Relation between soil organic matter and physical properties of a degraded Oxisol in recovery with green manure, lime and pasture

Carolina dos Santos Batista Bonini[A] and Marlene Cristina Alves[B]

[A]Faculdade de Engenharia, Universidade Estadual Paulista, UNESP. Caixa Postal 31, CEP 15385-000, Ilha Solteira, São Paulo, Brazil, Email, cdsbatista@aluno.feis.unesp.br.
[B]Faculdade de Engenharia, Universidade Estadual Paulista, UNESP. Caixa Postal 31, CEP 15385-000, Ilha Solteira, São Paulo, Brazil, Email, mcalves@agr.feis.unesp.br.

Abstract
Cultivation of species that accelerate soil chemical and physical balance is an option for accelerating the recovery of degraded soil. The objective this work was to study the spontaneous occurrence of native tree species and pasture development of an Oxisol in process of recovery for 11 years using green manures, soil correction and gypsum. The experimental design was completely randomized with nine treatments and four repetitions. We used *Stizolobium aterrium, Cajanus cajan* and *Canavalia ensiformis* until 1999 which was then replaced by *B. decumbens.* The treatments were installed in 1992 and remained for seven years. In 1999 we planted pasture. We evaluated soil bulk density, aggregate stability and soil organic matter for the depths 0.00-0.10; 0.10-0.20 and 0.20-0.40 m. The physical properties of the soil were measured and soil bulk density was a good indicator of soil quality.

Key Words
Soil reclamation, soil quality, soil structure.

Introduction
Due to population growth the economic development of environmental resources is submitted to strong pressure, providing in the last decades large impacts on the environment. Among the natural resources most degraded by man, the soil is most changed in its natural characteristics due to improper exploitation. The history of soil use shows that this change always carries a new unsustainable ecological system, thus, soils used, intensively and in inappropriate way, are led to degradation (Alves and Souza 2008).
In Brazil, deforestation and agricultural activities are the main factors of degradation of soils. The engineering works (roads, railways, dams) and the activities of mining in the open sensitize the population in general. This is because these activities have high impact.
From the 60s, with the population growth and demand for greater quantities of energy, the Brazilian government began efforts to supply their needs. Thus, several hydroelectric power plants were designed for this purpose. While hydroelectricity as an alternative for energy production may be more environmentally advantageous compared to other options, because it uses a renewable natural resource and is non-polluting, the formation of reservoirs involves the occurrence of multiple impacts on the environment (Cesp 1998).
As consequences of construction, many areas, enclosed or not within the body of the work, tend to show sharp deterioration, which manifests itself in the form of disruption of the balance between the lithosphere (especially in its weakest part, the soils), the hydrosphere and biosphere (especially land cover). The areas where this process is more aggravating, are the areas of loan (excavation), the unstable slopes and boggy areas, flooded areas, etc. (Alves and Souza 2008). These locations, where the materials are taken to supplement the volume of soils necessary for the performance of earthwork and foundations, are "loan areas" (Lopes *et al.* 1994).
The areas of loan consist of degraded ecosystems, because their means of biotic regeneration were eliminated. The seed bank, seedlings and sprouts were removed along with the mature vegetation. Therefore, the sites have low resilience, i.e., their return to the previous state may not occur or is extremely slow.
For the recovery you must select and identify suitable species for the new edaphics conditions and accelerate the organization and formation of more superficial horizons of soil (Carpanezzi *et al.* 1994). The adaptation and development of these species depend on physical, chemical, biological and hydrological and microclimate conditions of the site.
Research has been developed with the purpose of generating solutions to mitigate the exposed surface. Restoring ecosystems is the name that has been attributed to the arduous challenge of, through planned interference, rebuilding the structure and creating conditions that restore the natural ecological processes of each ecosystem.

Boni *et al.* (1994) evaluated the contribution of green manure in improving physical characteristics of a degraded soil, they found that the legume species *Crotalaria juncea* and *Cajanus cajan* reduced soil bulk density and consequently increased the porosity of the compacted layers. Melo (1994) working in an area of loan found that forage species associated with chemical manure promoted improvements in physical and chemical characteristics of soil.
Alves *et al.* (2007) working in the recovery of degraded area remaining from the construction of a hydroelectric power station used the addition of sewage sludge, green manure, cultivation of native species and pasture to increase 27 times the production of *Brachiaria decumbens* evaluated 274 days after sowing. The same authors evaluated the diameter and height of plants of *Astronium fraxinifolium* and found that the best performance was for a treatment with *A. fraxinifolium + sewage sludge + B. decumbens* and physical conditions of soil improved.
Therefore, with the purpose to evaluate the recovery of an Oxisol that for over 11 years, gypsum and pasture were used, soil bulk density, aggregate stability and soil organic matter were measured.

