# Potential compaction in two soils of the flat area of Valle del Cauca

## Compactación potencial en dos suelos de la parte plana del Valle del Cauca

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## Abstract

Samples from the first 20 cm topsoil of two soils in CIAT Palmira (Calciustoll and Haplustoll both vertic mixed loamy isohyperthermic with 0.5% slope), usually used in secondary forest cover and diverse crops for more than fifty consecutive years, were compacted into the apparatus of Richards at two soil moisture contents (0.1 and 0.5 bar) to compare the point of maximum soil compaction and its influence in the variation if the soil bulk density, rate of oxygen diffusion, aeration porosity, saturated hydraulic conductivity and rupture modulus. A complete randomized design with factorial arrangement was used. It consisted of 2 soils x 2 uses x 2 soil moisture contents x 3 repetitions. To separate means, a Duncan test was used. The study showed that high soil content of O.M. do not always prevent soil degradation due to agricultural machinery traffic at high soil moisture contents. Regardless soil use, siltier Calciustoll had a slightly more potential to compaction than Haplustol. The continued cultivation of the two soils has made them more susceptible to physical damage since in wet conditions those soils were extremely compacted and, showed the physical degradation which in practice is the result from traffic machinery on soils. In moisture state the compaction was moderated.

**Key words:** Potential soil compaction, Richards's compactor, soil management.

## Resumen

Muestras de los primeros 20 cm de la superficie de dos suelos en CIAT-Palmira (Calciustol y Haplustol, vérticos mezclados francos isohipertérmicos con pendiente 0.5%), utilizados en coberturas tanto de bosque secundario como de cultivos diversos por más de cincuenta años consecutivos, fueron compactados en el aparato de Richards bajo dos condiciones de humedad (0.1 y 0.5 bar) para comparar el punto de máxima compactación, y su influencia en la variación de la densidad aparente, la tasa de difusión de oxígeno, la porosidad de aireación, la conductividad hidráulica saturada y el módulo de ruptura. Se utilizó un diseño completamente al azar con arreglo factorial (2 suelos x 2 usos x 2 humedades) con tres repeticiones. Para la separación de medias se utilizó la prueba de Duncan ($P < 0.05$). El estudio concluye que los altos contenidos de M.O. no siempre evitan la degradación del suelo por efecto del tráfico de maquinaria en contenidos de humedad altos; independientemente del uso, el Calciustol más limoso tuvo ligeramente mayor potencial a la compactación que el Haplustol; y el cultivo continuado de los dos suelos los ha hecho más susceptibles al daño físico, ya que en estado muy húmedo, se compactaron al extremo, y mostraron el deterioro físico que en la práctica puede acarrear el tráfico de maquinaria sobre el suelo, y en estado húmedo, se compactaron moderadamente.

**Palabras clave:** Compactación potencial, Compactador de Richards, manejo del suelo.

## Introduction

The Cauca River valley has a total area of approximately 400,000 hectares, and about half of it, is dedicated to the production of sugar cane and other crops (Cenicaña, 2001). Soil is a fundamental resource and as such should be preserved for the maintenance and production of fiber for a growing population. Soils cultivated with sugarcane in the Cauca Valley have a high traffic of harvesting equipment, often in conditions of high moisture content due to stepwise plantings and climate variability (Amezquita *et al.,* 2000). This situation, besides the use of tillage system for puddling in areas where rice is grown, has increased the formation of compacted layers, sealing and crusting the soil surface in localized areas. These conditions lead to lower water infiltration into the profile, creating erosion problems which do not allow the expression of genetic crop potential affecting productivity (Amézquita 1994. Amézquita *et al.*, 2002). Tillage for planting incorporates topsoil parts to deeper and less disturbed parts, so that physical damage may be hidden in the early years.

