Vegetation-induced soil water repellency as a strategy in arid ecosystems. A geochemical approach in Banksia woodlands (SW Australia)

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Introduction

Banksia woodlands (BW) are iconic ecosystems of Western Australia (WA) composed by an overstorey dominated by Proteaceae, e.g. *Banksia menziesii* and *Banksia attenuata*, in combination with other species, such as *Eucalyptus* spp., *Verticordia* spp. or *Melaleuca* spp. Although located in very poor sandy dune soils, BW provide numerous ecosystem services and sustain a high biodiversity.

In this area (Figure 1), annual rainfall is relatively high (about 800 mm) but high infiltration rates in sandy soils leads to a functionally arid ecosystem and the development of different plant strategies for water uptake.

Currently, BW are threatened by sand mining activities and expansion of urban areas; therefore conservation and restoration of these woodlands are critical. Despite numerous efforts, the success of restoration plans is usually poor, mostly due to the high sensitivity to drought stress and poor seedling survival rates (5-30%) (Benigno et al., 2014).

A characteristic feature of banksia plants is their root architecture, formed by a proteoid (cluster) system that spreads to form thick mats below the soil surface (Figure 2), favouring the uptake of nutrients (especially, P). This also helps to fix soil and prevent soil erosion. Root exudates are related to numerous plant functions, as they facilitate penetration of roots in soil and enhance the extraction of scarce mineral nutrients and its further assimilation. Exudates may also interact directly with soil or indirectly through microbial mediated events being also related to soil water repellency (SWR) (Lozano et al, 2014).

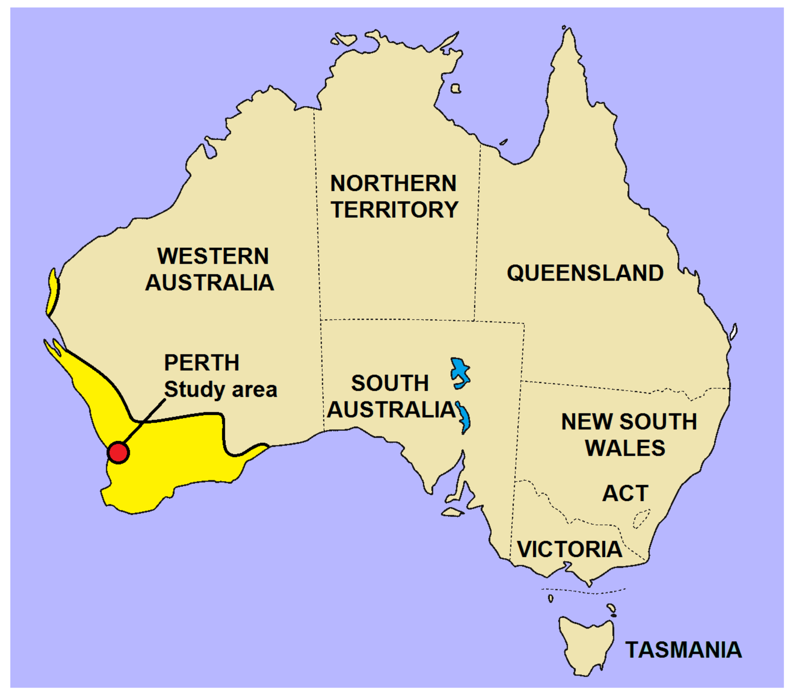

Figure 1. Aproximate distribution of banksia species in Western Australia and study area.

Figure 2. Detail of soil aggregate formed by banksia cluster roots.

Knowledge about the specific compounds able to induce SWR is limited (Doerr et al., 2000), but it is generally accepted that is caused by organic molecules coating the surface of soil mineral particles and aggregates (Jordán et al., 2013).

Proteaceae release short-chained organic acids to enhance phosphate acquisition, which have been also reported to be related with SWR (Jiménez-Morillo et al., 2014). It is hypothesized that disruption of water dynamics in mature BW soils is underlying the failure of restoration plans. This research aims to study SWR and its impact on water economy in relation with soil functioning and plant strategies for water uptake in pristine BW. Results are expected to shed light on the origin and implications of SWR in the area and provide useful information for improving ongoing restoration plans.