Methods
The experiment was conducted at the Teaching and Research Farm, belonging to the Faculty of Engineering, Campus of Ilha Solteira of the Universidade Estadual Paulista (UNESP), municipality of Selvíria, Mato Grosso do Sul, Brazil. It is located on the right bank of the Paraná river, with the geographical coordinates of 51° 22' west longitude of Greenwich and 20° 22' south latitude, with height of 327 meters. Average annual precipitation, temperature and humidity of air: 1370 mm, 23.5° C and 70-80% respectively.
The original soil of the study area was classified as an Orthic Ferralsol according to the FAO classification (FAO 1990).
The hydroelectric power plant of Ilha Solteira, São Paulo, Brazil begin its construction in the 60's, the area under study had soil removed for earthworks and foundation of the storage dam, resulting in a degraded area. A layer of 8.6 meters was removed from the original soil profile, and the subsoil of the area under study had been exposed since 1969 (Alves and Souza 2008).
Physical-chemical characterization of the exposed soil gave values of, soil bulk density = 1,76 kg/dm^3; P = 0,5 mg/dm^3; M.O. = 5,5 g/dm^3; pH ($CaCl_2$) = 4,1; K = 0,2 mmol$_c$/dm^3; Ca = 2,0 mmol$_c$/dm^3; Mg = 1,0 mmol$_c$/dm^3; H+Al = 20,0 mmol$_c$/dm^3; SB = 3,2 mmol$_c$/dm^3; CEC = 23,2 mmol$_c$/dm^3 e Base saturation = 14 %.
The treatments were installed in 1992 and remained for seven years, until 1999 with *B. decumbens* in all plots. In 2006, to evaluate the spontaneous presence of native savannah tree species the experimental design was completely randomized, consisting of nine treatments and four replications. The size of each plot was 10 m *x* 10 m, spaced 2 m between them.
The treatments were: one control (tilled soil without culture) until 1999 after implanting of *Brachiaria decumbens*; *Stizolobium aterrium* until 1999 after the planting of *B. decumbens*; *Cajanus cajan* until 1994 and then substituted by *Canavalia ensiformis* and since 1999 was planted *B. decumbens*; lime+*S. aterrimum* until 1999 after the planted the *B. decumbens*; lime+*C. cajan* until 1994 then substituted by *C. ensiformis* and since 1999 planted with *B. decumbens*; lime+gypsum+*S. aterrimum* until 1999 after the *B. decumbens*; lime+gypsum+*C. cajan* until 1994 and then substituted by *C. ensiformis* and since 1999 was planted with *B. decumbens*, and to two control, native vegetation (savannah) and exposed soil (without recuperation practice).
Soil bulk density, aggregate stability and soil organic matter were measured at depths 0.00-0.10; 0.10-0.20 and 0.20-0.40 m. Chemical analysis of soil (organic matter) was carried out according to the methodology described by Raij and Quaggio (1983) and physical analysis of soil (soil bulk density and aggregate stability represented by mean weight diameter (MWD) were carried out according to the methodology described by EMBRAPA (1997) and Angers and Mehuys (2000), respectively.
The data were analyzed by performing regression and the Excel computer program was used to perform the statistical analysis.

Results
Comparing soil organic matter to soil bulk density showed that with higher contents of soil organic matter the lower was soil bulk density for the three depths. Surface samples (0.00-0.10 m) showed a greater reduction in soil bulk density in all treatments of soil reclamation, due to the higher concentration of the root system of *B. decumbens* in this depth, developing much organic matter.
At the depths 0.10-0.20 and 0.20-0.40 m there were similar results, with a lower content of organic matter and therefore a higher value of soil bulk density. This indicates show that soil reclamation mainly benefits

the surface soil horizon. Addition and balance of organic matter are essential in maintaining and improving soil physical conditions and can only be achieved through macro and microbial activity and decomposition of organic matter (Andrade Junior 2004).
Similar results were found by Alves and Suzuki (2004) who studied the use of cover crops combined with the succession of crops (maize and soybeans) under no-tillage and observed improvements in soil porosity, soil bulk density and penetration resistance. Campos and Alves (2006) studied penetration soil resistance in the degraded area similar to this study and found that reclamation has reached a depth of 0.00-0.05 m, this study shows that the effect of organic matter has reached to a depth of 0.10 m.
The relationship between organic matter and the mean weight diameter was the same for the three soil depths (0.00-0.10 and 0.20-0.40 m), with increasing content of soil organic matter resulting in higher mean weight diameter. Results of this study agree with the claim that Campos *et al.* (1995) and Campos and Alves (2008) that the continuous supply of organic matter by litter and/or root excretions, whose products are made of organic molecules in various stages of decomposition, act as agents of formation and stabilization of aggregates, providing a better soil structure.

