Effect of leaching on hydrophobicity and infiltration into a texture contrast soil

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Abstract
Water repellence in a texture contrast soil was found to be more strongly related to rainfall/leaching history, than the soil moisture content at the time of analysis. Field samples collected after prolonged rainfall had significantly lower water drop penetration time (WDPT) than samples collected after a prolonged period with minimal rainfall. A sequential leaching experiment also demonstrated that compounds causing water repellence could be leached from the soil, and that water repellence did not return following drying. Infiltration experiments demonstrated that leaching of water repellent substances was sufficient to prevent the development of finger flow even when soils were air dried, however fingering was observed in both leached and non-leached soil when air flow at the base of the Helle-Shaw tank was prevented. The work has important implications for timing of application of many agrochemicals to these soils.

Key Words
Water repellence, duplex, finger flow, infiltration, preferential flow

Introduction
Water repellence is thought to affect approximately 5 million hectares in Australia (Blackwell, 2000). Water repellence has been associated with increased erosion, poor seedling establishment, uneven crop growth, reduced irrigation efficiency and accelerated leaching of solutes including pesticides and fertiliser (Blackwell, 2000; Ritsema and Dekker, 2000). In water repellent soil, development of soil water fingers or 'fingering' results from instability in the wetting front when either the infiltration rate of a soil is less than the saturated hydraulic conductivity, or the depth of ponding is below the water entry potential (Wang *et al.,* 1998). Numerous studies have demonstrated that water repellence is inversely related to soil water content and that a critical water content exists below which fingering develops (Ritsema *et al.* 1998). Doerr and Thomas (2003) however found that for at least some soils that the relationship between soil moisture and water repellence is hysteretic, and that water repellence is not re-established after seasonal rainfall, unless input of new hydrophobic substances occurred. This paper details findings resulting from seasonal rainfall and leaching of a water repellent texture-contrast soil.

Methods
Effect of moisture content and leaching on water repellence
Samples were collected from the A horizon (0-10 cm) of a texture contrast soil, at the end of summer in April 2008, following 12 mm rainfall in the 30 days prior to sampling (non-leached), and July 2009 following 103 mm rainfall in the 30 days prior to sampling (leached). The relationship between antecedent soil moisture and water drop penetration time (WDPT) was determined by wetting a 1 kg sample of air dried non-leached soil to saturation. Subsamples were then dried at 40°C for durations ranging from 6 to 140 hours to produce a range of soil moisture contents. Samples were cooled to room temperature and the WDPT determined according to Caron *et al.*(2008). The relationship between leaching history and water repellence was investigated by sequentially leaching a 1200 cm^3 air dried, non-leached soil. Following leaching, soil was dried at 40°C for 24 hours, and the WDPT and water entry potential (WEP) determined, following similar procedure to Wang *et al.*(2000).

Finger flow – Helle Shaw tank
The effects of soil moisture and air entrapment on infiltration was investigated by applying water to leached and non-leached soil packed into a 2 cm wide glass walled tank (Helle-Shaw cell) (Wang *et al.,* 2003). Infiltration was conducted with and without air entrapment into soils with differing moisture content and leaching history. The head of water was maintained between 0.5 and 0.8 mm by controlling the rate of flow from the drippers or setting the air tube to the depth of ponding. Water flow down the sides of the glass

panes was prevented by coating the glass with either Teflon (moist soil) or thinly smeared Vaseline (dry soil). Visualisation of infiltration into wet soil was aided by application of 20 g/L Brilliant Blue FCF (C.I. Food Blue 42090) and recorded by still camera every 1 to 5 minutes depending on rate of infiltration.

Results

Prolonged rainfall significantly reduced water repellence (WDPT). Non-leached samples collected in April 08 had significantly higher WDPT than leached samples collected in July 09 (Table 1).

Table 1. Effect of leaching history on water repellence.

Site	Non Leached (April 08)			Leached (July 09)		
	Grav. Soil Moisture %	WDPT (mins)	Repellence Class[+]	Grav. Soil Moisture %	WDPT (mins)	Repellence Class[+]
B	0.91	5	High	0.42	0.18	Weak
C	1.13	15-20	Severe	0.40	0.63	Weak

[+] Classification based on Dekker *et al.* (2000).

The relationship between soil moisture and WDPT was poor (r^2 = 0.56, df 16) (Figure 1b), however artificial leaching significantly (p<0.05) reduced water repellence measured as both WDPT and WEP (Figure 1a). The WDPT decreased significantly from 170 minutes to 7.8 minutes following the first leaching event. Further leaching events did not significantly reduce WDPT, however the water entry potential (WEP) decreased significantly (p<0.05) with each leaching event (except second and third events) (Figure 1a). The relationship between WDPT and *WEP* was best described by a logarithmic function (r^2 = 0.94, p <0.001, df 7). Difference between the WDPT and *WEP* response suggests that initial leaching had greater effect on the time required for water repellence to breakdown, than the water entry pressure required to overcome water repellence and initiate infiltration.

