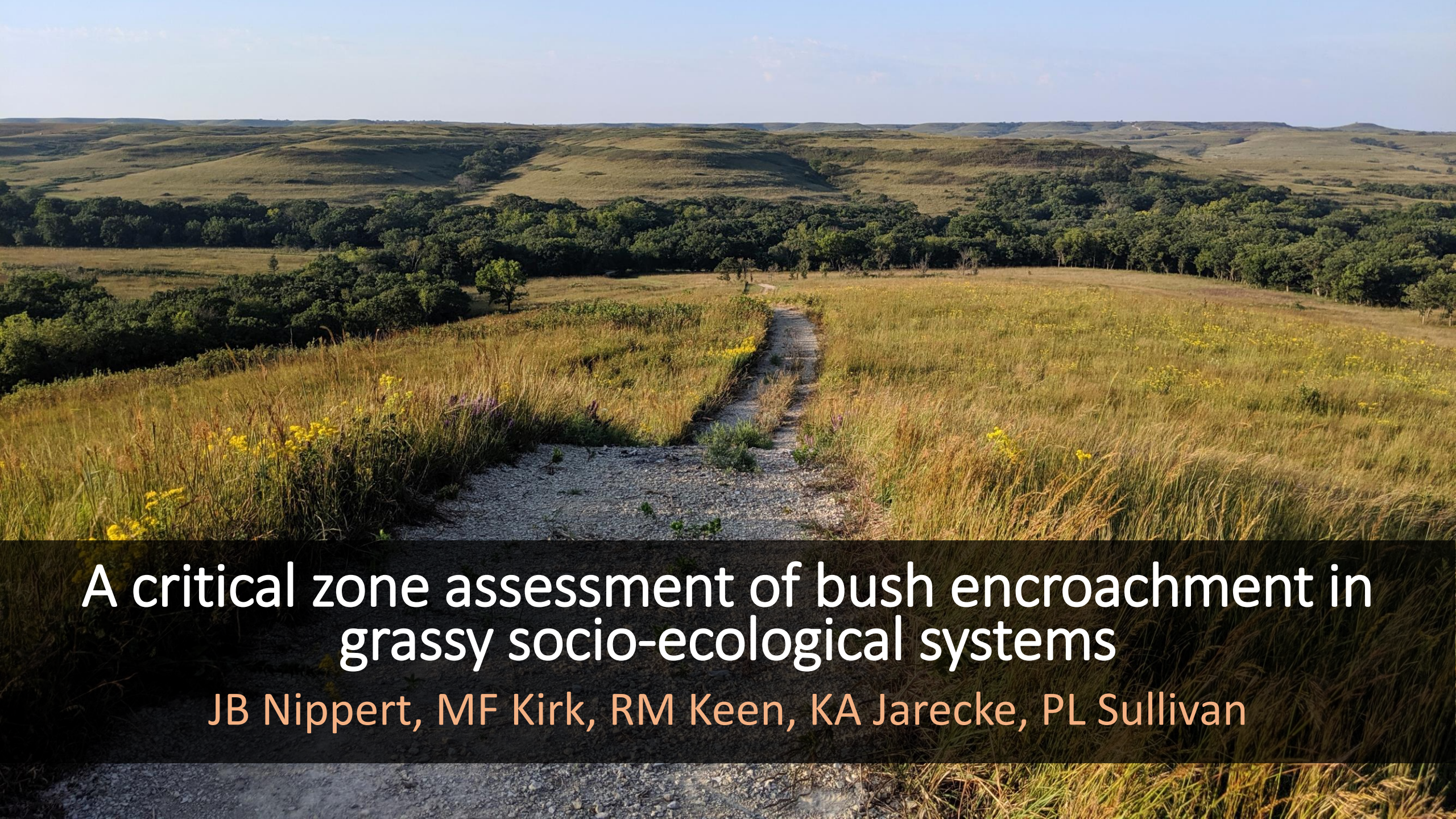
