The RiCC soil moisture network – Monitoring deep unsaturated zones in Western Australia to reveal crucial insights for water resources managers

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Background

Soil Moisture is a critical component of ecosystem dynamic for a variety of ecosystem services such as plant growth, nutrient cycling, groundwater recharge or preserving soil structure (erosion).

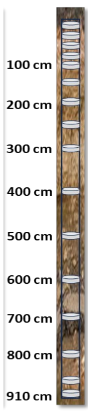
Globally, soil moisture observations are relatively shallow due to the difficulties and costs of installing sensors at greater depth and as often designed for validating satellite observations (i.e. top 50 cm).

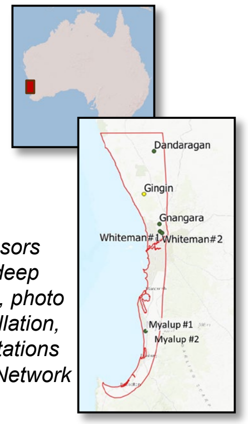
In deeper profiles, such observations fall short in detecting hydrological processes, such as vegetation/ groundwater interaction, which processes are then poorly represented in models used by water resources regulatory agencies.

Network aims and Locations

The RiCC network aims at capturing soil moisture dynamics in deep sandy profiles of the Mediterranean-type zone in Western Australia to inform numerical models and reduce the uncertainties

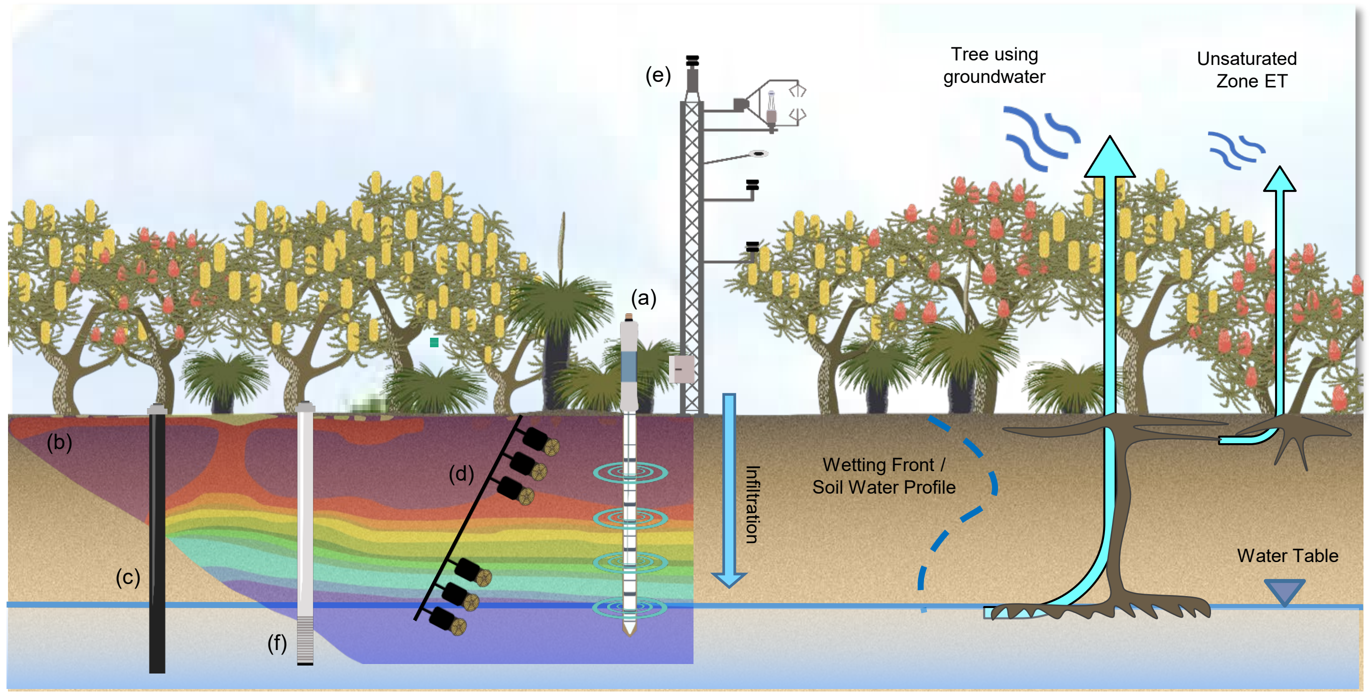
RiCC has been operating since 2022 and now comprises over 75 soil moisture sensors strategically distributed across 7 locations with different land uses around the city of Perth at **depths of up to 9 meters.**





Clockwise: Sensors depths at the deep Gingin installation, photo from sensor installation, locations of the stations forming the RiCC Network

The Recharge in a Changing Climate (RiCC) Project



Layout of the instruments composing the monitoring stations.

