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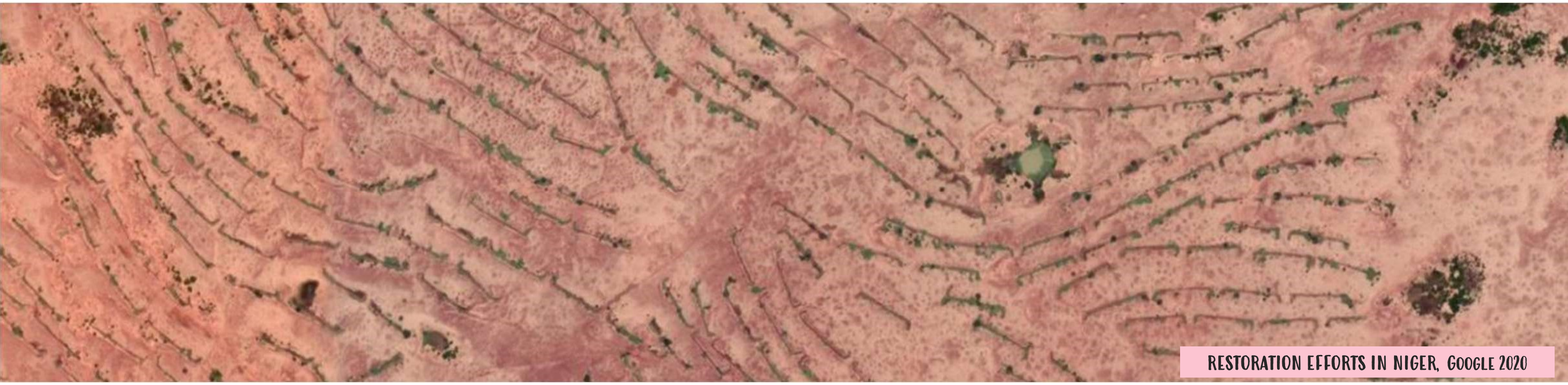
The role of cover and pattern of resource sinks in the recovery of degraded drylands



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- The need for widespread and efficient restoration actions is recognized by the upcoming UN Decade on Ecosystem Restoration.
- Restoration rates need to exceed land degradation rates to achieve land degradation neutrality aimed by the UN Convention to Combat Desertification.
- This need is particularly urgent in developing countries, the world's regions most affected by land degradation and climate change.
- Simple and low-cost restoration options are possible in these countries.

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Low-cost restoration in patchy drylands:
Installation of resource sinks
(obstructions to break runoff pathways and retain resources)

- Effectivity tested in several field studies in drylands worldwide
- Testing mainly focused on the materials used to build the sinks
- <u>There is no information on the spatial design of this restoration</u>



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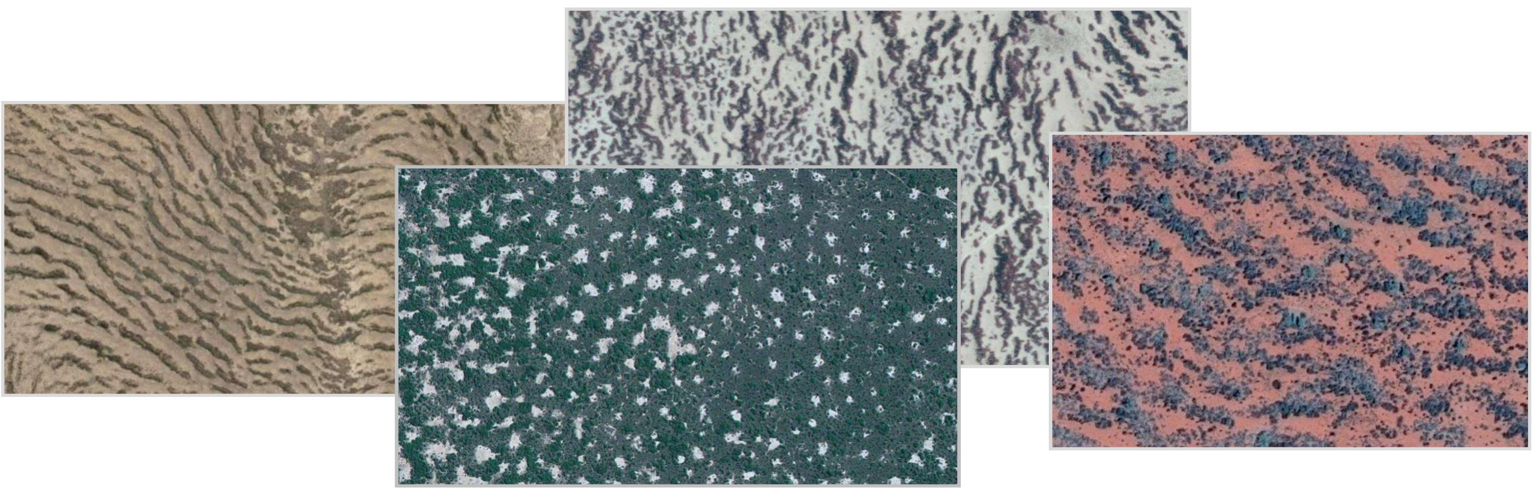
Role of spatial pattern and cover?