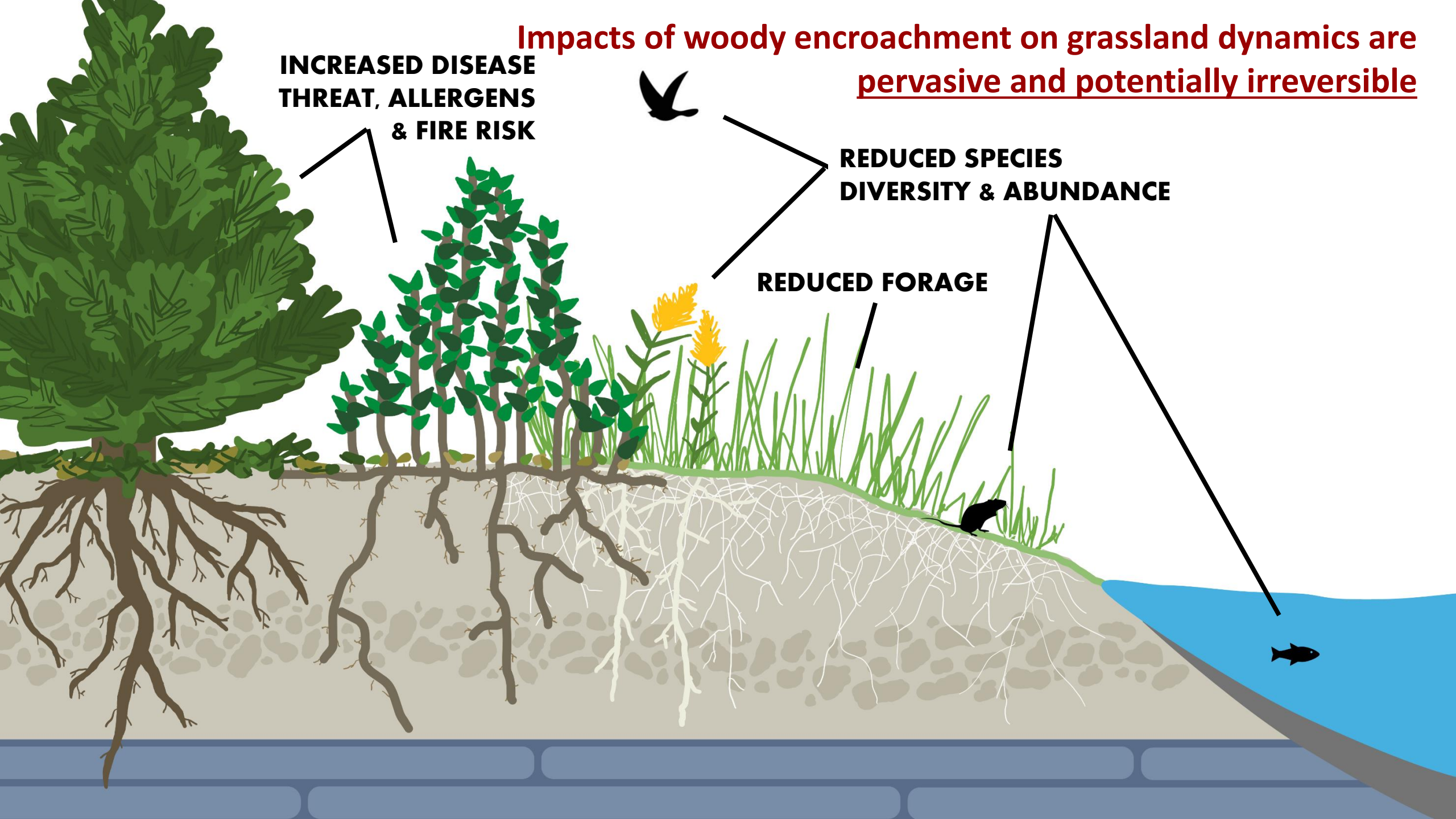


