Impact of burning severity on soil structure and water repellency in the Neo-volcanic Axis Range (central Mexico)

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Introduction

The degree of fire-induced WR depends mainly on temperatures reached during burning . It is know that WR changes slightly at soil temperatures below 175 ºC, increases considerably between 175 and 200 ºC, and is destroyed when temperatures above 280 ºC are reached but these thresholds can vary depending on time of residence of temperatures and also on soil properties .

Soil WR has been previously related to different soil fractions, both coarse and fine fractions.In addition, aggregate stability is generally enhanced by WR, since the aggregate wetting is retarded by repellency, and hydrophobic coatings act as cementing agents. Thus, soil WR plays a key role in the hydrology and the re-establishment of vegetation in fire-affected areas making necessary the study of the influence of soil type and conditions.

The objective of this research was to study the effects of burning intensity on the occurrence and degree of WR and aggregate stability in burnt volcanic soils under pine and fir forests in central Mexico. Thus, three low intensity and two high intensity burnt sites of different fire-affected areas were selected for this experiment and compared with two long-unburnt control sites. The effects of different intensity burning on soil WR, aggregate stability, and the distribution of soil WR in aggregate sieved fractions were studied.

Methodology

Figure 1. Location of study area. Squares corresponds with bunrt sites affected by low (orange) and high (black) burning severity. Green circles show unburnt control areas.

Figure 2. Control unburnt soils under *Abies religiosa* and *Pinus pseudostrobus* forest.

Study area

The study area (Fig. 1) is located in the Neo-Volcanic Axis Range (Michoacán, México, 791- 3860 masl). The main soils are Andosols, Leptosols and Regosols developed mostly from basalts and andesites. Mean air temperature is 10-14 ºC and annual rainfall is 1200 -1500 mm. The main vegetation types are pine, fir and oak forests, and grasslands.

Seven sites with similar vegetation types, slope (20-25%) and soil characteristics were selected for this study (Fig. 1). Five sites were affected by fire in 2008. Sites 1-2 were burnt at low severity and 3-5 at high severity. Two unburnt sites were sampled as control (6 -7; Fig. 2).

Soil sampling

Undisturbed core samples, soil surface (0-20 mm) and subsurface samples (20-40 mm) were collected from 10 points randomly selected at each site. Samples were air-dried and sieved (2 mm). Subsamples of the original surface samples were classified by size, selecting 1-2, 0.5-1, 0.25-0.5 and <0.25 mm size aggregates.

Soil analyses

Dry bulk density was measured by the core method. Persistence of soil WR from original surface and subsurface samples (n =140) and from sieved fractions (n =280) was analyzed by the water drop penetration time (WDPT) test [8] and WDPT classes were classified . Intensity of soil WR was analyzed in sieved fractions (n =280) by measuring the contact angle (CA). Aggregate stability was analyzed by the 'counting the number of water drop impacts' (CND) test [9].

