Concepts, Theories, and Models of Macropore Flow in the Riparian Vadose Zone

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Background

The excess of agrochemical and fertilizers applied to the fields leads to a release of pollutants and pesticides that degrade surface water bodies adjacent to riparian areas

Surface water pollution control practices such as riparian buffers (RB) typically focus on surface runoff with little attention given to subsurface flow and transport

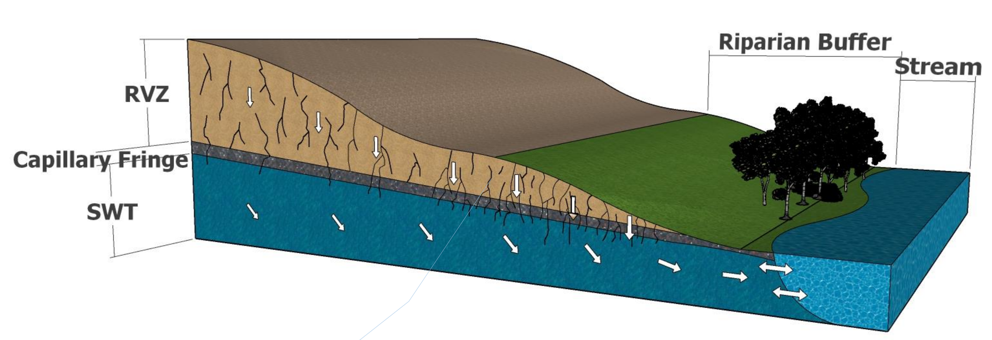


Fig 1. Riparian area with RB. RVZ, riparian vadose zone; SWT, shallow water table (Orozco-López *et al.*, 2018).

Field evidence suggests a **prevalence of macropore flow (MF) in RVZ** due to high hydraulic gradients created by the adjacent draining stream, and abundant biological activity (roots, worms, etc.)

Hypothesis

Subsurface transport of contaminants to SWT and surface water bodies can be significant with MF in RVZ, negating the intended benefits of RB

Objective

- To review and identify the theories and concepts describing MF, suitable to the RVZ specific conditions.
- To analyze the influence that a typical RVZ seasonal SWT can exert on MF and transport processes.

