COMPARISON OF THREE EQUIPMENT FOR ASSESSMENT OF SOIL COMPACTION

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INTRODUCTION

- Soil compaction is known as an important cause of crop yield loss due to its adverse effect on plant root growth, soil water availability and water infiltration.
- The easiest way to assess soil compaction in large fields is by using soil cone penetrometers, which measure the soil resistance to penetration (PR). Such parameter is a measure of the soil strength and it is a good indicator of soil compaction when soil moisture is close to field capacity.
- Two types of cone penetrometers have been used for field measurements, the static (constant penetration velocity) and the dynamic (cone-shaft system is driven by repeated hammer blows). Since reference values of PR has been used as critical values for root elongation, accurate measurements and accordance among different equipment are important for correct soil compaction diagnosis.
- In this study we compare the response of a manual dynamic (hammer) penetrometer with an automatic motor-operated static penetrometer in four soils of contrasting textures. Additionally, a newly designed instrument, that is an automatic drilling soil sampler machine equipped with a pressure sensor inside the hydraulic block (manifold), to measure the soil's resistance is tested and compared to the soil cone penetrometers.

MATERIAL AND METHODS

- The two cone penetrometers evaluated are the static penetrometer SoloStar, Falker, Brazil (Fig. 1A) and the manual dynamic penetrometer model Stolf-IAA Kamaq, Brazil (Fig. 1B), both designed and operated according to the ASABE penetrometers standards (ASABE, 2010).
- The third equipment is an automatic drilling soil sampling machine with a pressure sensor, a 13 hp stationary engine, GPS, a control electronic box and a 60 cm long and one inch diameter drill (Saci Trail, Saci Soluções, Brazil). The pressure sensor is installed into the hydraulic block (manifold) in the line that powers the rotation drill. Preliminary evaluations (Vaz et al. 2014) showed a linear correlation between this measure and the soil cone penetration resistance (PR).
- Number of plots measured in each soil were variable and are described in Table 1. For each plot twenty measurements were performed up to the depth of 40 cm. Soil S1 consist of a long term experiment comparing no tillage, conventional tillage and no tillage performed in previously compacted soils (4 and 10 tractor passes).