In related terminology, soil compaction is an irreversible loss of volume and elasticity that a soil mass experiences due to external forces acting on it in the ranges of moisture near the plastic limit. In agricultural activity, these forces have their origin mainly in aspects related to tillage implements, the loads produced by the weight, the operation of the tractor tires and the trampling of animals (Amezquita, 1994). According to Pla (1995), indicators of soil compaction are: (i) bulk density (BD), which is useful to estimate the reduction of the pore space. This pore space is related to the drainage and moisture retention readily available. Fine textures show compaction levels >1.3 g/cm3, considered as critical. Medium textures have critical levels >1.4 g/cm3. Thick textures have >1.6 g/cm3 as critical levels. (ii) Porosity Aeration (PA) representing pore with radius >15 microns. Those pores lose water when the soil is subjected to a suction of 100 cm of water column. The critic level is <6-8%. (iii) Modulus of Rupture (RM), which is a measure of the consistency of the dry soil at 50°C, expresses the cohesive force between the particles when the soil dries. The critical level is >3.2 kg/cm$^2$. (iv) The rate of oxygen diffusion (ROD) expresses the $O_2$ movement per concentration gradient in a saturated medium. This can be from compacted to non-compacted soils. The critical level is 0.5µg/cm$^2$ per minute. (v) Saturated hydraulic conductivity (Kh) expresses the rate at which water passes through the soil mass per unit of hydraulic gradient. Critical levels are <5 mm/h for rainfed and 2mm/h for irrigated agriculture (Pla, 1995).

The aim of this study was to compare, under controlled conditions, surface compaction of two Mollisols after decades of cover crop and forest. The compaction was measured after 24 and 48 h of draining (from saturation) and a simulation of heavy machinery traffic (Pla, 1977, 1995, Proctor, 1933).

## Materials and methods

The study was conducted with two soils: Calciustol and Haplustol, which are vertic loam mixed, isohyperthermic with 0.5% slope (Garavito, 1976). The named soils are from the International Center for Tropical Agriculture (CIAT), located at 3° 30' N and 76° 21' W in Palmira Colombia. These soils have been covered for more than 50 consecutive years by secondary forest (B) and different crops (C). Undisturbed soil samples were collected from 5x5 cm cylinders between 0 and 20 cm deep. Then, they were compacted in the device of Richards (Richards, 1954, 1965) in two humidity conditions (0.1 and 0.5 bar). A completely randomized design was used with 2 soil x 2 covers x soil moisture x 3 repetition factorial. Variations in bulk density, oxygen diffusion rate, aeration porosity, saturated hydraulic conductivity and the modulus of rupture were studied.

## Results and discussion

### Initial Physical Properties

The soils have similar average texture, but C1 soil has more silt while B2 has more sand. Organic matter was medium to high in crop, while it was very high in forest, and C2 and B2 was lower (Table 1). Physical properties started in the appropriate critical ranges Pla (1995). However, forest condition was unbeatable for BD, Kh, and MR with no differences between soils, which agrees with OM levels. On the other hand, C1 crop had low Kh and high MR, perhaps because of the higher silt content (Wischmeier and Smith, 1978).

## Compaction potential

Regardless of the use, a very significantly degradation was found in both soils after compaction, with MR values above the critical level. It means a probable sign of clay dispersion due to the hardness of the crust and the compacted layer (Madero and Herrera, 2004) (Table 2). The Kh of Calciustoll soil was significantly lower, together with a low density. This situation occurs when reaching the critical moisture threshold and then, the soil is rolled and the water films make a damping effect that prevent further increases in density (Proctor, 1933).

Regarding uses, degradation occurred only with crops and that was expressed in almost all variables. This occurred due to the impact of agriculture, as has been reported by Amezquita *et al.,* 2002; Pla, 1995, and Quirk, 1994 (Table 3 ).

Interaction soil x use x moisture showed compaction at 0.5 bar moisture, which negatively affected all variables ($p \leq 0.05$) of soil 1 (Calciustoll) in both, forest and cropland. This situation was, perhaps, by higher contents of silt that reduce soil elasticity. However, only the MR exceeded critical levels, in both cropland soils, with 8 and 10 kg/cm2. Therefore, the strength after trafficking machinery in wet was evident. In forest, the soils were less sensitive to compaction, and also Soil 1 was more affected (Table 4).

Mechanical action when there was higher moisture (0.1 bar) produced a significant deterioration of the cropland soils. This situation happened until the point that its porous space with radius >15μm was significantly reduced and the soil volume was reduced to less than 5%. Thus, this is an indicator of the

**Table 1.** Some initial physical properties of soils in cropland (C) and forest (B).

| Soil | BD ($g/cm^3$) | Kh (mm/h) | MR ($kg/cm^2$) | M. O. (%) | Sand (%) | Silt (%) | Clay (%) | Texture |
|---|---|---|---|---|---|---|---|---|
| **C1** | 1.24a* | 0.90b | 2.9a | 5.1b | 15.0c | 73.3a | 11.7b | FL |
| **C2** | 1.20a | 18.1a | 1.9a | 3.2b | 33.1b | 60.7b | 6.3b | FL |
| **B1** | 1.01b | 15.1a | 1.1b | 8.0a | 25.7b | 55.2b | 19.1a | FL |
| **B2** | 1.11b | 14.5a | 0.9b | 6.8a | 40.2a | 40.0c | 19.8a | F |

* Averages in the same column and with the same letter are not significantly different ($P \leq 0.05$).
BD: bulk density, Kh: saturated hydraulic conductivity, MR: modulus of rupture, OM: organic matter.