Conceptual Framework

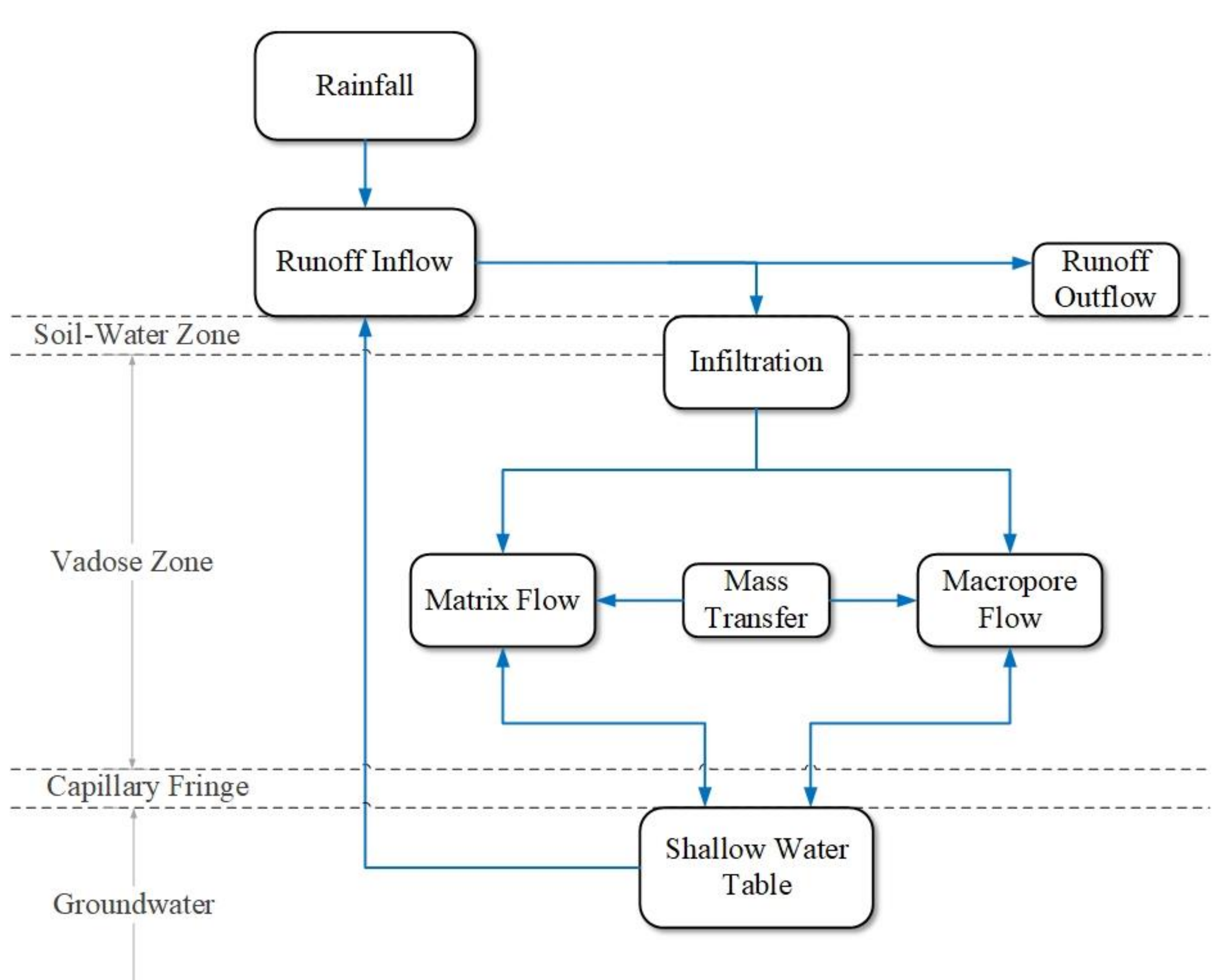


Fig 2. Conceptual framework of riparian transport processes (Orozco-López *et al.*, 2018).

Concepts, Theories, and Models of MF

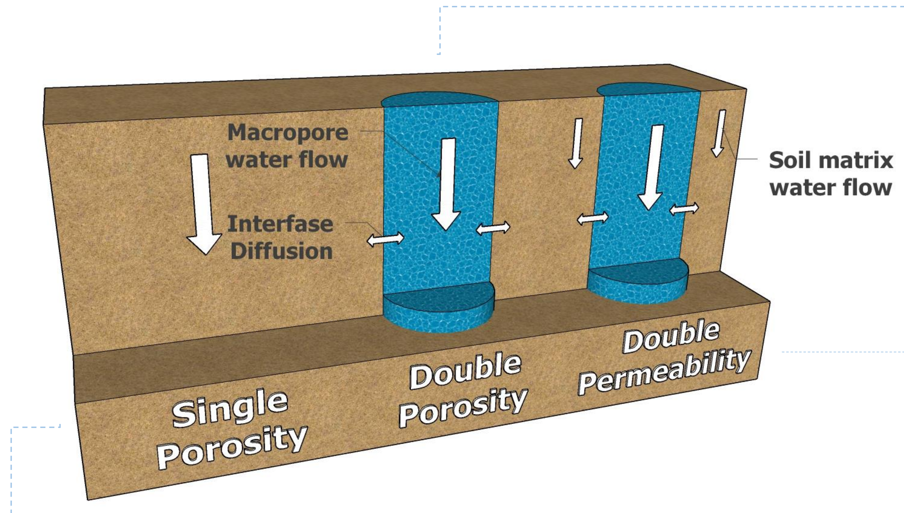


Fig 3. Classification of conceptual models of water flow and transport in porous media (Orozco-López *et al.*, 2018)

Kinematic Wave (Germann, 1985)

