].

The study of changes in soil structure and aggregation, induced by its use, assumes relevant importance in forecasting these changes, with the purpose of subsidizing the adoption of a management system, which aims to maintain or recover its agricultural and productive potential [7]. In this context, the stability of aggregates can be used to evaluate the effects of different uses and management on soil quality [8]. This quality indicator refers to the arrangement of solid particles in the formation of aggregates. A soil is considered to be of good structural quality when well aggregated, because it is a primary factor to improve soil permeability to water, causing better conditions for aeration and penetration of the roots and, as a consequence, increase in agricultural productivity [6].

Soil and crop management, including species with different root systems, has great influence on the stability of soil aggregates. The effects of plants can be direct or indirect, mainly by the action of protection of the superficial aggregates. In the present study, the presence of organic matter on the surface or in the soil by the action of the root system [9]. In view of the above, the objective of the present work was to determine the granulometry and stability of aggregates under different types of land use in the Santa Catarina Plateau of southern Brazil.



## 2. Materials and methods

The experiment was carried out in a rural property in the municipality of Capão Alto, SC, located between 27º 55 ' to 27º 57' S and of 50º 25' to 50º 29' W. The local climate, according to the climatic classification of Köppen, is mesothermal humid subtropical (Cfb), presenting average temperature of 14 ºC and average altitude of approximately 1,022 m [10]. The predominant soil type is a Nitossolo Bruno [11].

The work consisted in the evaluation of four types of land use: a) Natural forest (NF), classified as mixed ombrophilous forest; b) *Pinus taeda* stands on first cycle of cultivation (PP), that was 8 to 10 years old. Previously these lands were occupied by natural field pasture and cattle; c) Crop-livestock integration (CLI). These lands were cultivated for 10 years under conventional tillage. For 8 years the annual cultivation has been carried out under direct sowing, without the stirring of the soil, with corn / soybean succession in spring-summer and under grazing with oats and ryegrass in autumn-winter; d) Burned natural rangeland (BR), in traditional extensive form for more than 70 years. The land is burnt and then grazed with cattle. With this type of use, the field is burned every two years.

The collections occurred between September 2012 and April 2013. The definition of the field collection points was done by means of a random sample survey, with nine sampling points by type of use. Non-preserved soil samples were collected at four soil depths (0-5, 5-10, 10-20, and 20-40 cm), with the aid of a cutting blade. Posteriorly, they were dried, twisted and sieved with a 2 mm mesh opening, where soil size (clay, silt and sand) was determined according to the methodologies described in [12].

The stability of aggregates in water, expressed by the mean geometric diameter of aggregates index of the aggregates (MGD), was performed after separation of the larger aggregates in smaller aggregates by a set of sieves with 8 and 4.76 mm mesh. Posteriorly, the aggregates were fractionated by means of a set of sieves of 4.76; 2; 1; and 0.25 mm of mesh opening by means of submerged stirring in water. The material was dried in an oven at 105 ° C and determined its mass according to Yoder [4], described by the equation below:

$$\mathrm{MGD} = \mathrm{EXP} \sum_{i=1}^{n} \left( \frac{\mathrm{AGRi} * \mathrm{Ln} * \mathrm{ci}}{\mathrm{TAGR}} \right)$$

AGRi represents the mass of aggregates in each class (g); TAGR is the aggregate mass of the initial sample (g); ci is the mean diameter of the class of aggregates i (mm); Ln is the Neperian logarithm.

The data were analyzed through descriptive statistics (means of the points sampled) and the confidence interval of the means (CI) at the level of 10% of error probability.

## 3. Results and discussion

### 3.1 Analyze granulometric

The mean values and confidence intervals of the particle size analysis are shown in Table 1. The content of sand, silt and clay presented differences between the types of land use. The sand contents varied from 50 to 62 g kg$^{-1}$ in NF; from 41 to 59 g kg$^{-1}$ in PP; from 33 to 54 g kg$^{-1}$ in CLI; and 41 to 65 g kg$^{-1}$ in BR. In general, the values presented a small variation among the types of land use, the confidence interval (CI) being similar between them, with the exception of CLI and BR for the 20-40 cm layer.