Methods

The study was conducted in natural BW near Perth, WA. Soil samples were collected at different soil depths (0-1, 1-10, 20-30 and 40-50 cm). Rationale for sampling depths was based on the different severities of SWR at each layer under field conditions. Soil acidity (pH) and salinity (EC) were determined. SWR was assessed under laboratory conditions in oven-dry samples (48 h, 105 ºC). SWR was assessed using the Water Drop Penetration Time (WDPT) test. Soil was considered wettable (WDPT < 5 s) and SWR was classified as slight (6-60 s), strong (61-600 s), severe (601-3600 s) and extreme (>3600 s). The chemical organic assemblage of bulked soil subsamples from each layer was analysed by direct analytical pyrolysis (Py-GC/MS).

Soil microbial activity was determined with the 1-day CO_2 test that is based on the measurement of the CO_2 burst produced after moistening dry soil (Muñoz-Rojas et al., 2016).

Results

Soil acidity and salinity values are shown in Figures 3 and 4 for different depths and plant species. SWR distributed discontinuously through the soil profile (Figure 5). The first thin layer (0-1 cm) composed of coarse sand and litter, located immediately above Banksia root clusters, showed wettable conditions. In contrast, the relatively well aggregated soil layer where the Banksia cluster root system is located (1-10 cm) was severely water-repellent. The 20-30 and 40-50 cm deep layers rendered wettable or subcritically water-repellent.

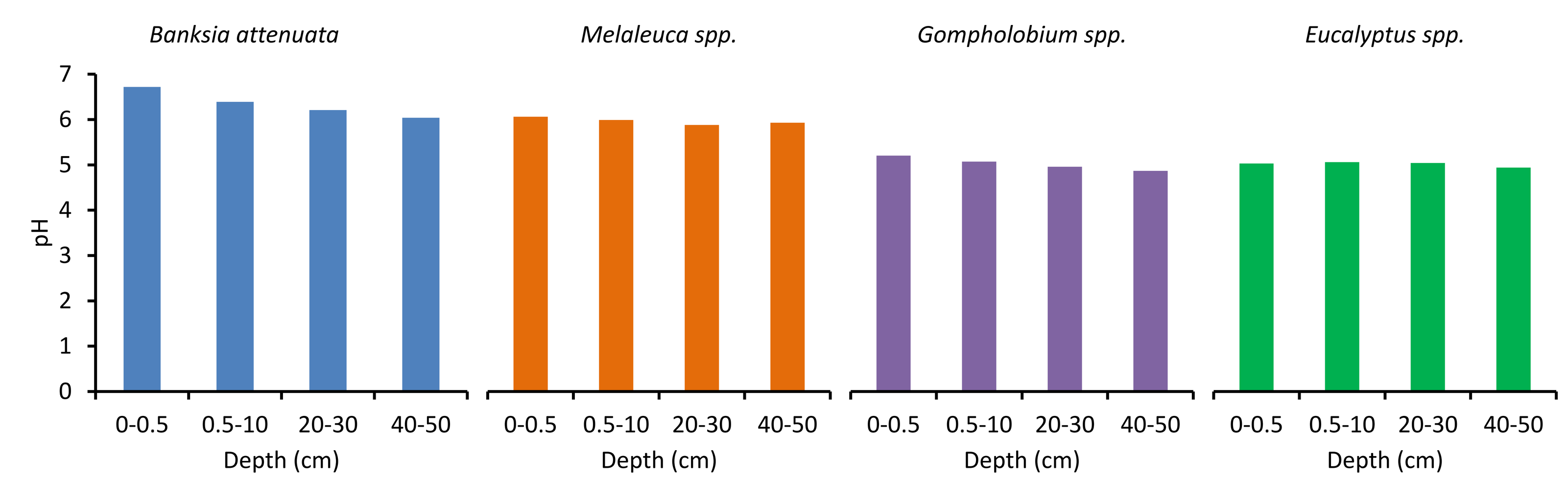

Figure 3. Vertical distribution (0-0.5, 0.5-10, 20-30 and 40-50 cm) of soil acidity (pH) below plants of *Banksia attenuata*, *Melaleuca* spp., Gompholobium spp. and *Eucalyptus* spp.