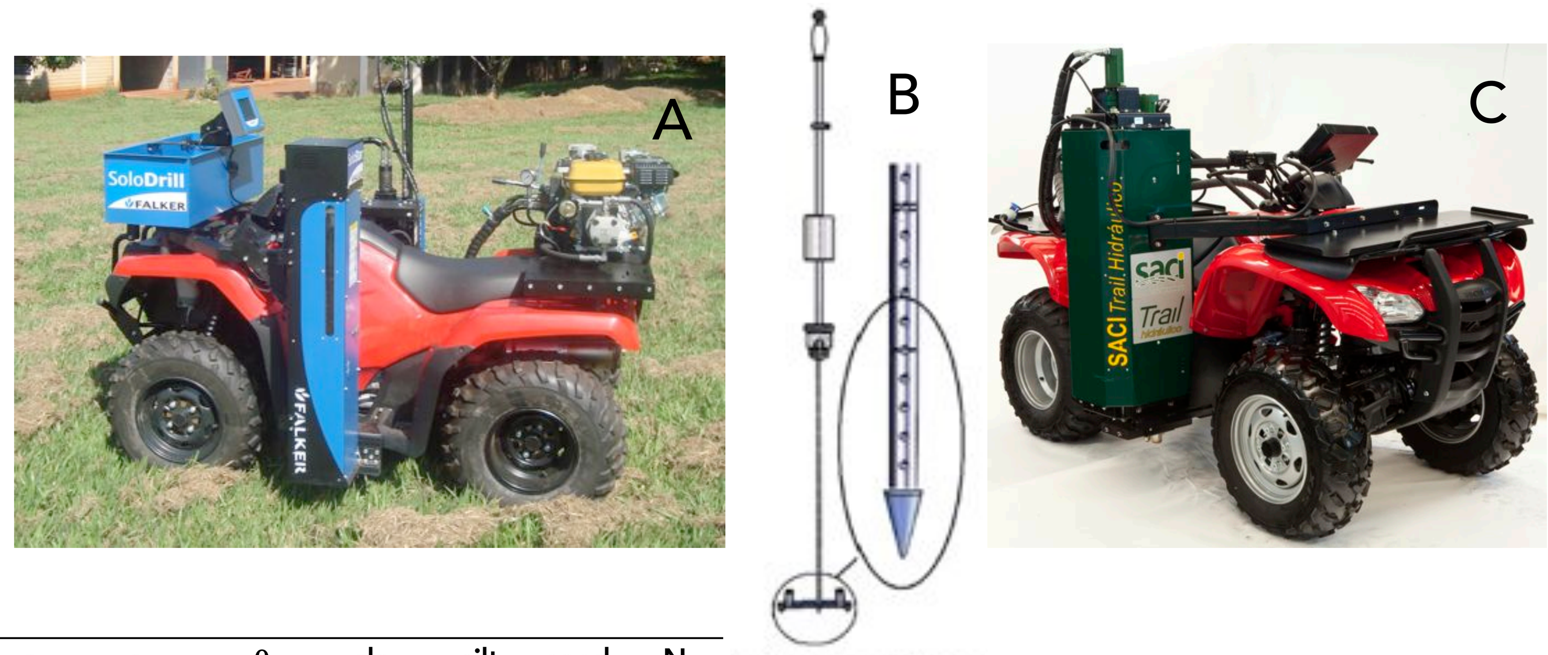

Figure 1. A static (A) and dynamic (B) penetrometers and a soil sampling drilling machine with a pressure sensor in the hydraulic block (C).

Soil	Local	Soil Cover	ρ_s	ρ_p	θ	clay	silt	sand	N
			g cm^{-3}		cm^{3}cm^{-3}		%		
S1	Londrina, PR	wheat	1.14	3.09	0.35	64	18	18	24
S2	São Carlos, SP	pasture	1.65	2.71	0.28	34	4	62	11
S3	São Carlos, SP	pasture	1.52	2.64	0.10	13	2	85	4
S4	São Carlos, SP	pasture	1.40	3.01	0.33	43	16	41	4

Table1. Physical properties of investigated soils. N: number of plots measured for each soil.

RESULTS

- Figure 2 depicts responses of the three equipment under no-tillage and conventional tillage system for soil S1. The dynamic penetrometer presents larger PR values compared to the static one. Another visible difference is that the drilling equipment presents a cumulative type curve because drilling area and pressure increase with depth.
- Larger PR values were obtained for the no-tillage system previously compacted (10x and 4x) as expected. PR values measured with the static penetrometer did not exceed the limit of 2.5 MPa for no-tillage and conventional systems, but it exceeded for the dynamic penetrometer.
- Correlations between the two penetrometers are shown in Figure 3. Differences in penetration resistances measured with the static and the dynamic penetrometers became higher as PR increases. This is due uncounted energy losses (vibration, friction) in the dynamic penetrometer (hammer-impact) formula used to calculate PR (Minasny 2012).
- Soil texture also affects the measurements. As clay content increases, differences between the two penetrometers increases as can be verified by the angular coefficient (tgα) in Table 2. This behavior is attributed to the specific ways each method penetrates the cone-shaft system into the soil (in the static penetration speed is constant and in the dynamic mode penetration is a results of several impacts) and to the complex metal cone-soil interaction (friction and adhesion forces) that depends on the soil texture.
- As larger is the clay content and the soil resistance, larger is the energy loss at the dynamic penetrometer and larger the differences between the two techniques.
- Comparisons between the drilling equipment and the penetrometers are presented in Fig. 4. Data obtained confirms previous linear relationships reported (Vaz et al. 2014), but such relationships showed to be soil dependent.