A critical zone assessment of bush encroachment in grassy socio-ecological systems

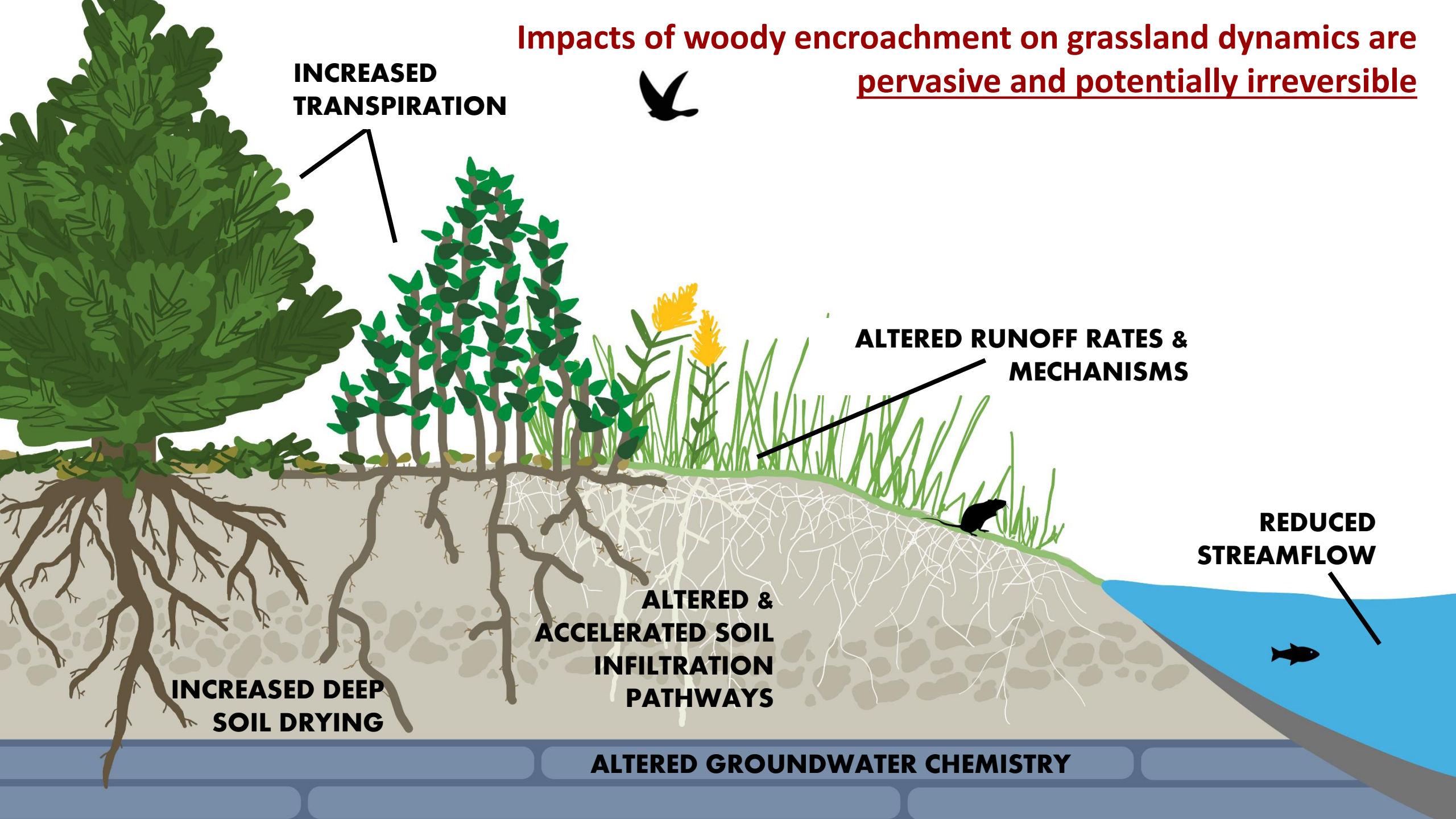
JB Nippert, MF Kirk, RM Keen, KA Jarecke, PL Sullivan