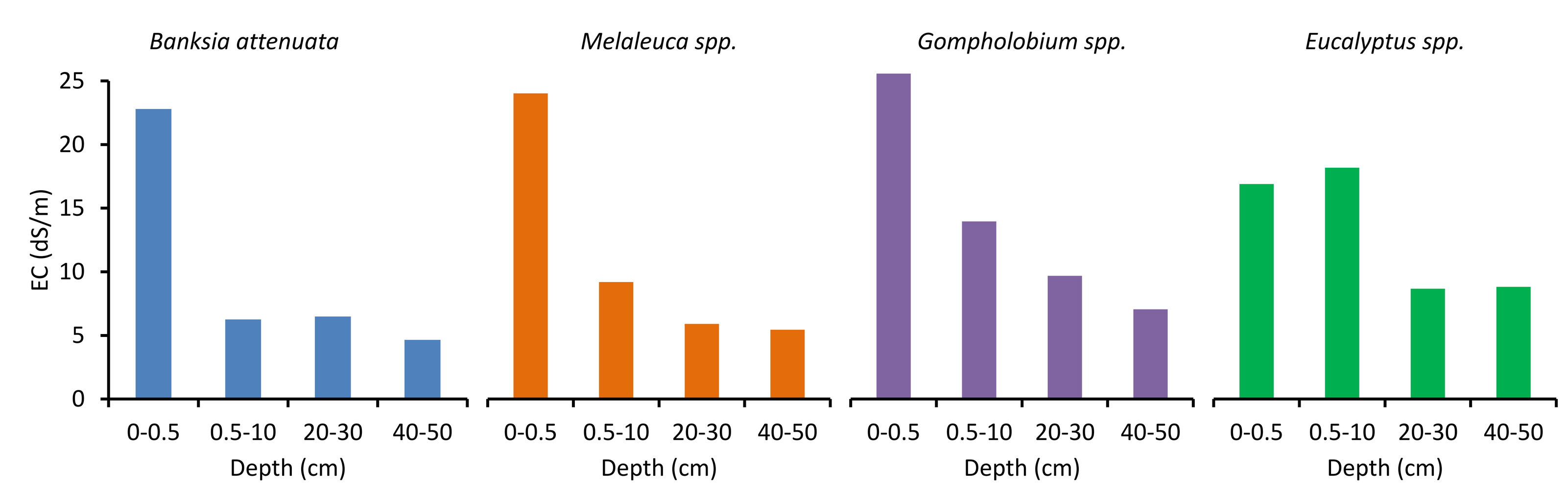

Figure 4. Vertical distribution (0-0.5, 0.5-10, 20-30 and 40-50 cm) of soil salinity (dS/m) below plants of *Banksia attenuata*, *Melaleuca* spp., Gompholobium spp. and *Eucalyptus* spp.

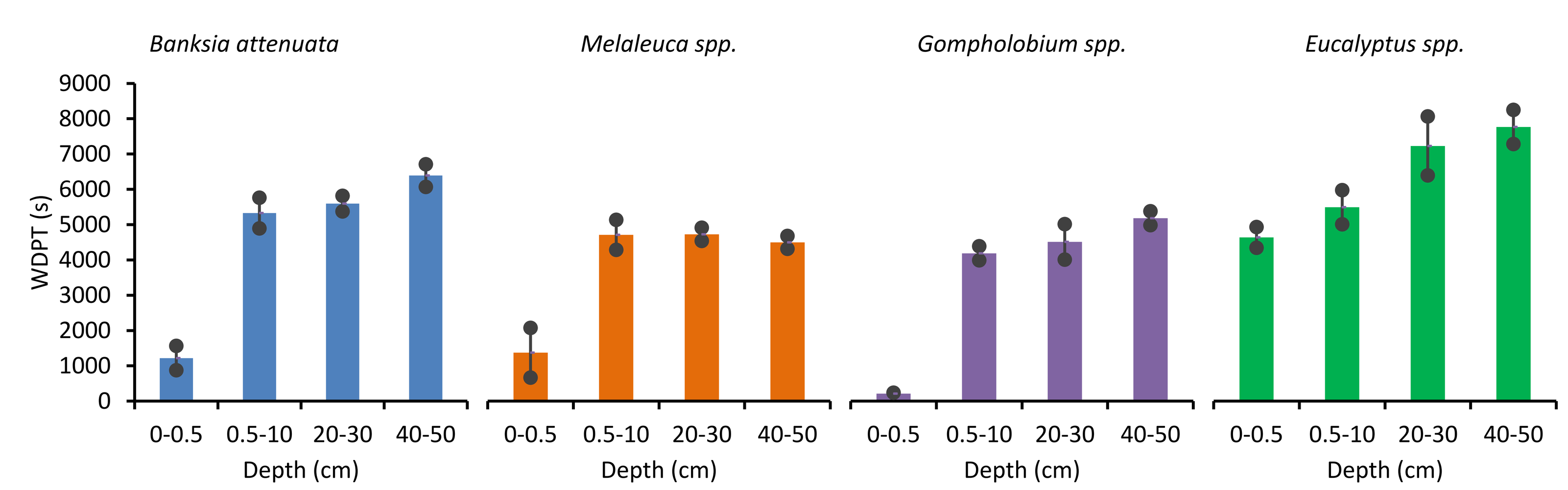

Figure 5. Vertical distribution (0-0.5, 0.5-10, 20-30 and 40-50 cm) of water drop penetration times (WDPT, s; mean ± SD) below plants of *Banksia attenuata*, *Melaleuca* spp., Gompholobium spp. and *Eucalyptus* spp.