**Table 1 - Mean values and confidence intervals of sand (g kg$^{-1}$), silt (g kg$^{-1}$) and clay (g kg$^{-1}$) in different types of use and depth of land**

| Layer (cm) | NF | PP | CLI | BR |
|---|---|---|---|---|
| | | Sand (g kg$^{-1}$) | | |
| 0-5 | 62± 21 | 55 ± 14 | 54 ± 16 | 63 ± 12 |
| 5-10 | 61± 20 | 59 ± 17 | 46 ± 8 | 65 ± 31 |
| 10-20 | 50± 16 | 45 ± 10 | 38 ± 10 | 40 ± 9 |
| 20-40 | 52± 17 | 41 ± 8 | 33 ± 6 | 47 ± 9 |
| | | Silt (g kg$^{-1}$) | | |
| 0-5 | 572 ± 28 | 411 ± 61 | 345 ± 24 | 362 ± 19 |
| 5-10 | 536 ± 35 | 408 ± 76 | 338 ± 26 | 331 ± 29 |
| 10-20 | 497 ± 69 | 388 ± 74 | 331 ± 19 | 387 ± 43 |
| 20-40 | 464 ± 62 | 334 ± 44 | 271 ± 22 | 273 ± 46 |
| | | Clay (g kg$^{-1}$) | | |
| 0-5 | 366 ± 33 | 534 ± 60 | 601 ± 24 | 575 ± 19 |
| 5-10 | 403 ± 36 | 533 ± 76 | 616 ± 24 | 604 ± 17 |
| 10-20 | 453± 70 | 567 ± 77 | 631 ± 24 | 573 ± 38 |
| 20-40 | 484± 61 | 625 ± 44 | 696 ± 21 | 680 ± 42 |

NF – Natural forest; PP - Pinus stand; CLI – Crop-livestock integration; BR - Burned natural rangeland

Mean ± confidence interval ($p \leq 0.10$). Means where the confidence limits overlap, are not significantly different.

The highest contents of silt were found in the NF, in all evaluated strata, without affinity with another type of use. The PP and CLI presented similar IC. According to [13], studies have found that, about six thousand years ago, there was a more humid period in the southern region of Brazil, which allowed the best adaptation of the araucaria forest that advanced on the fields. As vegetation is one of the soil formation factors, it is believed that the mixed ombrophilous forest may have influenced the granulometry of the soil in the areas where it is located, over these thousands of years.

The clay contents ranged from 366 to 484 g $kg^{-1}$ in Natural forest (NF)~~NF~~; 533 to 626 g $kg^{-1}$ in *Pinus taeda* stands on first cycle of cultivation (PP)~~PP~~; 601 to 696 g $kg^{-1}$ in Crop-livestock integration (CLI) ~~CLI~~ and 575 to 680 g $kg^{-1}$ in Burned natural rangeland (BR)~~BR~~. The highest clay content, in all layers, were found in CLI, being the lowest in the NF, without any similarity to any other mode of use through the confidence interval (CI), with the exception of PP that showed similarity with the CLI in the 10-20 cm layer. In average layers, the clay content was 24.3% lower in the NF in relation to the other uses and, in general, increased in depth for all types of use, which also occurred in studies by [14 and 15].

According to [16], the granulometry is considered a stable characteristic in the soil and of this form, it is not subject to change in a short time or depending on the type of use and handling. However, erosion can affect grain size, resulting in reduced soil productive capacity and nutrient loss [17].

### 3.2 Stability of aggregates

The mean geometric diameter of aggregates (MGD) ranged from 4.43 to 5.70 mm in the NF; from 4.06 to 5.81 mm in PP; of 3.00 to 5.45 mm in the CLI; and from 4.35 to

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5.57 mm in the BR (Table 2). According to Bertol et al. [2], the stability of the structure varies with the intrinsic soil conditions and with the management and cultivation systems.

**Table 2 - Mean values and confidence intervals of the mean geometric diameter - MGD (mm) of the soil aggregates in the different types of use and in the different depths**

| Depth | NF | PP | CLI | BR |
|---|---|---|---|---|
| (cm) | MGD (mm) | | | |
| 0-5 | 5,70 ± 0,44 | 5,81 ± 0,27 | 5,45 ± 0,23 | 5,54 ± 0,38 |
| 5-10 | 5,25 ± 0,83 | 5,63 ± 0,27 | 5,41 ± 0,24 | 5,57 ± 0,22 |
| 10-20 | 5,18 ± 0,96 | 5,00 ± 0,89 | 4,55 ± 0,78 | 5,39 ± 0,41 |
| 20-40 | 4,43 ± 0,91 | 4,06 ± 0,83 | 3,00 ± 0,46 | 4,35 ± 0,32 |

NF – natural forest; PP - pinus stand; CLI – Crop-livestock integration; BR - Burned natural rangeland

Means ± confidence interval ($p \leq 0.10$). Means where the confidence limits overlap, are not significantly different.