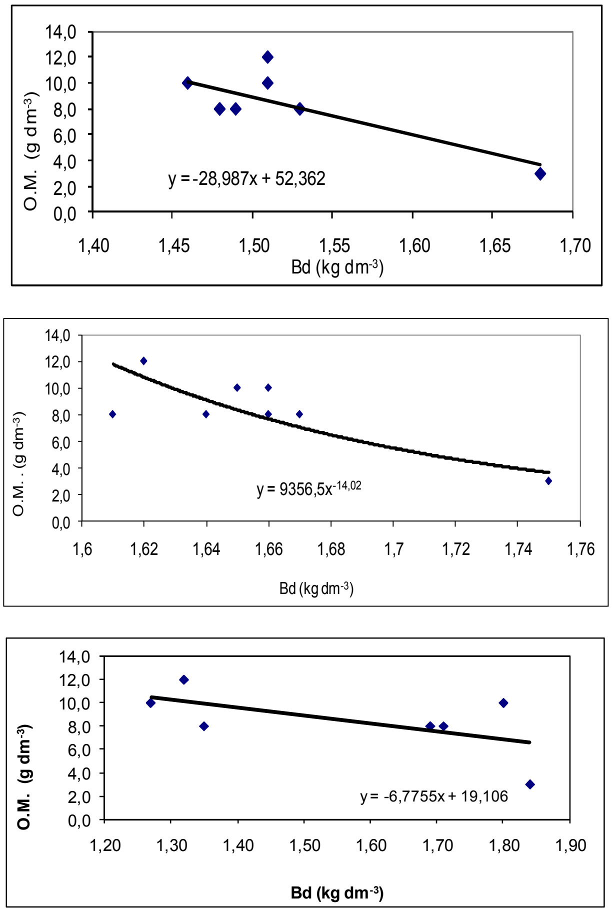

Figure 1. (a) Relationship organic matter (O.M.) x bulk density (Bd) in the depth 0.00-0.10m. (b) Relationship organic matter (O.M.) x bulk density (Bd) in the depth 0.10-0.20m, (c) Relationship organic matter (OM) x bulk density (Bd) in the depth 0.20-0.40 m.

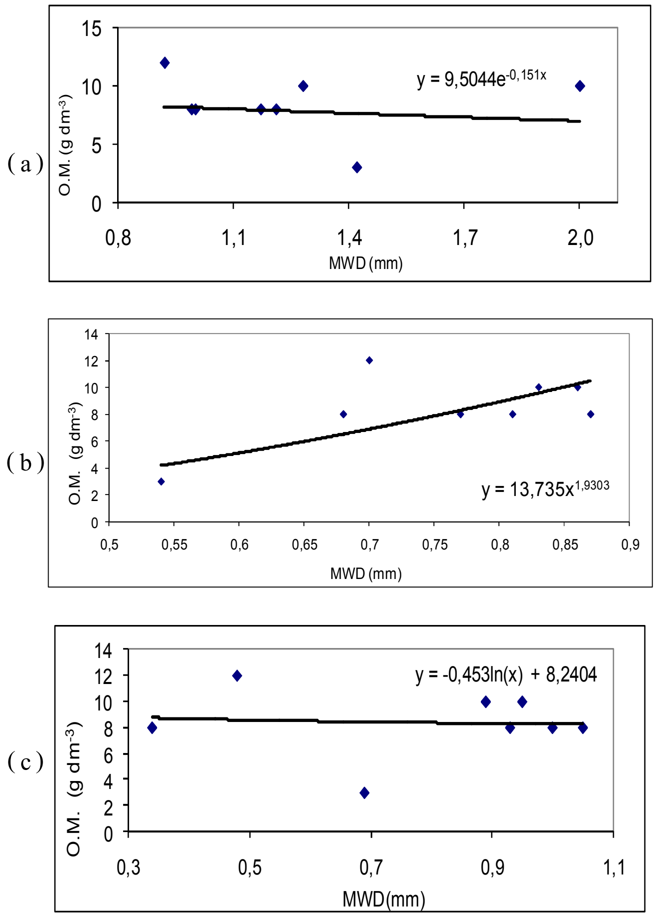

Figure 2. (a) Relationship organic matter (O.M.) x mean weight diameter (MWD) in the depth 0.00-0.10 m, (b) Relationship organic matter (O.M.) x mean weight diameter (MWD) in the depth 0.10-0.20 m (c) Relationship organic matter (O.M.) x mean weight diameter (MWD) in the depth 0.20-0.40 m.