- Vegetation cover and pattern, and its associated redistribution of surface water from runoff sources to runoff sinks, are known to play a critical role in the sustenance of patchy drylands.
- <u>How do cover and pattern of installed resource sinks affect the recovery of degraded drylands?</u>
- We used a well-known dryland model (Rietkerk et al. 2002) to answer this question



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Methods

The model and experimental design

(3 state variables, 3 partial differential equations[1])

[*plant biomass*]

$$\frac{\partial P}{\partial t} = c\, g_{\max} \frac{W}{W + k_1} P - dP + P_{\text{seed}} + D_{\text{p}} \Delta P,$$

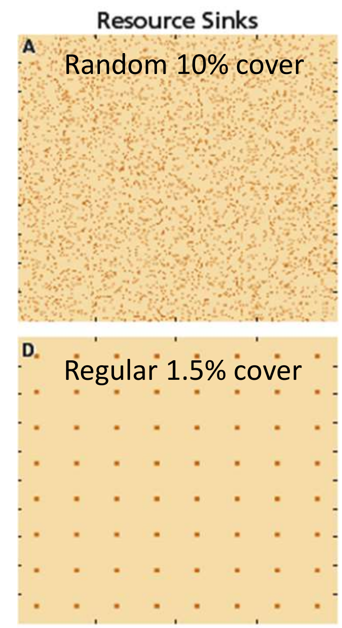
[*soil water*]

$$\frac{\partial W}{\partial t} = \alpha\, O \frac{P + k_2 W_{\text{inf}}}{P + k_2} - g_{\max} \frac{W}{W + k_1} P - r_{\text{w}} W + D_{\text{w}} \Delta W,$$

[*surface water*]

$$\frac{\partial O}{\partial t} = R - \alpha\, O \frac{P + k_2 W_{\text{inf}}}{P + k_2} + D_{\text{o}} \Delta O.$$

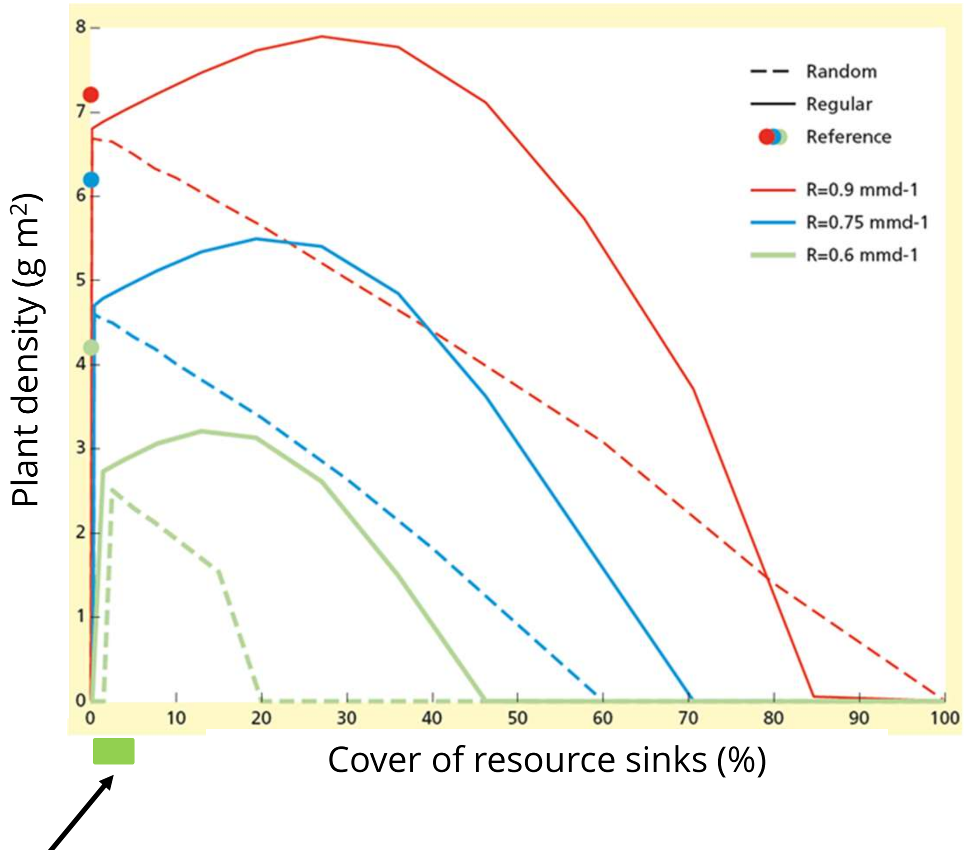
[1] *Parameter symbols, units, values and definitions can be found in Rietkerk et al. 2020, American Naturalist*