At the depth of 0-20 cm, all types of land use presented similarity considering the CI. The same occurred in [7], where the stability of aggregates also did not change between uses at this depth. [8], evaluating the stability of aggregates of a Red Dystrophic Latosol under different uses, also did not find significant differences between treatments.

In contrast, according to [2], an aggregate of high average diameter does not always present adequate distribution of pore size in its interior, which implies in variable structural quality. What, according to [18] can be seen in degraded pastures, where physical degradation is observed, evidenced by high densities, even though it presents high stability of aggregates. In this context, macroaggregates formed by physical processes, by means of mechanical operations of machines or equipment or by the trampling of animals, may not be stable.

At depth of 20-40 cm, CLI had the lowest MGD value. This behavior can be attributed to soil disaggregation when submitted to conventional tillage, which consequently reduces the carbon stock and the stability of aggregates, compared to other types of use. For example, Martins et al. [19], studying the effect of deforestation and cultivation, in the physical characteristics of the soil, pointed out that the stability of aggregates is strongly affected by the removal of vegetation and subsequent exposure of the soil to the warming and the impact of the rain drops. Mota et al. [14], evaluating the physical quality of a Cambisol, observed that under native forest greater stability of aggregates was verified when compared to the areas under cultivation. The authors [20, 21, 18, 22, 23], also found greater stability of aggregates in natural forest compared to other types of uses. According to Salton et al. [18], management systems that provide more robust aggregates are desirable, because they will maintain the structure of the soil without major changes when submitted to external forces, such as animal trampling and mechanized operations, besides greater resistance to erosion losses.

In all types of land use there was a tendency for soil MGD to decrease with increasing depth, which may have occurred by reducing organic matter in deeper layers. In general, the results showed that MGD varied little in different types of use.

According to Demarqui et al. [24], the aggregation and stability of soil aggregates depend on some of their physical and chemical properties, especially organic matter, clay minerals and iron and aluminum oxides. In this context, probably the natural soil conditions (clayey to very clayey textural class with high levels of organic matter and oxides) exerted greater influence on the stability of aggregates than the type of land use.

## 4. Conclusions

The levels of sand, silt and clay presented differences between the types of land use.

Overall, the results showed that MGD varied little in different types of use.

In all types of land use there was a tendency for soil MGD to decrease as the depth increased.

**Comment [REV A2]:** PLEASE INLCLUDE A RECOMENDATION. RESULTS ARE VERY WELL BUT IS IMPORTANT IN THSI CASE A RECOMENDATION. WHAT MORE DO WE HAVE TO DO ???

## 5. Bibliographic references

**Comment [REV A3]:** PLEASE CONSIDER 4 OR 5 REFERNCES FROM JEAI

1. Bertol I, Beutler JF, Leite D, Batistela O. Propriedades físicas de um Cambissolo Húmico afetadas pelo tipo de manejo do solo. Scientia Agrícola. 2001; 58 (3): 555-560. Portuguese.

2. Bertol I, Albuquerque JA, Leite D, Amaral AJ, Zoldan Junior WA. Propriedades físicas do solo sob preparo convencional e semeadura direta em rotação e sucessão de

culturas comparadas às do campo nativo. Revista Brasileira de Ciência do Solo. 2004; 28 (1): 155-163. Portuguese.

3. Almeida RF et al. Correlação do tamanho e distribuição dos agregados em Latossolos Amarelo da Região do Triângulo Mineiro em diferentes ambientes. Bioscience Journal. 2014; 30 (5): 1325-1334. Portuguese.

4. Yoder REA. Direct method of aggregate analysis of soil and a study of the physical nature of erosion losses. American Society of Agronomy. 1936; 28 (5): 337-551.

5. Salton JC, Mielniczuk J. Relações entre sistemas de preparo, temperatura e umidade de um Podzólico Vermelho Escuro de Eldorado do Sul (RS). Revista Brasileira de Ciência do Solo. 1995; 19 (2): 313-319. Portuguese.