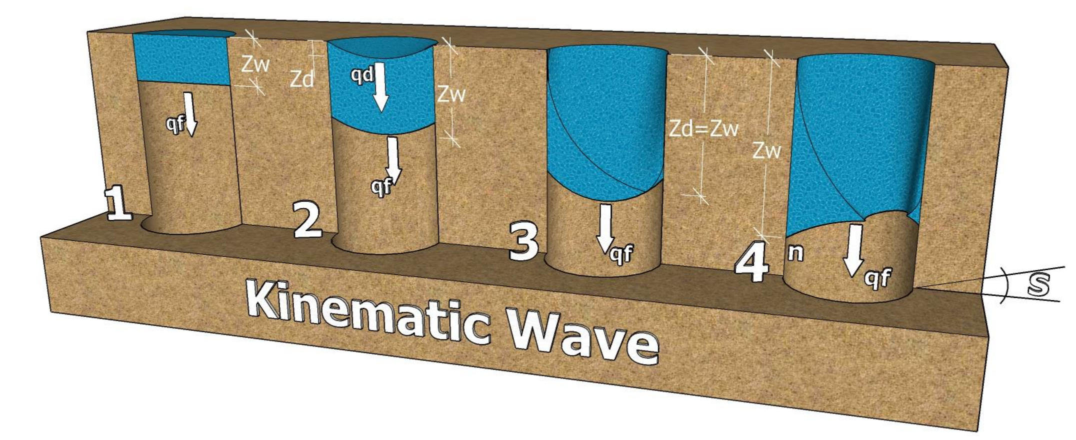


Fig 4. Macropore kinematic wave stages: (1) wetting shock front (**W**) with velocity q_f and position Z_w; (2) draining front (**D**) after cessation (**S**) with q_d and Z_d; (3) D intercepts W; (4) wave breaks up with velocity q_f. (Orozco-López *et al.*, 2018)

Rivulet of MF (Germann *et al.*, 2007)

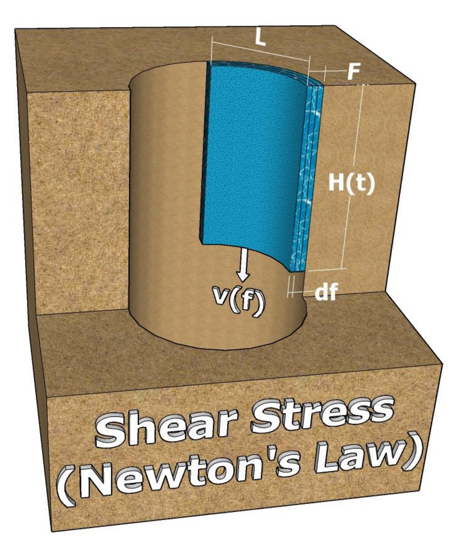


Fig 5. Shear stress in a macropore under Stokes flow.

L, width; F, thickness; *df, differential of F; H(t),* height in time; *v(f),* velocity. (Orozco-López *et al.*, 2018)

Source-Responsive Theory (Nimmo, 2010)