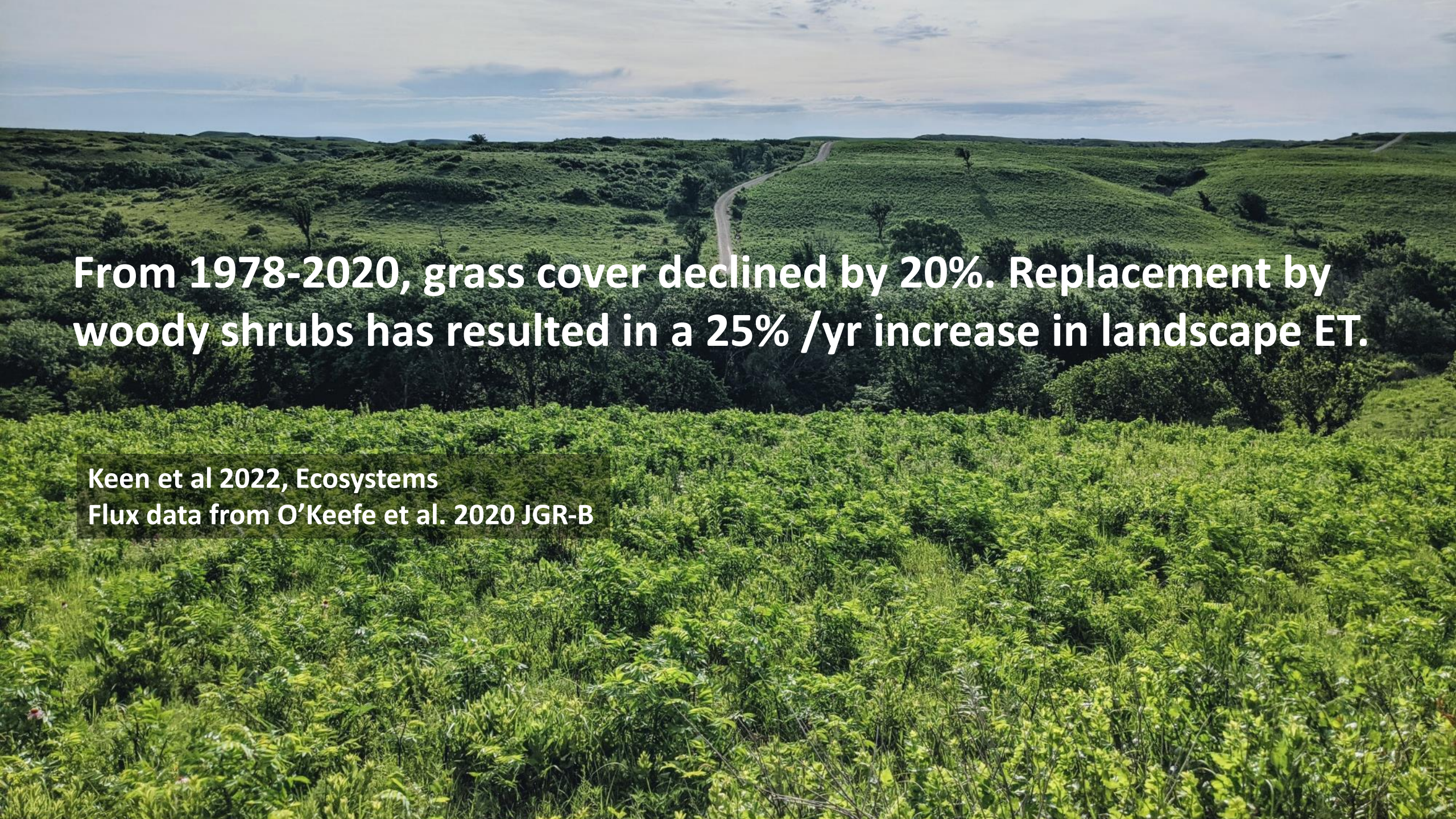
KONZA PRAIRIE

Ecosystem states

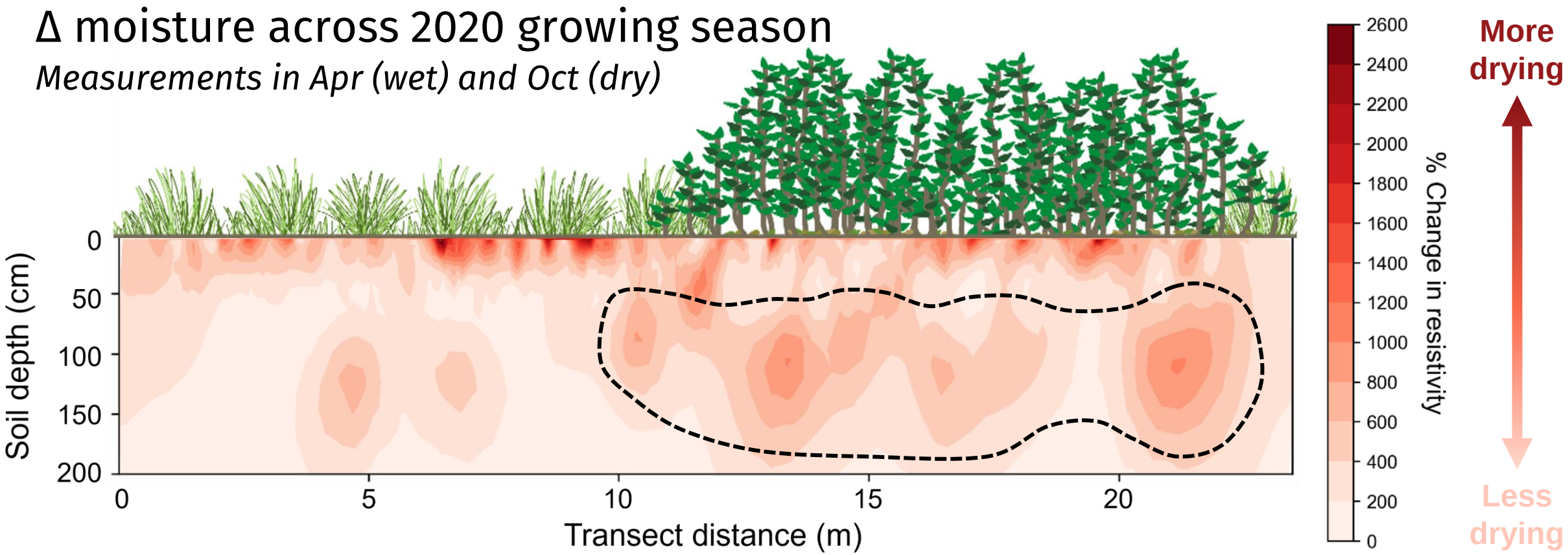

Impacts of woody encroachment on grassland dynamics are pervasive and potentially irreversible
INCREASED DISEASE THREAT, ALLERGENS & FIRE RISK
REDUCED SPECIES DIVERSITY & ABUNDANCE
REDUCED FORAGE

Impacts of woody encroachment on grassland dynamics are pervasive and potentially irreversible