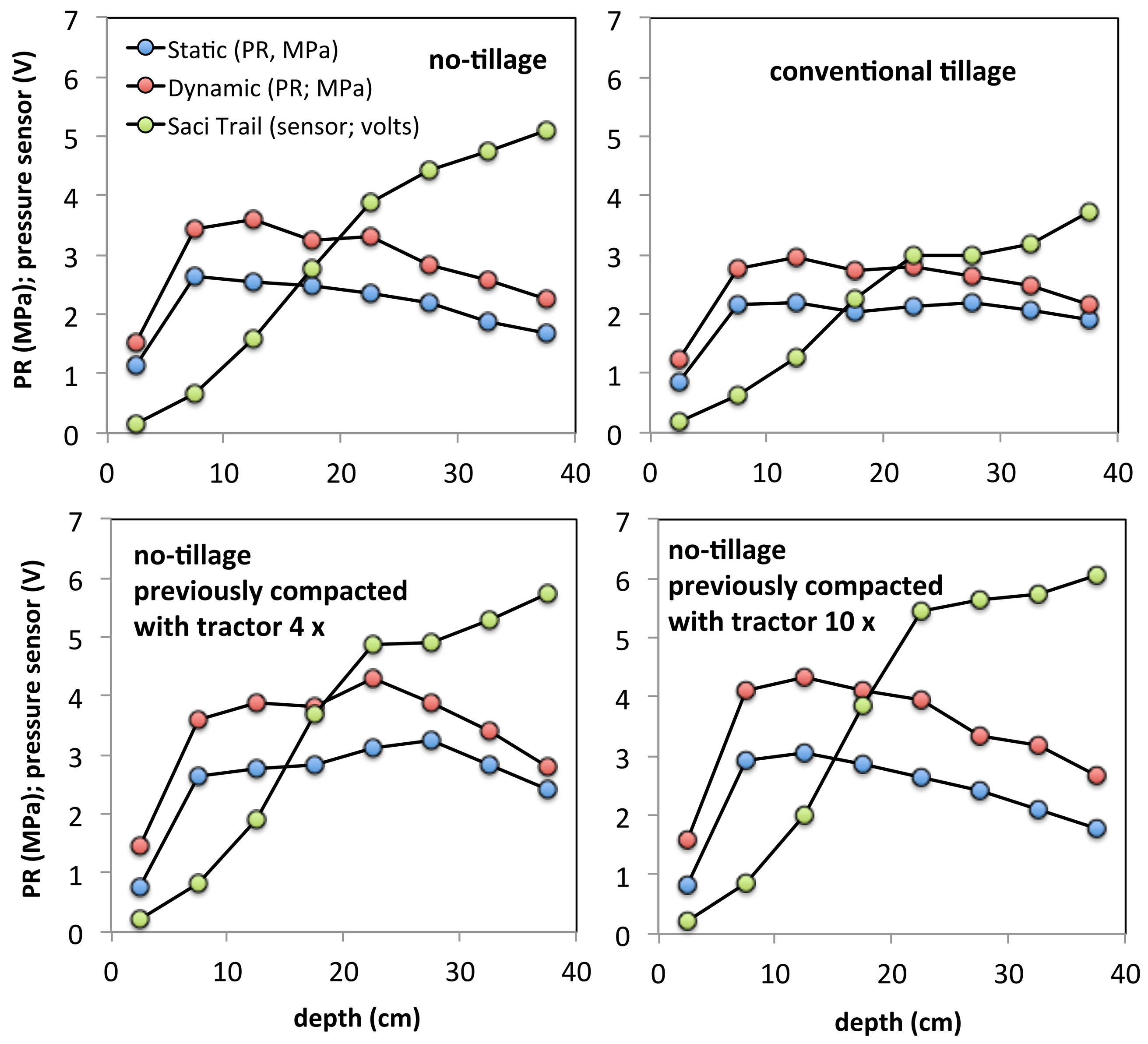

Figure 2. PR measured with the static and dynamic penetrometers and the soil drilling equipment in soil S1, for no-tillage (non-compacted and previously compacted) and conventional tillage.