Schematic of the ecosystem processes captured by the monitoring stations

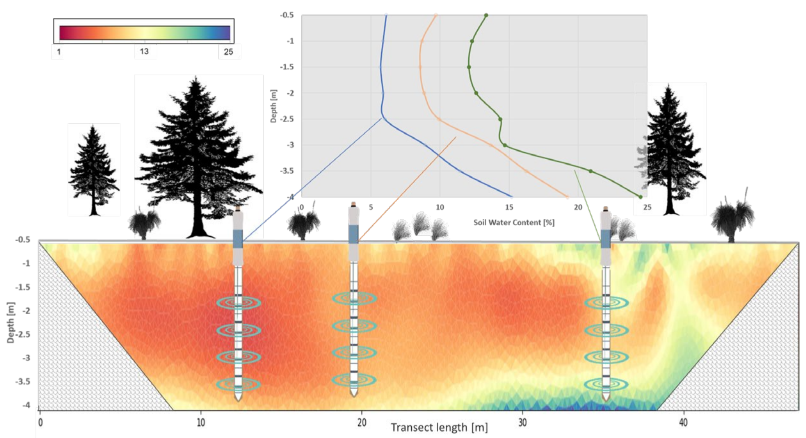
The RiCC project is a network of monitoring stations, focusing on soil moisture dynamic observations, to characterize hydrological and biophysical processes over deep unsaturated zones.

To represent spatial heterogeneity, the soil moisture sensors (a) are complemented by Electrical Resistivity Tomography transects (b) and access tubes (c) for neutron moisture probe readings.

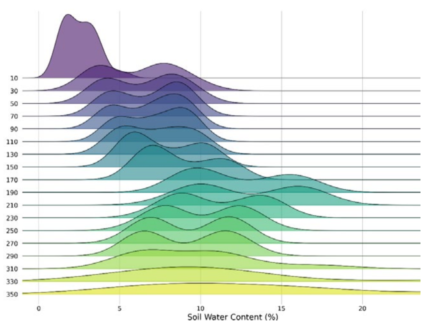
Water potential sensors (d) characterize flux and soil hydrological properties.

To measure ET, 3 locations have Eddy Covariance systems (e). All sites have groundwater bores (f).

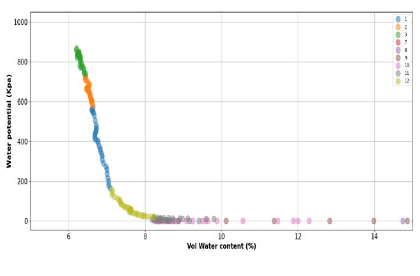
Ancillary Data to Inform Models



ERT transect and three soil water content profiles showing the site heterogeneity

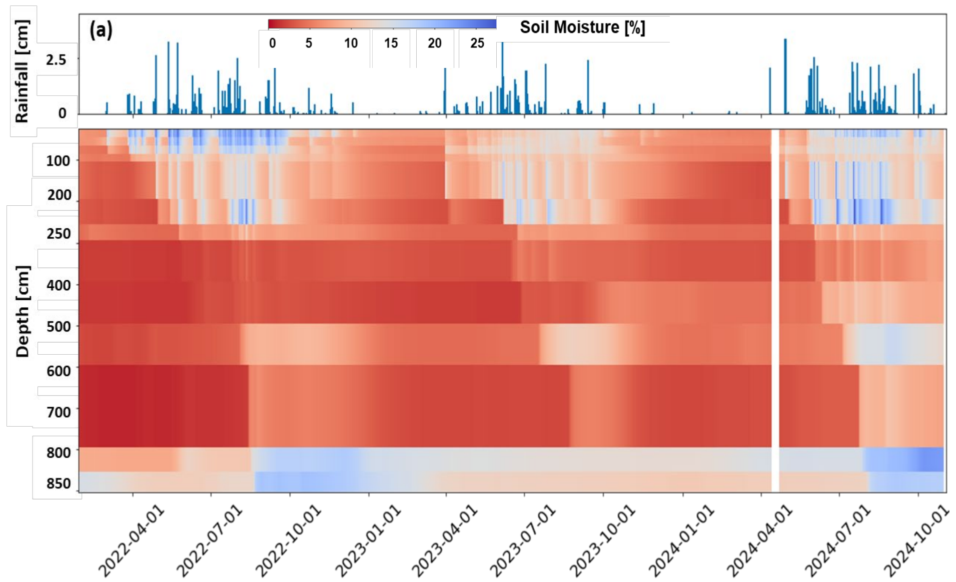


Ridge plots of soil moisture observations from the neutron moisture probe indicating the presence of soil layering from 190 cm