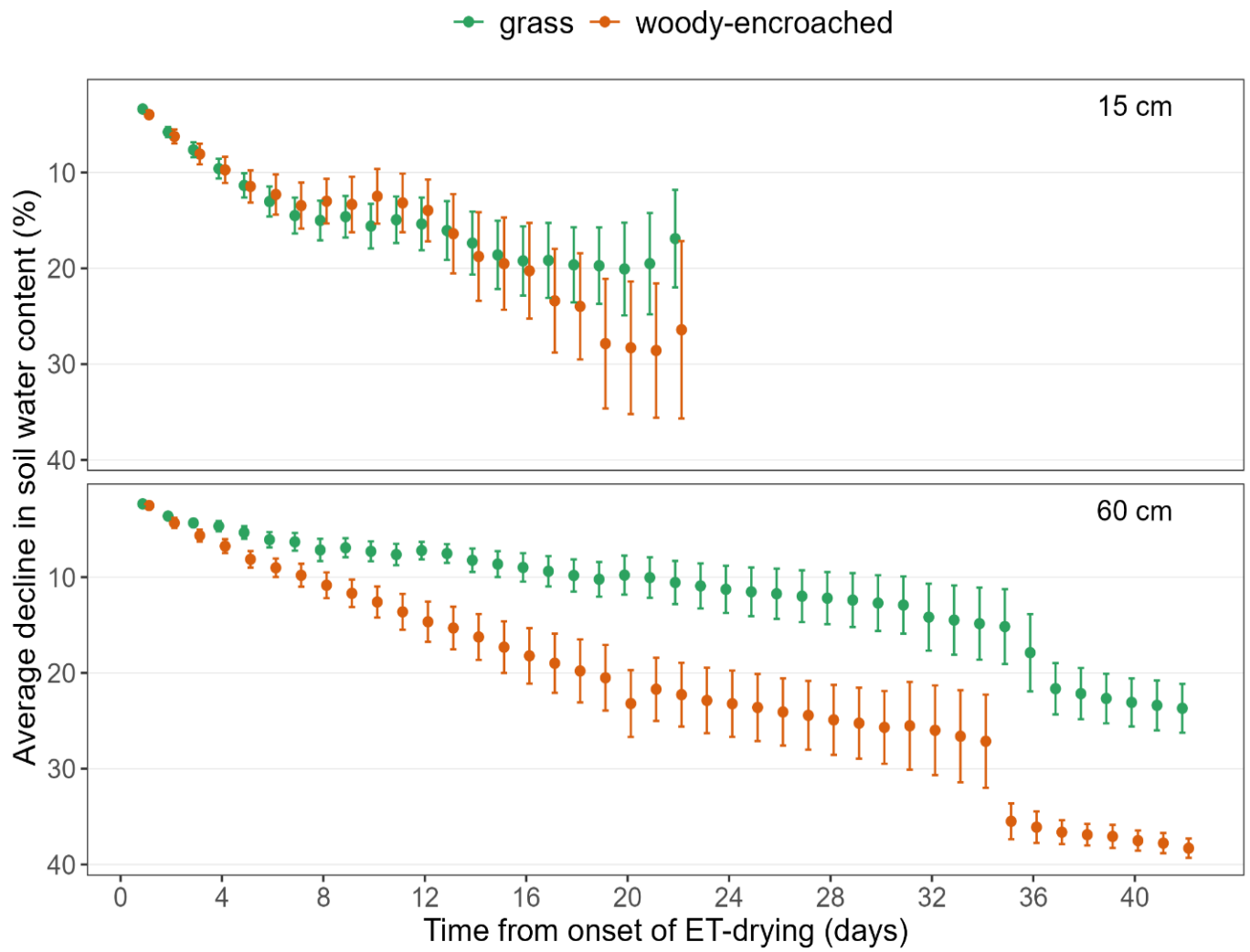

From 1978-2020, grass cover declined by 20%. Replacement by woody shrubs has resulted in a 25% /yr increase in landscape ET.
Keen et al 2022, Ecosystems
Flux data from O'Keefe et al. 2020 JGR-B