Results

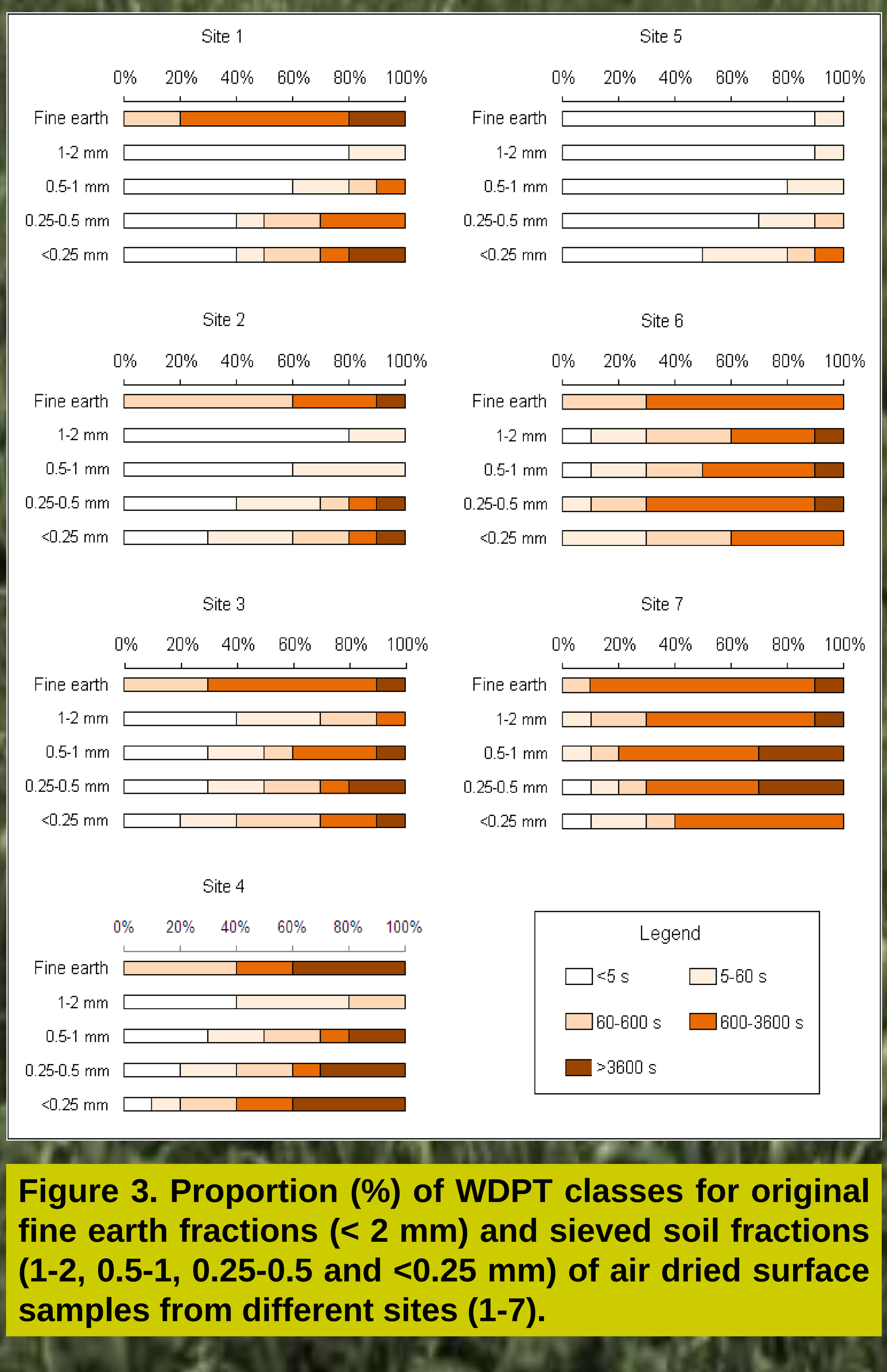

Figure 3. Proportion (%) of WDPT classes for original fine earth fractions (< 2 mm) and sieved soil fractions (1-2, 0.5-1, 0.25-0.5 and <0.25 mm) of air dried surface samples from different sites (1-7).

Water drop penetration times from long-unburnt sites (6 and 7) were 118-2536 s (site 6) and 390-3701 s (site 7) at the surface, and 0-554 s (site 6) and 4-1335 s (site 7) at the subsurface layer. The mean proportion of wettable samples from both sites was 0 and 20 % at the surface and the subsurface layer, respectively. Most of the samples were classified as strongly water repellent at the surface (80 %, on average).

WR from air-dried samples was not affected by low fire severity with respect to control sites (Figure 4) Different responses were observed in sites affected by high severity fires (Figure 4). In the first case (site 4), the proportion of extremely water repellent samples was 40 % at the surface and 10 % at the subsurface layer, while extremely water repellent samples were observed just at the surface of one of the control sites (7SU). In contrast, 5SH and 5BH samples were classified as wettable (90 %) or slightly water repellent (10 %).