6. Corrêa JC. Efeito de sistemas de cultivo na estabilidade de agregados de um Latossolo Vermelho-Amarelo em Querência, MT. Pesquisa Agropecuária Brasileira. 2002; 37 (2): 203-209. Portuguese.

7. Figueiredo Portugal A, Juncksh I, Schaefer CERG, Lima Neves JC. Estabilidade de agregados em argissolo sob diferentes usos, comparado com mata. Revista Ceres. 2010; 57 (4): 545-553. Portuguese.

8. Souza LHC, Nunes MCM, Neves SMAS, Cuiabano MN, Ferreira FS, Souza AL. Estabilidade de agregados de um latossolo vermelho distrófico sob diferentes usos e manejos em Lambari D'Oeste-MT. Cerrado Agrociências. 2015; (6): 12-23. Portuguese.

9. Reichert JM, Reinert DJ, Braida JA. Qualidade dos solos e sustentabilidade de sistemas agrícolas. Ciência & Ambiente. 2003; 27: 29-48. Portuguese.

10. Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM, Sparovek G. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift. 2013; 22 (6): 1-18.

11. EMBRAPA. Solos do Estado de Santa Catarina. Rio de Janeiro: EMBRAPA Solos, 2004. Portuguese.

12. EMBRAPA. Manual de métodos de análise de solo, 2. Rio de Janeiro: Embrapa Solos; 1997. Portuguese.

13. Boldrini II. Flora. In: Boldrini II. (org). Biodiversidade dos campos do planalto das Araucárias. Brasília: PROBIO Cadernos de Biodiversidade; 2009. Portuguese.

14. Mota JCA, Freire AG, Assis Junior RN. Qualidade física de um cambissolo sob sistemas de manejo. Revista Brasileira de Ciência do Solo. 2013; 37 (5): 1196-1206. Portuguese.

15. Silva Junior CA, Carvalho LA, Centurion JF, Oliveira ECA. Comportamento da cana de açúcar em duas safras e atributos físicos do solo, sob diferentes tipos de preparo. Bioscience Journal. 2013; 29 (1): 1489-1500. Portuguese.

16. Ferreira MM, Dias Júnior MS, Mesquita MGBF, Alves EABF. Física do solo. Lavras: Editora UFLA; 2003. Portuguese.

17. Bertol I, Mello EL, Guadagnin JC, Zaparolli ALV, Carrafa MR. Nutrients losses by water erosion. Science Agricola. 2003; 60 (3): 581-586, 2003.

18. Salton JC et al. Agregação e estabilidade de agregados do solo em sistemas agropecuários em mato grosso do sul. Revista Brasileira de Ciência do Solo. 2008; 32 (1): 11-21, 2008. Portuguese.

19. Martins PFS, Cerri CC, Volfkoff B, Andreux F. Efeito do desmatamento e do cultivo sobre características físicas e químicas do solo sob floresta natural na Amazônia Oriental. Revista do Instituto Geológico. 1990; 11 (1): 21-33. Portuguese.

20. Lacerda NB, Zero VM, Barilli J, Moraes MH, Bicudo SJ. Efeito de sistemas de manejo na estabilidade de agregados de um Nitossolo Vermelho. Engenharia Agrícola. 2005; 25 (3): 686-695. Portuguese.

21. Neves CSVJ, Feller C, Kouakoua E. Efeito do manejo do solo e da matéria orgânica solúvel em água quente na estabilidade de agregados de um Latossolo Argiloso. Ciência Rural. 2006; 36 (5): 1410-1415. Portuguese.

22. Coutinho FS, Loss A, Pereira MG, Rodrigues Junior DJ, Torres JLR. Estabilidade de agregados e distribuição do carbono em Latossolo sob sistema plantio direto em Uberaba, Minas Gerais. Comunicata Scientiae. 2010; 1 (2): 100-105. Portuguese.

23. Rozane DE, Centurion JF, Romualdo LM, Taniguchi CAK, Trabuco M, Alves AU. Estoque de carbono e estabilidade de agregados de um latossolo vermelho distrófico, sob diferentes manejos. Bioscience Journal. 2010; 26 (1): 24-32. Portuguese.

24. Demarqui JC, Perusi MC, Piroli EL. Análise da estabilidade de agregados de solos da microbacia do Ribeirão São Domingos, Santa Cruz do Rio Pardo-SP, sob diferentes tipos de uso e ocupação. Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias. 2011; 4 (2): 7-29. Portuguese.