**Table 2.** Simulated compactation effect on physical properties of the studied soils .

| Soils and vegetation | BD ($g/cm^3$) | PA (%) | TDO ($\mu gr/cm^2$ por min) | Kh (mm/h) | MR ($kg/cm^2$) |
|---|---|---|---|---|---|
| **Soil 1 (Calciustol)** | 1.19b* | 15.2a | 1.67a | 3.931b | 5.72a |
| **Soil 2 (Haplustol)** | 1.24a | 15.9a | 1.87a | 10.48a | 4.98a |

* Averages in the same column and with the same letter are not significantly different ($P \leq 0.05$).

**Table 3.** Simulated compactation effect of five soil physical properties regarding use .

| Sample | BD($g/cm^3$) | PA (%) | TDO ($\mu gr/cm^2$.min) | Kh (mm/h) | MR ($kg/cm^2$) |
|---|---|---|---|---|---|
| **Bosque-B** | 1.12b | 23.32a | 2.57a | 11.55a | 2.28b |
| **Cultivo-C** | 1.31a | 7.79b | 0.95b | 2.86b | 8.42a |

* Averages in the same column and with the same letter are not significantly different ($P \leq 0.05$

**Table 4.** Simulated compactation effect on physical properties in the function of soil use

| **Use**[a] | **Suction** (bars) | **BD** (g/cm³) | **PA** (%) | **TDO** (µgr/cm²por min) | **Kh** (mm/h) | **MR** (kg/cm²) |
|---|---|---|---|---|---|---|
| **C1** | 0.5 | 1.25c* | 9.87d | 0.92a | 6.08c | 8.29a |
| **C1** | 0.1 | 1.35b | 4.93e | 0.91a | 0.13e | 8.42a |
| **C2** | 0.5 | 1.20d | 11.79c | 1.02a | 10.83b | 10.12a |
| **C2** | 0.1 | 1.43a | 4.57f | 0.97a | 0.02e | 8.88a |
| **B1** | 0.5 | 1.06e | 20.28b | 2.92a | 11.58a | 3.04b |
| **B1** | 0.1 | 1.08e | 25.72a | 2.78a | 3.52d | 3.14b |
| **B2** | 0.5 | 1.16e | 22.11c | 3.28a | 13.34b | 1.63c |
| **B2** | 0.1 | 1.16e | 25.17b | 3.17a | 17.73a | 1.32c |

a. C = Crop. B = Forest. 1 = Calciustol 2 = Haplustol
* Averages in the same column and with the same letter are not significantly different (P ≤ BD: bulk density, PA: aeration porosity, TDO: oxygen diffusion rate, Kh: saturated hydraulic conductivity, MR: modulus of rupture

tendency of these soils to degrade in very wet conditions, which sometimes is unavoidable with rainfed agriculture (Pla, 1977). The relative influence of compaction at 0.1 bar was also reflected in the values of hydraulic conductivity of croplands, with Kh < 1mm/h. These values can be very limiting even under irrigation systems (Pla, 1995 Amézquita *et al.*, 2002; Quirk, 1994) (Table 4).

Soils with forest cover maintained a soil pore space with radius > 15µm, above 20%. The oxygen diffusion rate at 0.1 bar was much higher than 0.5 µgr/cm² per min, and generally maintained their physical nature (Table 4).

## Conclusions

- This study concludes that high contents of OM not always prevent soil degradation as a result of traffic in high moisture contents.
- Regardless of use, the more silt Calciustoll had slightly higher compaction potential than the Haplustol.
- The continued cropping of the two soils had made them more susceptible to physical damage. In very wet conditions, the soils were extremely compacted, simulating the physical deterioration that in practice lead to traffic on soils. In wet, the soils were moderately compacted.

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