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Occurrence of soil water repellency and implications for the filtering function of soils
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Karin Mueller[1*], Markus Deurer[1], Carlo van den Dijssel[1], Karen Mason[1], Paramsothy Jeyakumar[1], John Carter[1], Brent Clothier[1]
MUELLER, Karin[1*], Markus Deurer[1], Carlo van den Dijssel[1], Karen Mason[1], Paramsothy Jeyakumar[1], John Carter[1], CLOTHIER, Brent[1]

[1]Plant & Food Research
[1]Plant & Food Research

There is increasing global concern about soil water repellency (SWR) as a soil degradation process. SWR is a transient property expressed in patchy wetting-up behaviour of soils once they dry out below a soil-specific critical water content. It might pose a threat to the delivery of soil ecosystem services in particular to the regulating services in relation to water and carbon, and food provisioning. The understanding of the economic, ecological and environmental consequences of SWR is still limited. Moreover, we are unable to predict when and where SWR will occur, or when it might disappear.

To improve our knowledge on the extent of SWR in the North Island of New Zealand, we conducted a survey on the occurrence of SWR under pastoral land use. We sampled the top 4 cm of soils across 50 sites from ten soil orders and five drought-proneness classes in the summer 2009/10. We found that 98% of the sites will become hydrophobic when they dry out, and that 70% of the sites were hydrophobic at the time of sampling. The survey revealed that the phenomenon of SWR is prevalent throughout all regions and it is independent of climate but it is influenced by soil order. The degree of SWR and its persistence for air-dried samples were positively correlated with the soils carbon and nitrogen contents, and negatively with bulk density. The persistence of SWR for field-fresh samples was additionally negatively correlated with the soil water content.

To improve our understanding of the environmental consequences of SWR, we conducted field and laboratory experiments with water-repellent soils from New Zealand. We focused on the local scale runoff, infiltration and leaching processes. Theoretically, in a hydrophilic dry soil, water infiltrates across the entire cross section of the soil surface. While in soils suffering from SWR, water infiltrates only across a fraction of the soil surface in the form of fingers, or it runs off. Measuring water and ethanol infiltration with tension disc-infiltrometers in the field, we found that SWR indeed reduced water infiltration by up to a factor of 20. Solute transport experiments through intact soil columns in the laboratory revealed that the soils buffering and filtering services were compromised by soil-water repellency. Enhanced preferential flow was found in the hydrophobic soils with elevated levels of soil organic matter. To quantify directly the impact of SWR on runoff, we developed a laboratory-scale runoff measurement apparatus. We compared the runoff resulting from the run-on of water with that resulting from an ethanol solution. The experiments with the ethanol solution can be taken as a proxy measure of the wetting-up behaviour of hydrophilic soils. No runoff occurred in the experiments with ethanol from any of the soils. We observed that runoff of water did not occur evenly across the entire soil slab, but was concentrated in channels, and covered only a fraction of the soil surface. Consequently, even a soil with an extremely high persistence of SWR resulting in almost the entire run-on water running off the soil slab, lost only a relatively small fraction of the solutes applied evenly to the soil surface, in runoff. We hypothesize that the channel-like pattern of runoff is typical for hydrophobic soils, and that the potential for nutrient loss in runoff from hydrophobic soils is limited.

Our research demonstrated that the filtering and buffering functions of water-repellent soils were compromised at the local scale. Integrating these local phenomena up to a larger scale of a catchment is not straightforward. We are unable to predict the larger-scale impact of water-repellent soils on catchment hydrology, and nor could we predict the impact on the regulating and provisioning ecosystem services that soils provide. More research is needed to understand better the causes and occurrence of SWR, and the larger-scale environmental, ecological and economic impacts of SWR.

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