Two examples of initial conditions

- Lattice of 200 x 200 cells of 2m x 2m. Cells vary in amount of plant biomass and form part or not of an installed resource sink.
- Installed resource sinks modelled as areas with 3 times higher water infiltration (W_{inf}) than bare soil (plant biomass = 0).
- Simulation started with varying cover of resource sinks X 2 patterns (random and regular) X 3 rainfall/aridity regimes.
- The model parameterization used results in a bare soil state if the cover of resource sinks is zero

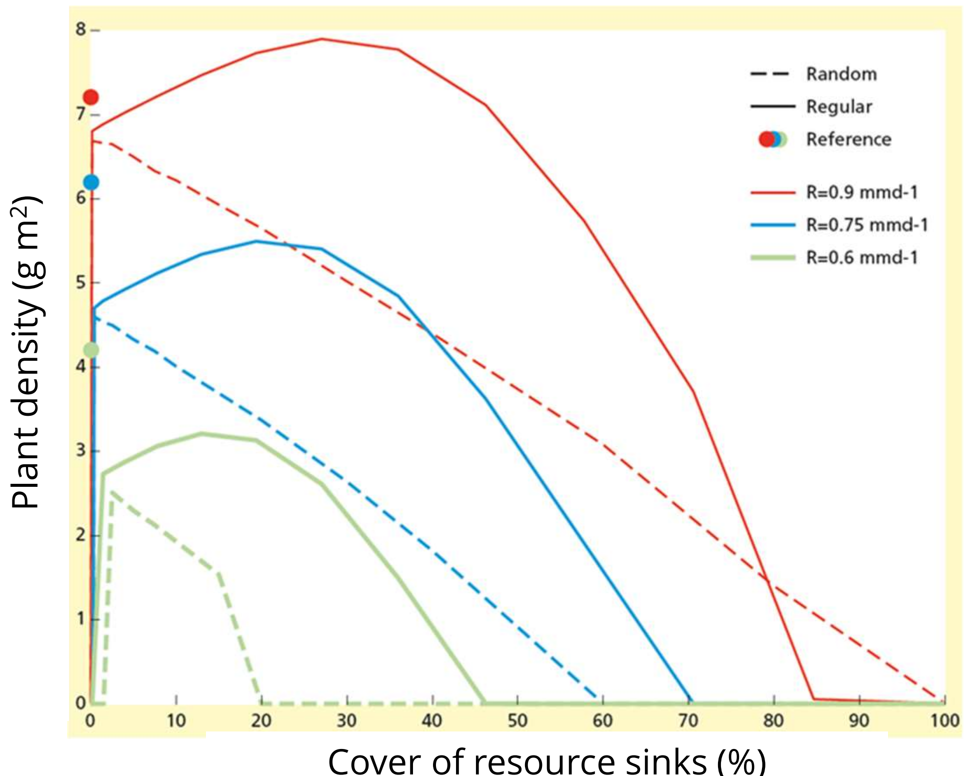
Results: role of cover



A very small cover of resource sinks suffices to trigger the recovery of vegetation

Related to a maximized displacement of surface water towards resource sinks

Results: role of cover



However, high covers of resource sinks lead to a complete failure of vegetation recovery

The displacement of surface water to vegetation patches decreases with the cover of resource sinks. At some level, there is not enough concentration of surface water anywhere that allows plants to establish at that level of aridity.