Alves (2001) states the influence of organic matter on soil aggregation is a dynamic process, as it adds organic material to soil, the activity is enhanced, resulting in products that play roles in the formation and stabilization (cementing agents) of clusters. Jastrow *et al.* (1998) state that the presence of stable aggregates enhances the ability to store water, reducing the loss of particles and nutrients by erosion and facilitates the physical protection and accumulation of soil organic matter.

For the depth of 0.20-0.40 m an opposite behavior was observed, and there was a positive relationship between mean weight diameter and the amount of soil organic matter.

Conclusion

The physical properties of soil are being reclaimed, and soil bulk density was a good indicator of soil quality and the physical properties studied showed good relationships with the amount of soil organic matter.

References

Alves MC, Suzuki LEAS (2004) Influência de diferentes sistemas de manejo do solo na recuperação de suas propriedades físicas. *Acta Scientiarum Agronomy* **26,** 27-34.

Alves MC (2001) Recuperação do subsolo de um Latossolo Vermelho usado para terrapleno e fundação da usina hidrelétrica de Ilha Solteira-SP. Tese (Livre Docência em Solos)-Faculdade de Engenharia-Câmpus de Ilha Solteira, Universidade Estadual Paulista. 83pp.

Alves MC, Souza ZM (2008) Recuperação de área degradada por construção de hidroelétrica com adubação verde e corretivo. *Revista Brasileira de Ciência do Solo* **32,** 2505-2516.

Alves MC, Suzuki LGAS, Suzuki LEAS (2007) Densidade do solo e infiltração de água como indicadores da qualidade física de um Latossolo Vermelho distrófico em recuperação. *Revista Brasileira de Ciência do Solo* **31,** 617-625.

Andrade RT (2004) Propriedades Físico-químicas de um solo em Recuperação e adaptação da *Brachiaria decumbens.* Trabalho de Graduação-Faculdade de Engenharia-Câmpus de Ilha Solteira, Universidade Estadual Paulista. 49pp.

Angers DA, Mehuys GR (2000) Aggregate stability to water. In 'Soil sampling and methods of analysis'. (Ed CARTER, M.R). pp. 529-539. (Canadian Society of Soil Science, Lewis Publishers)

Boni NR, Espindola CR, Guimarães EC (1994) Uso de leguminosas na recuperação de um solo decapitado. In: Simpósio nacional sobre recuperação de áreas Degradadas, Curitiba. pp. 563-568. (Fundação de Pesquisas Florestais do Paraná)

Campos FS, Alves MC (2006) Resistência à penetração de um solo em recuperação sob sistemas agrosilvopastoris, *Revista Brasileira de Engenharia Agrícola e Ambiental* **10,** 759–764.

Campos FS, Alves MC (2008) Uso de lodo de esgoto na reestruturação de solo degradado. *Revista Brasileira de Ciência do Solo* **32,** 1389-1397.

Campos BC, Reinert DJ, Nicolodi R, Ruedell J, Petrere C (1995) Estabilidade estrutural de um Latossolo Vermelho-Escuro distrófico após sete anos de rotação de culturas e sistemas de manejo de solo. *Revista Brasileira de Ciência do Solo* **19,** 121-126.

Carpanezzi AA, Costa LGS, Kageyama PY, Castro CFA (1994) Funções múltiplas das florestas. Conservação e recuperação do meio ambiente. In: Congresso florestal brasileiro, Campos de Jordão. pp. 216-217. (Sociedade Brasileira de Silvicultura)

CESP–Companhia Energética do Estado de São Paulo (1998) Diretoria do Meio Ambiente. Recomposição vegetal. São Paulo. 11pp.

Empresa Brasileira de Pesquisa Agropecuaria (1997) Manual de métodos de análise de solo. 212 pp. (EMBRAPA/CNPSO)

FAO (1990) Soil map of the world. Revised legend. Rome, *World Resources Report* **60,** 119.

Ferreira DF (2003) Sisvar versão 4.2. (DEX/UFLA)

Jastrow JD, Miller RM, Lussenhop J (1998) Contributions of interacting biological mechanisms to soil aggregate stabilization in restored prairie. *Soil Biology and Biochemistry* **30,** 905-916.

Lopes JAV, Queiroz SMP (1994) Rodovias e Meio Ambiente no Brasil: Uma resenha crítica. In: Simpósio nacional sobre recuperação de áreas degradada, Curitiba. pp. 75-90. (Fundação de Pesquisas Florestais do Paraná).

Melo EFRQ (1994) Alterações nas características químicas do solo de uma área degradada em recuperação. In: Simpósio nacional sobre recuperação de áreas degradada, Curitiba. pp. 371-381. (Fundação de Pesquisas Florestais do Paraná).

Raij BV, Quaggio JA (1983) Métodos de análises de solo para fins de fertilidade. 31 pp. (Instituto Agronômico)