Microbial activity decreased strongly with soil depth (Figure 6) below all plants, although observed values were significantly lower in the 0-0.5 cm soil layer below banksia plants than for the rest of species. In contrast, respiration was considerably higher in the 0.5-10 cm layer below banksia. SWR (WDPT) was poorly correlated with microbial activity (R^2 = 0.1463), but decreased significantly with pH (R^2 = 0.3404) and increased with EC (R^2 = 0.5428).

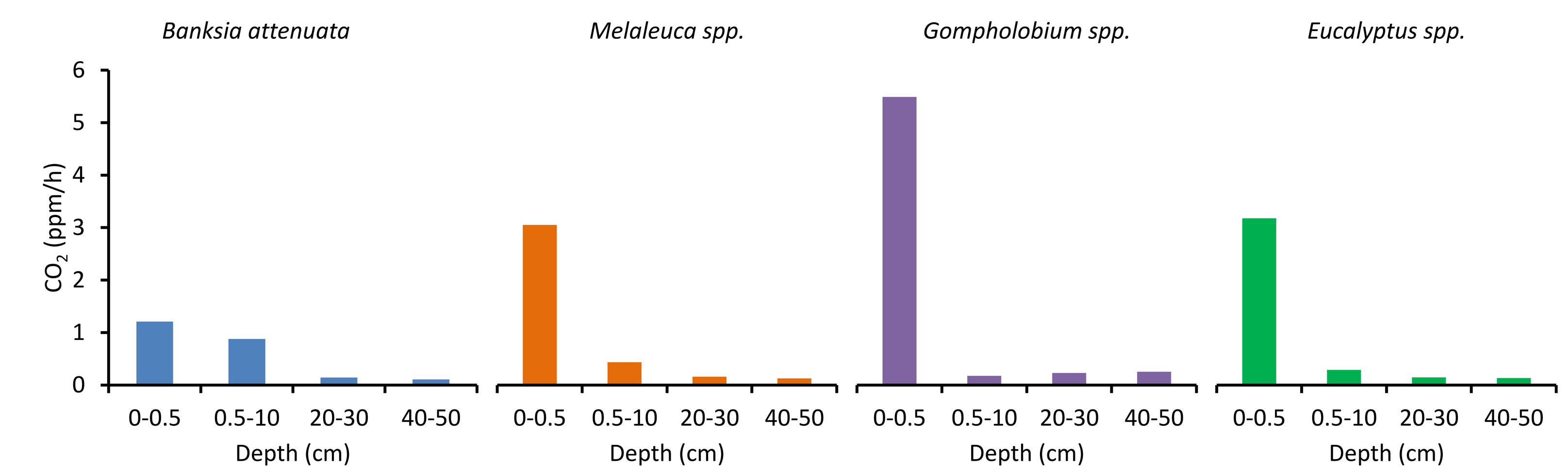

Figure 6. Vertical distribution (0-0.5, 0.5-10, 20-30 and 40-50 cm) of microbial activity (ppm CO_2/h) below plants of *Banksia attenuata*, *Melaleuca* spp., Gompholobium spp. and *Eucalyptus* spp.

After Py-GC/MS analysis, major compounds were identified and grouped according to their probable biogenic origin (lignin, polysaccharides, peptides, etc.). Among other soil organic compounds, well resolved bimodal alkane/akene (C8-C31, maxima at C13 and C26) and fatty acids series (short-chained, C5-C9, and long-chained even-numbered C12-C18) were associated to the root cluster soil layer (1-10 cm). Also, a relatively high contribution of fire-derived polycyclic aromatic hydrocarbons (PAHs) was observed (7%), which is consistent with frequent fires occurring in BW.

These results point to possible indirect links between organic substances released by roots and soil wettability involving soil microorganisms. An hypothesis of the role of these mechanisms as a strategy for water harvesting in arid ecosystems by banksia plants may be suggested (Figure 7). Further discussion should shed light on possible ecological plant strategies and specific adaptations for water uptake in such arid ecosystems of WA.