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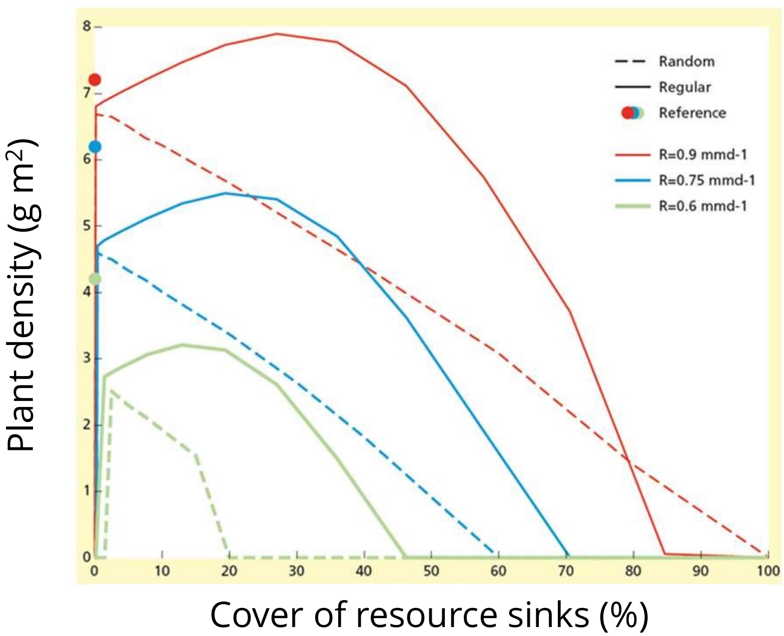
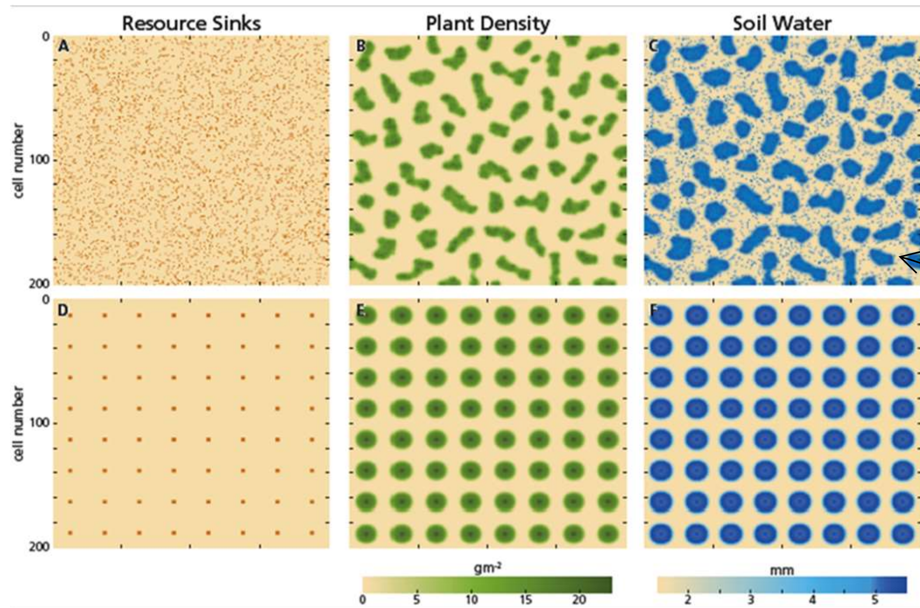
Results: role of spatial pattern



Regular distributions allowed higher plant densities than random distributions for a given resource-sink cover.



The little blue dotes between plant patches here

Explained by the nature of vegetation in our system to form regular patches. When resource sinks are applied randomly and regular vegetation patterns emerge, some of the (installed) <u>resource sinks will stay in the areas between vegetation patches</u> where water will infiltrate at a higher rate than in bare soils, lowering the net displacement of surface water towards vegetation patches and therefore decreasing plant density.

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Take-home messages

- Both the cover and the spatial pattern of resource sinks affect the success of the restoration.
- The most effective cover and pattern are those that characterize the reference healthy state.
- If reference plant cover is unknown, it is safer to install lower than higher covers of resource sinks.
- The high efficiency of low covers combined with the low-cost materials needed suggest that the installation of resource sinks in severely degraded drylands has the potential to be a key contributor to achieve land- degradation neutrality, particularly in developing countries.