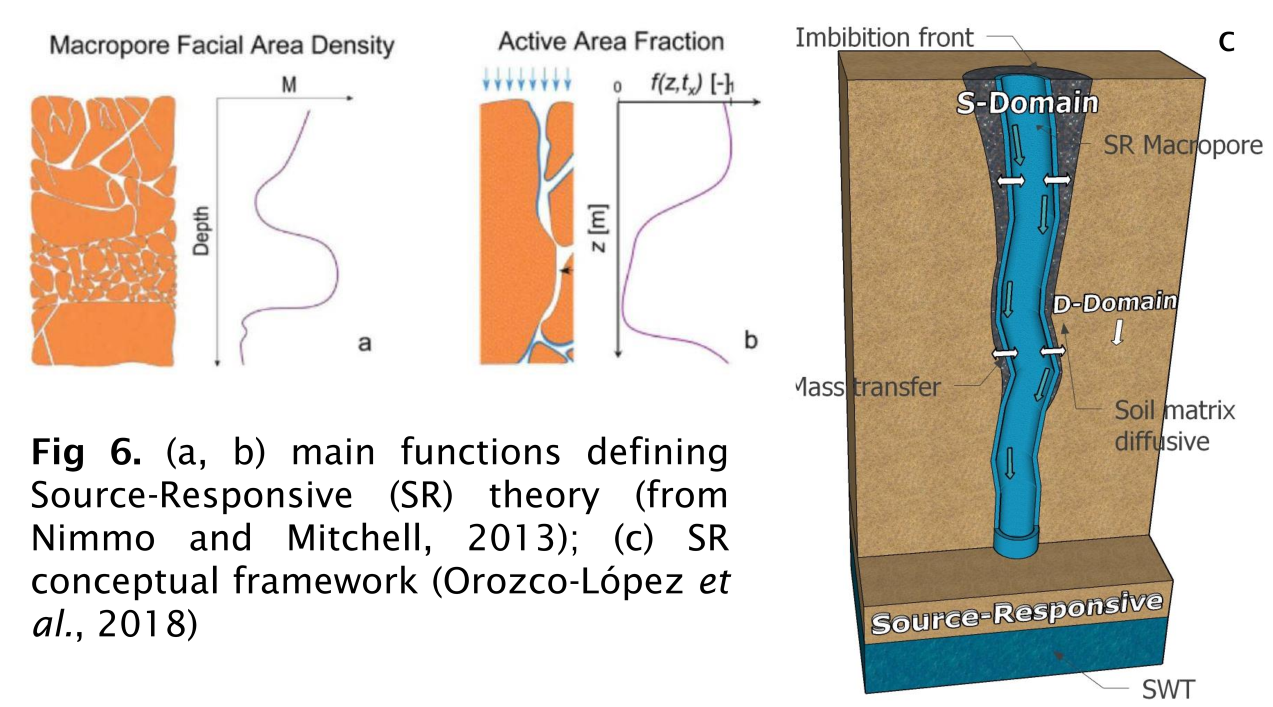


Fig 6. (a, b) main functions defining Source-Responsive (SR) theory (from Nimmo and Mitchell, 2013); (c) SR conceptual framework (Orozco-López *et al.*, 2018)

SWT Influence on Infiltration and MF in RVZ

A SWT will increase the antecedent water content θ along the soil profile, resulting in a reduction in the infiltration capacity of the soil. A SWT will reduce the threshold at which the overland runoff occurs.

When MF is present, the existence of a SWT can potentially increase the rate of MF transport of water and pollutants through the RVZ.

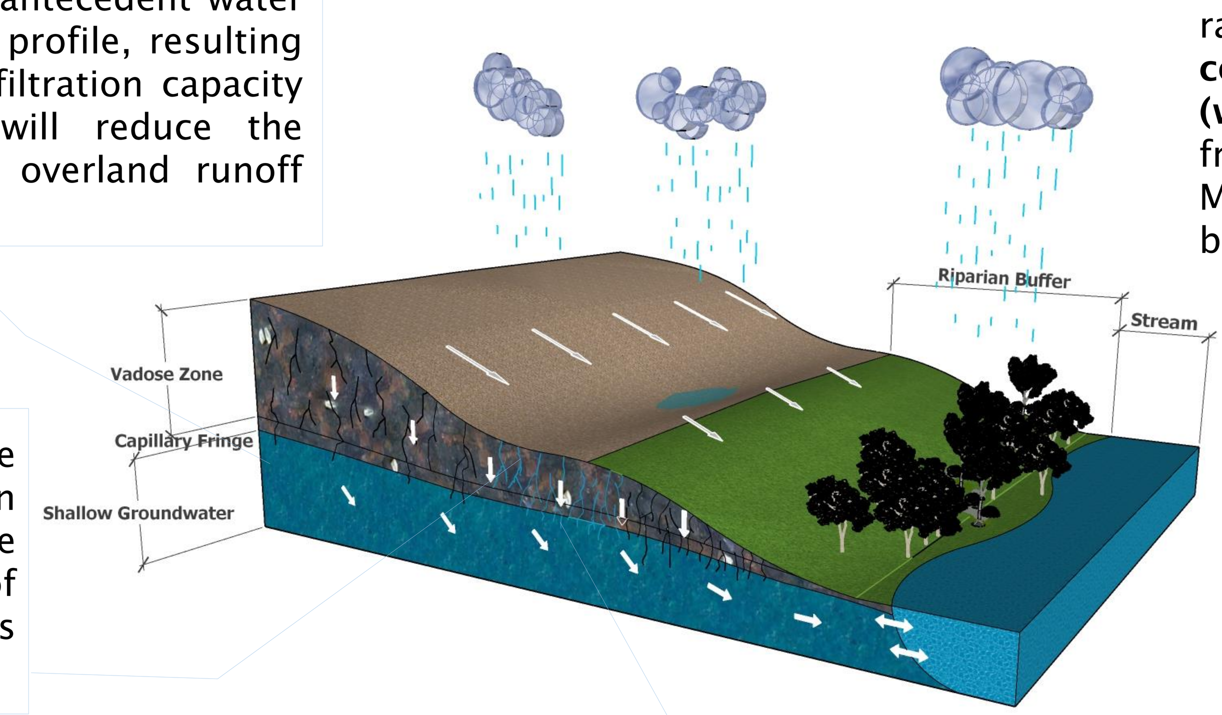


Fig 7. Riparian area during a rainfall event under **ponding conditions (p)**. **Wetting front (w)** arrived to the capillary fringe. Under these conditions MF is more easily activated (in blue).