Soil moisture depletes faster and at deeper depths under areas with woody plants



Jarecke et al. *In Prep*

Soil moisture depletes faster and at deeper depths under areas with woody plants

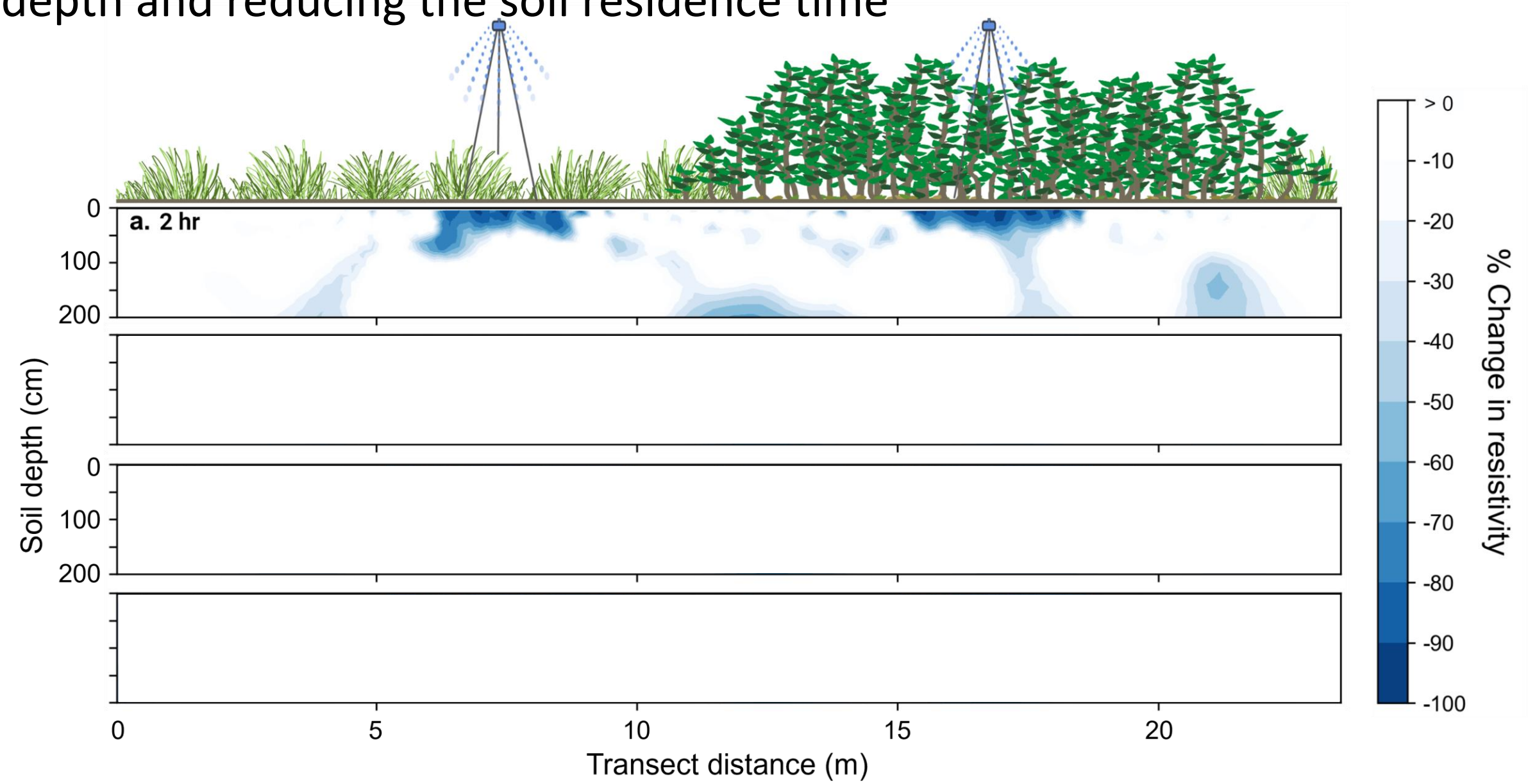


Declines at 15 cm were similar beneath shrubs and grasses.

Soil moisture declined up to 20% more at 60 cm depth beneath shrubs compared to grasses