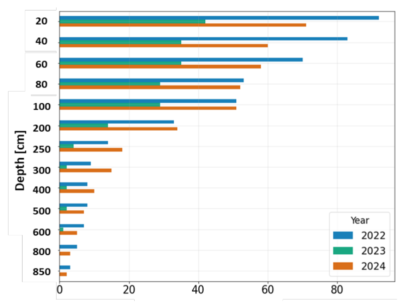


In-situ soil water retention curve (soil moisture vs soil water potential sensors) at 0.5 meters. Colours indicate month of the year.

Tracking Water Through the Unsaturated Zone



(Above) Precipitation (bars), curtain plots (i.e. heatmaps) from depth-interpolated soil moisture sensors at the Banksia Woodland site (Gingin). Year 2023 recorded the historical lowest precipitation.



(Left) Number of wetting fronts detected at each sensor's depths grouped by year

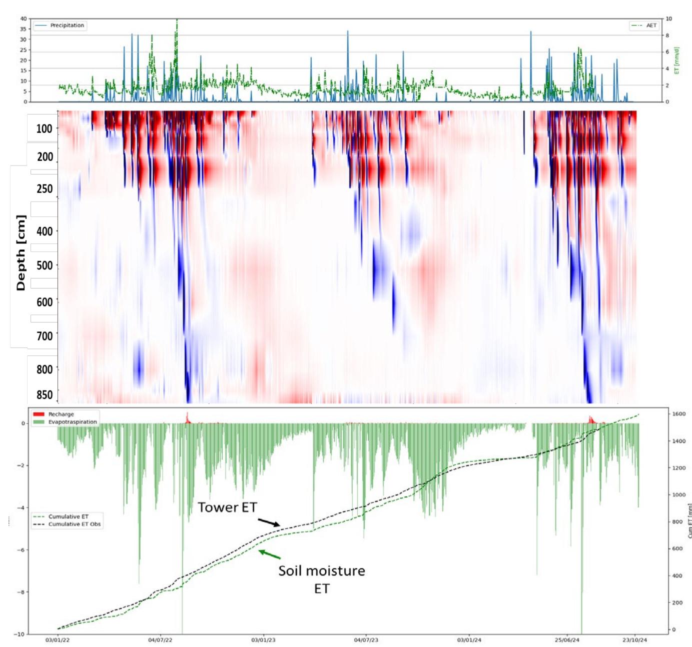
Observation driven model

Soil moisture observations can be used in a simple data-driven model to infer fluxes.

D_n is the positive rate of soil moisture change above field capacity

ET_n is the negative rate of soil moisture change below field capacity (negative change is due to root water uptake)

$$\Delta\theta_n^t = \theta_n^t + \theta_n^{t-1} \qquad \begin{cases} D_n^t = \Delta\theta_n^t \cdot \Delta z & \text{if } \Delta\theta_n^t > 0 \text{ and } \theta_n^t > F_c \\ ET_n^t = \Delta\theta_n^t \cdot \Delta z & \text{if } \Delta\theta_n^t < 0 \text{ and } \theta_n^t < F_c \end{cases}$$



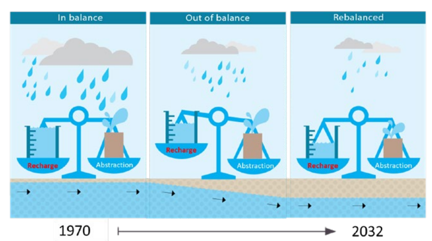
Evapotranspiration (green) and recharge (red) inferred from soil moisture observations. Cumulative ET from soil moisture and Eddy covariance tower.

Conclusions

Processes characterization in thick unsaturated zones cannot be thoroughly accomplished if observations are only constrained to the top part of the soil.

Extending system knowledge to capture the interface between unsaturated zone and groundwater allow for enhanced calibration/validation of Earth System Models. (i.e. bottom boundary conditions)

RiCC provides variables not only for standard water balance but also for the validation of new approaches (e.g. observation driven model).



Integrating several soil moisture techniques helps quantifying uncertainties for groundwater resource management

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