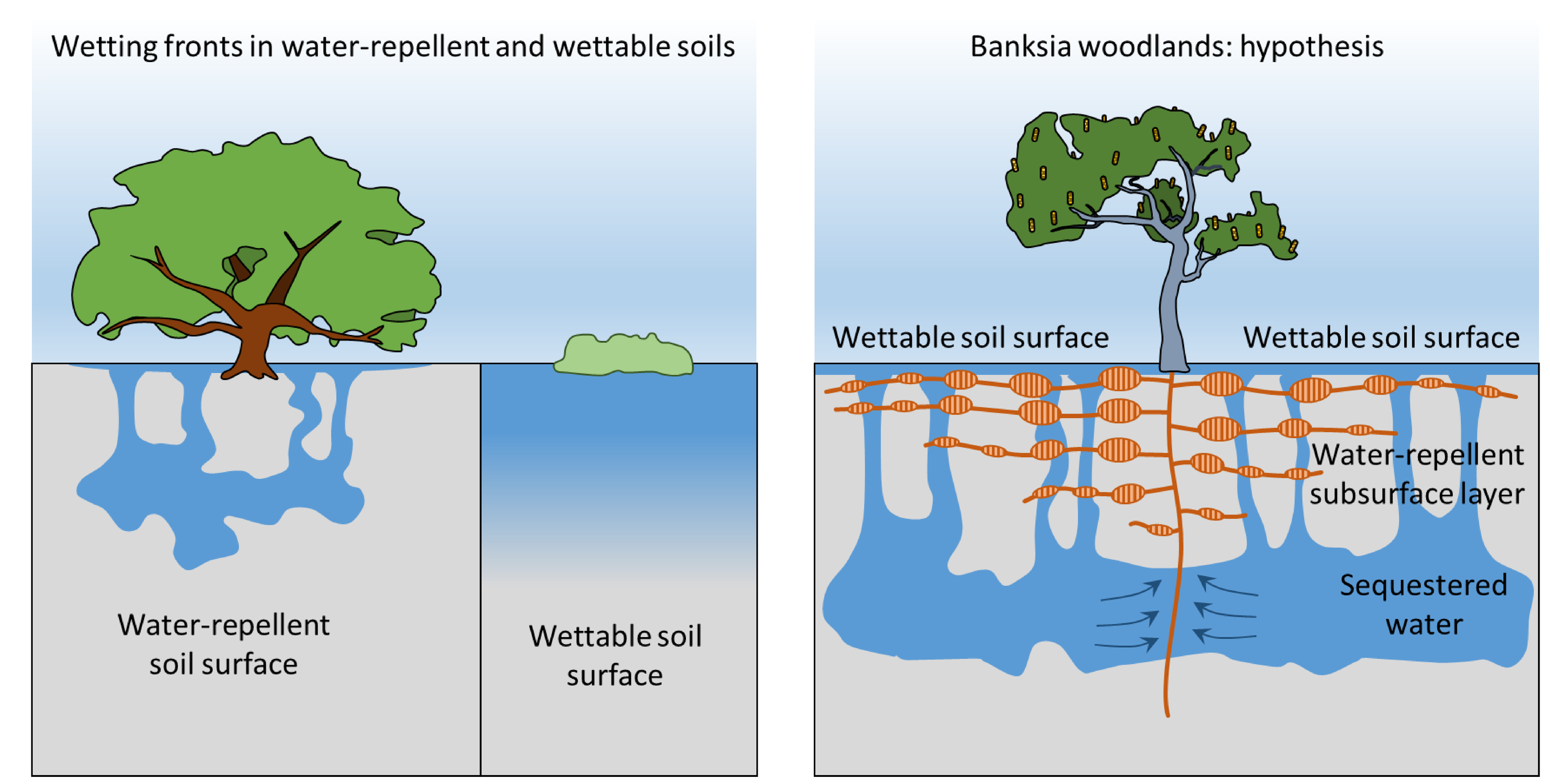

Figure 7. Suggested hypothesis of soil water repellency as a plant-induced process for water harvesting in arid ecosystems.

References. All cited references are included in Muñoz-Rojas et al. 2016. Vegetation-induced soil water repellency as a strategy in arid ecosystems. A geochemical approach in Banksia woodlands (SW Australia). Geophysical Research Abstracts, Vol. 18, EGU2016-1820-2.

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