When water fills a macropore, flow and transport can be extremely fast towards the SWT and the stream nearby

SWINGO (Muñoz-Carpena *et al.* 2018)

SWINGO is an infiltration model for initially non-ponded soils under unsteady rainfall conditions with a SWT. Initial hydrostatic "drained to equilibrium" condition with $\theta = \theta(h)([-])$. Stages of infiltration rates in SWINGO are given by:

$$q = I; 0 < t \leq t_p$$

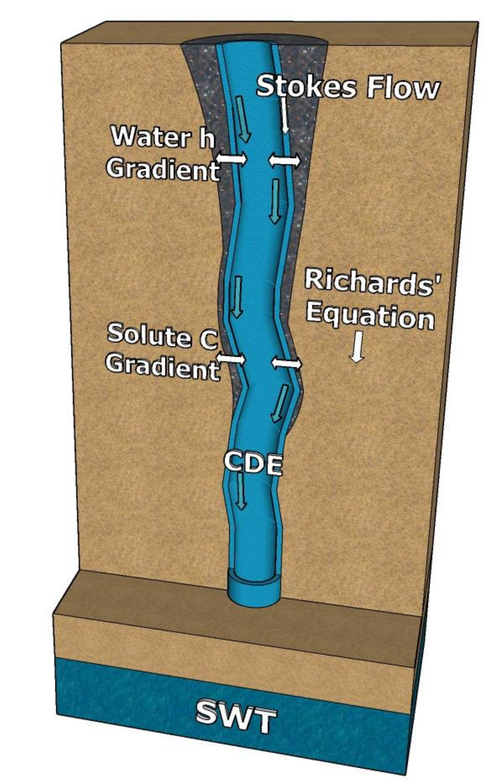
$$q = q_p; t_p < t < t_w$$

$$q = min(q_w, i); t \geq t_w$$ (Fig. 7)

Future Perspectives

MF Model Layout

Fig 8. Selection of theories and concepts in MF modeling. Dual-Permeability model (Fig 3) with a SWT (Fig 7). C, concentration; CDE, convective- dispersive equation; h, pressure.



Limitations

There is a gap between the idea of how the water flows in a pore and what impact MF has in the field. How to characterize MF in the field is a limiting factor to resolve this issue.

Future Research

Field studies of MF in RVZ are in crucial needs to test and refine the MF theories and models:

- Laboratory experiments to determine flow dynamics and characterize the required parameters (Fig. 9)
- Field experiments to calibrate and validate those parameters (e.g. Electrical resistivity tomography, magnetic resonance imaging, passive capillary lysimeter)

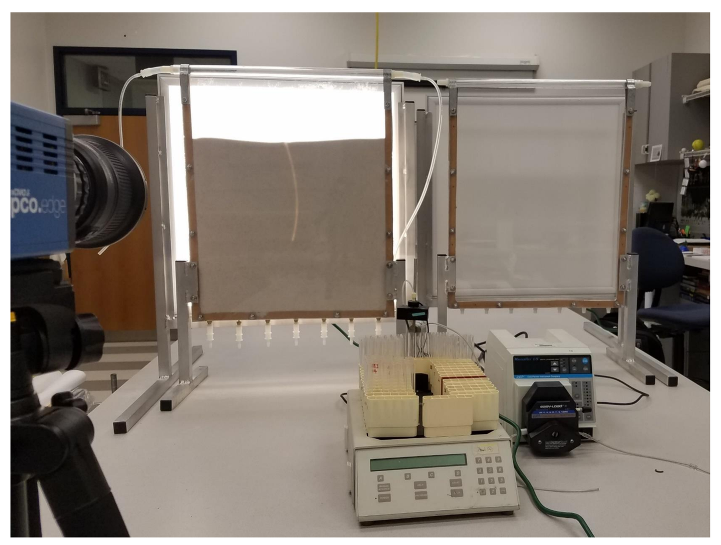


Fig 9. MF laboratory experiment. Determination of flow dynamics in porous media using light transmission method. 2-D flow chamber equipped with rainfall simulator

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