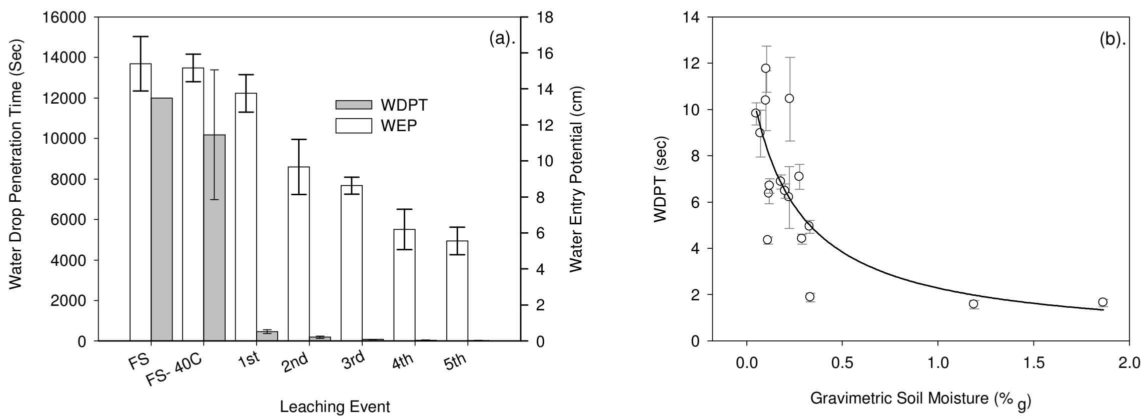

Figure 1 (a). Effect of leaching on water drop penetration time (WDPT), and water entry potential (WEP), FS = Field sample, FS-40°C = field sample dried to 40°C (b). Relationship between WDPT and WEP. Error bars represent ±1 standard deviation.

Finger flow and uneven wetting fronts, developed in dry non-leached soil (Figure 2b) and wet, leached soil with air entrapment (Figure 2d). Uniform flow occurred in leached soil with no air entrapment regardless of soil moisture (Figures 2 a & c). Results indicate that the reduction in water repellence followed prolonged rainfall (Table 1) prevented development of finger flow in soils with no air entrapment (Figures 2 a & c). However finger flow was induced in leached soil as a result of air entrapment at the base of the soil horizon. Finger flow propagation rate in dry, non-leached soil was 355 mm/hr (Figure 2b), which was similar to the infiltration rate for uniform flow in leached, dry soil at 385 mm/hr and wet soil at 410 mm/hr (figures 2 a &c respectively). Finger propagation with air entrapment in leached soil (Figure 2d) was considerably slower than the other infiltration events at 45 mm/hr.

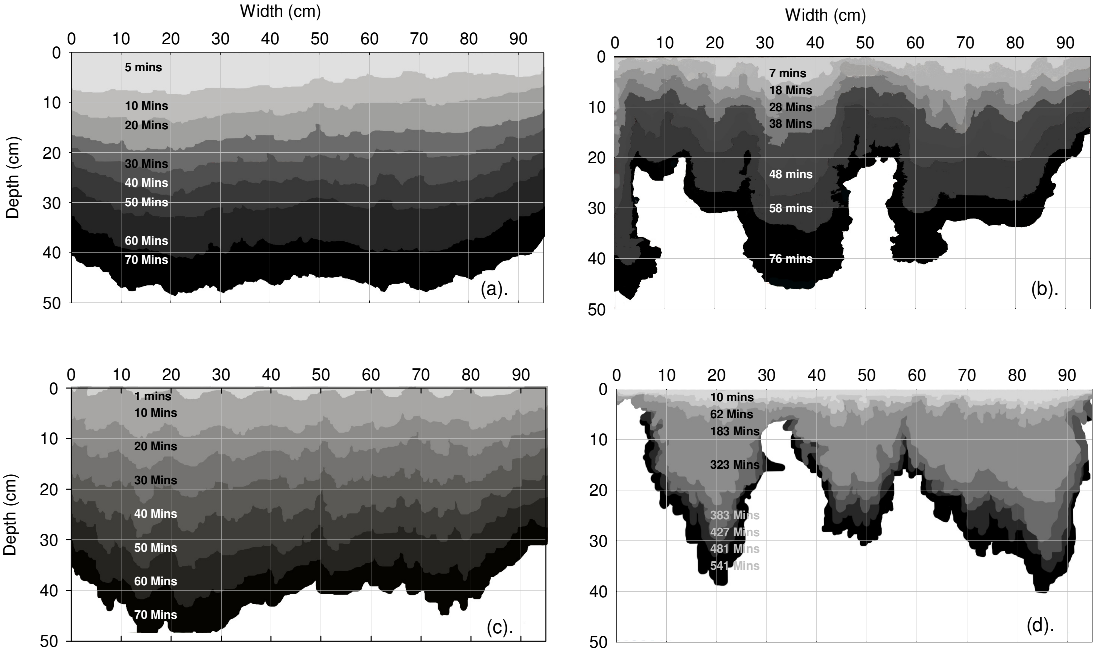

Figure 2. Helle-Shaw tank experiment. Infiltration into (a) leached, dry soil collected July 09, no air entrapment (b) non-leached, dry soil collected April 08, no air entrapment (c) leached, wet soil collected July 09, no air entrapment (d) leached, wet soil collected July 09, with air entrapment.

Discussion & Conclusion

Water repellence was found to be dependent on rainfall/leaching history. Leaching resulting from rainfall and the laboratory experiment significantly reduced water repellence, resulting in uniform infiltration. Results from this study confirm previous findings by Doerr and Thomas (2003) of a hysteretic relationship between soil moisture and water repellence in some soils, and that input of hydrophobic substances is necessary to re-establish water repellence after leaching. These findings cast doubt on the modelling approaches based on Ritsema *et al.* (1993) in which finger flow develops below a static critical water threshold. In the absence of rainfall, it is recommended agricultural managers apply irrigation or wait for rainfall to leach hydrophobic substances from soils prior to application of pesticides or fertiliser, in order to reduce the risk of shallow groundwater contamination via finger flow.

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