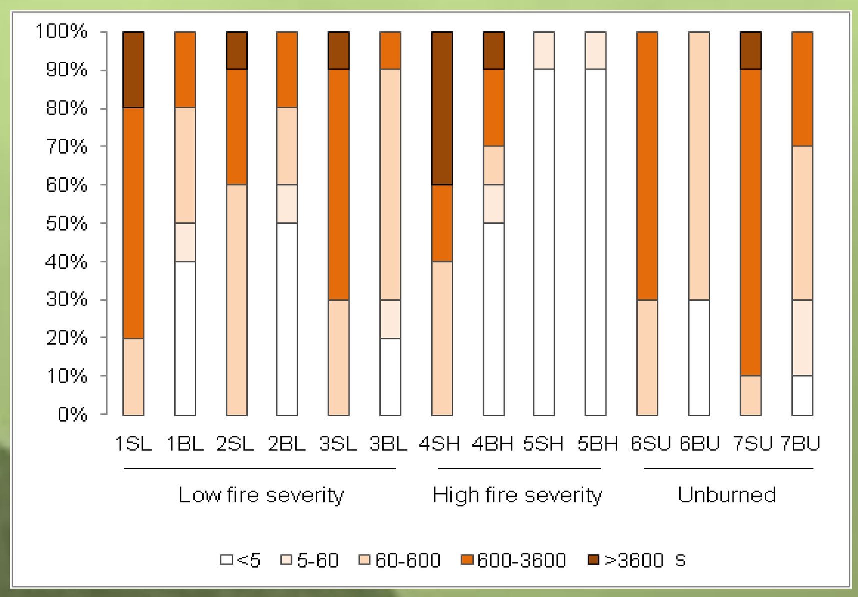

Figure 4. Surface (S) and subsurface (B) distribution of WR classes (WDPT s) from low intensity bunrt (L), high intensity bunrt (H), and unburnt (U) sites (1-7).

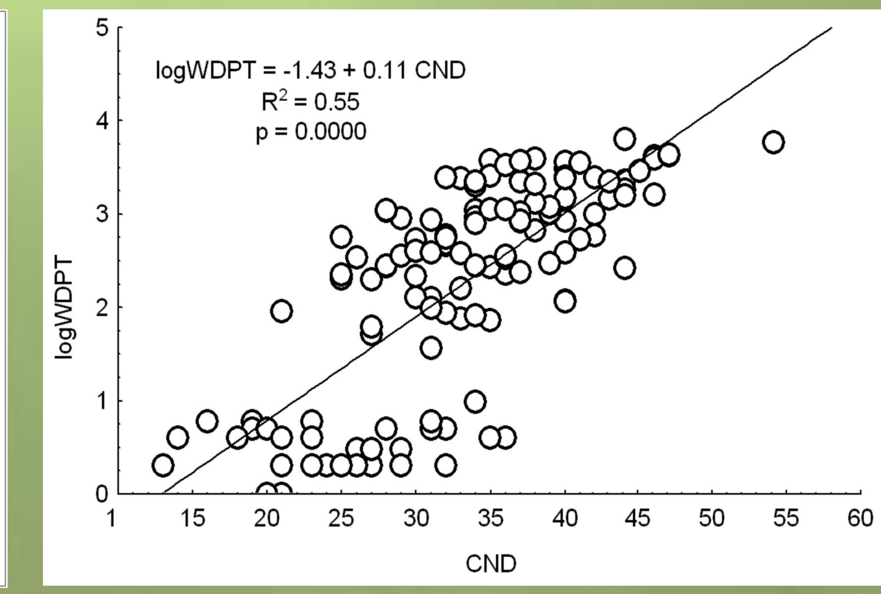

Figure 5. Linear regression between log (WDPT) and aggregate stability (CND).

Contact angles also showed significant differences between sites with different burning intensities and control sites at the surface and subsurface layer. Mean contact angles were relatively low for soil samples from sites with high fire severity, but increased for soil samples from low severity burnt sites.

In general, the distribution of WDPT classes in coarser sieve fractions was poorly related to the distribution in original surface samples. (Fig. 3) Although the finer sieve fractions always showed a proportion of wettable samples, slight to extremely water repellent classes are present both in original surface samples and sieved fractions from low and high severity burnt sites.

Soil WR and CND are related by an exponential function (Fig. 5). CND from wettable samples was 24.7 ± 5.3 drops, whereas CND from water repellent samples was 35.1 ± 6.5 drops. The higher degree of stability was observed in extremely water-repellent samples, in which CND 43.4 ± 5.8 drops.

Organic matter content was positively related to aggregate stability, WR. And CA (Fig. 6), while bulk density was negatively correlated with organic matter content, aggregate stability and WR.

No significant differences were observed between bulk densities of samples from low severity burnt and control sites, but it increased considerably in sites affected by high severity fire.