Table 2. Angular coefficients (tgα) and determination coefficients (r^2) from linear fittings between the static and dynamic penetrometers.

soil	tgα	r^2	clay (%)
S1	1.33	0.80	64
S4	1.26	0.87	43
S2	1.16	0.84	34
S3	0.86	0.97	13

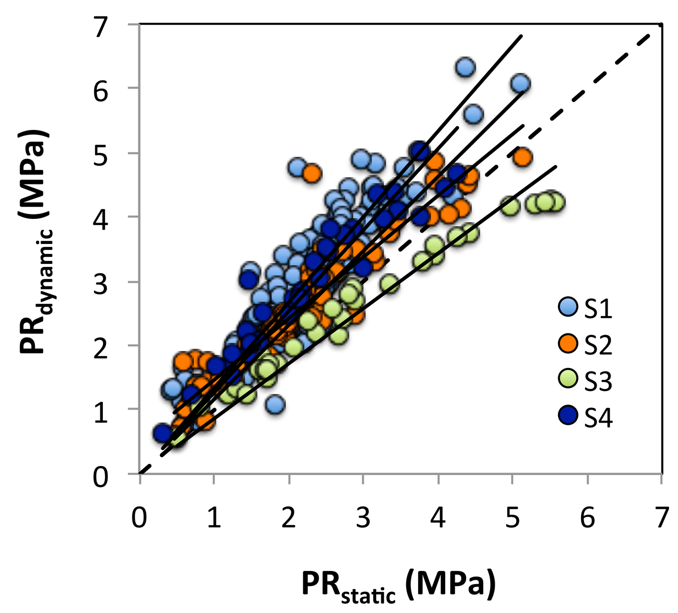

Figure 3. Comparison of soil cone penetration resistance measured in four soils with a dynamic and static penetrometer.

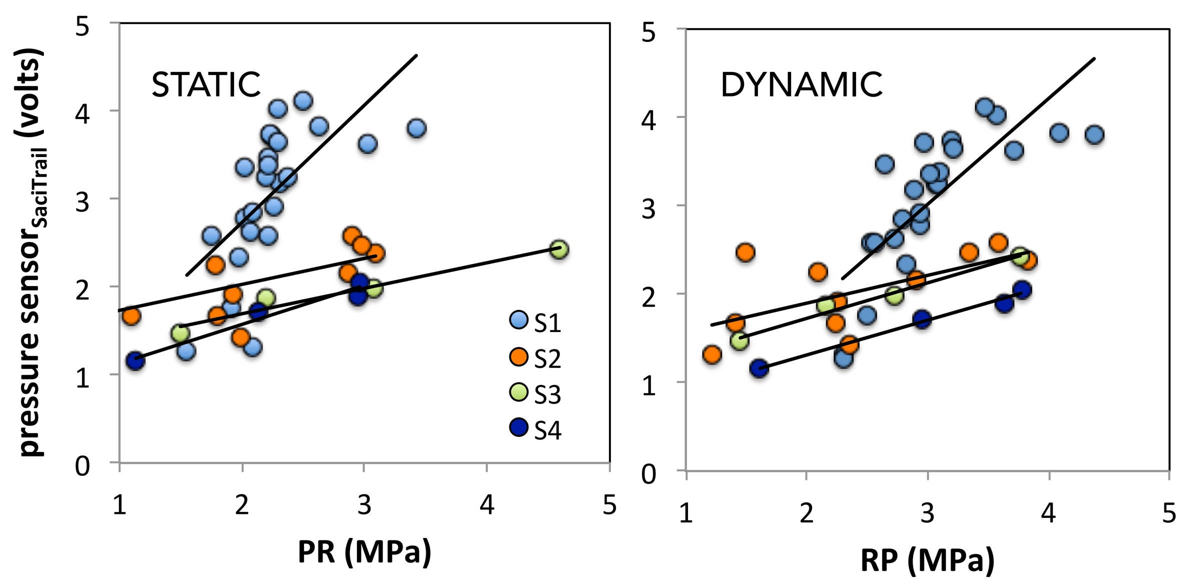

Figure 4. Relationships between the drilling equipment and penetrometers for soils of different textures.

DISCUSSION AND CONCLUSIONS

- The dynamic penetrometer overestimated PR for soils S1, S2 and S4 (clay content higher than 32%) and underestimated for soil S3 (sandy). Therefore it needs corrections for an adequate use as a soil compaction indicator.
- The drilling equipment needs improvements for a future use in soil compaction analysis, since it was very sensitive to soil type. One possible improvement would be a better control in the drill penetration velocity.

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