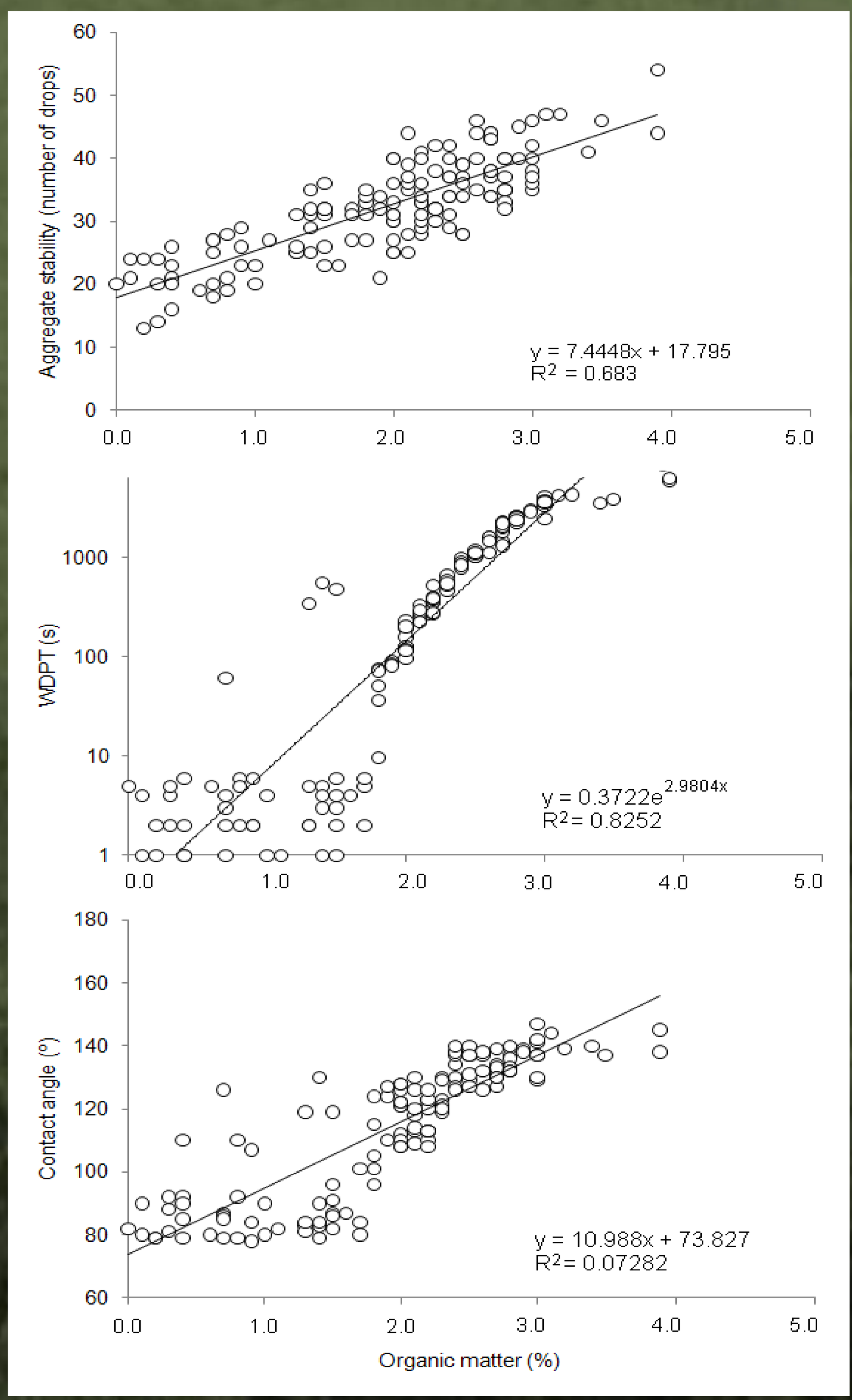

Figure 6. Different interaction between soil organic matter and aggregate stability (a); WDPT (b); contact angle (c) .

Conclusions

1) Volcanic soils under pines and firs in the study area show a natural WR background, comparable to observations from other studied acidic soils under coniferous species. The degree of soil WR after low severity fire was similar to that observed in control long-unburnt sites, although extreme repellency was observed in a higher proportion of samples.

2) High severity burning produced different responses: after severe burning, different temperature peaks and time of residence of high temperatures can modulate the effect on soil WR. Suspected relatively low temperature peaks or times of residence of high temperatures at severely bunrt site 4 did not induced significant changes in repellency, while it was destroyed after partial destruction of soil organic matter at site 5, probably due to high fire intensity.

3) Finer sieve fractions showed a higher degree of repellency in some cases. The degree of wettability of coarser sieve fractions was not related with the WDPTs of original surface samples from bunrt sites. Nevertheless, finer sieve fractions showed a range of WR more comparable to the original samples. Therefore, it is suggested that destruction of organic matter during burning occurs mainly in coarse aggregates, since combustion can be more intense due to oxygen present in large pores. Another explanation is that hydrophobic organic coatings are more easily destroyed during burning at the higher specific surface of coarse aggregates than in finer aggregates.

4) High aggregate stability could be explained as a consequence of a high degree of WR.