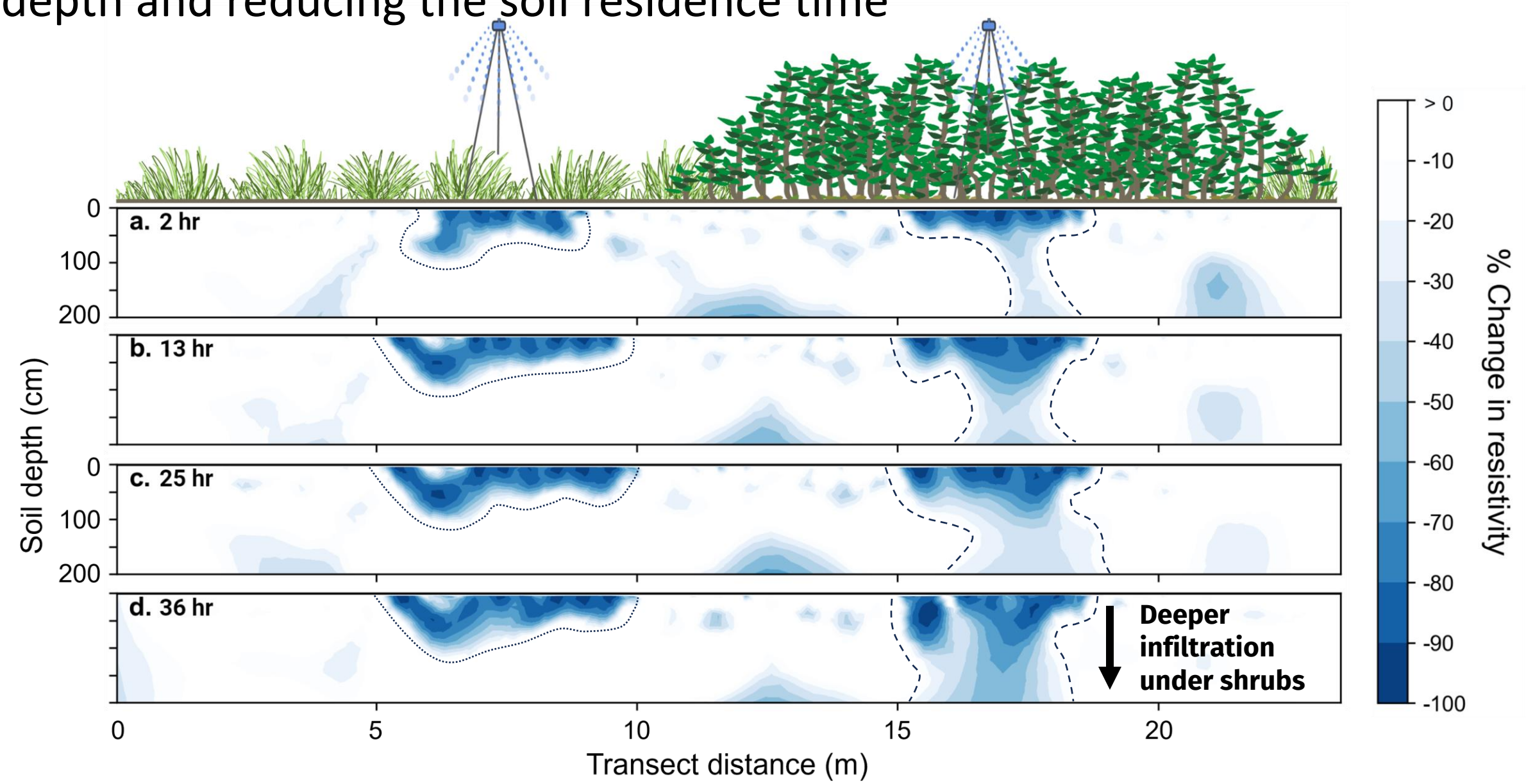
Jarecke et al. *In Prep*

Coarse woody roots create macropores, increasing rainfall infiltration depth and reducing the soil residence time

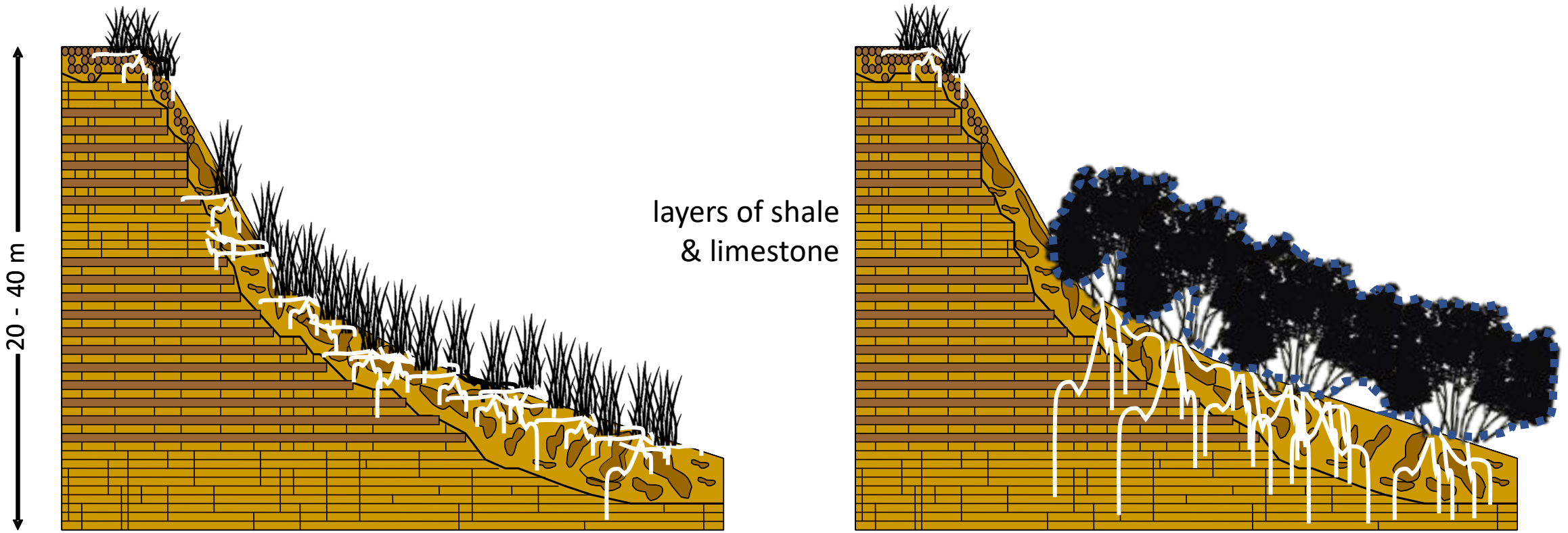


Jarecke et al., 2024 *Ecohydrology*

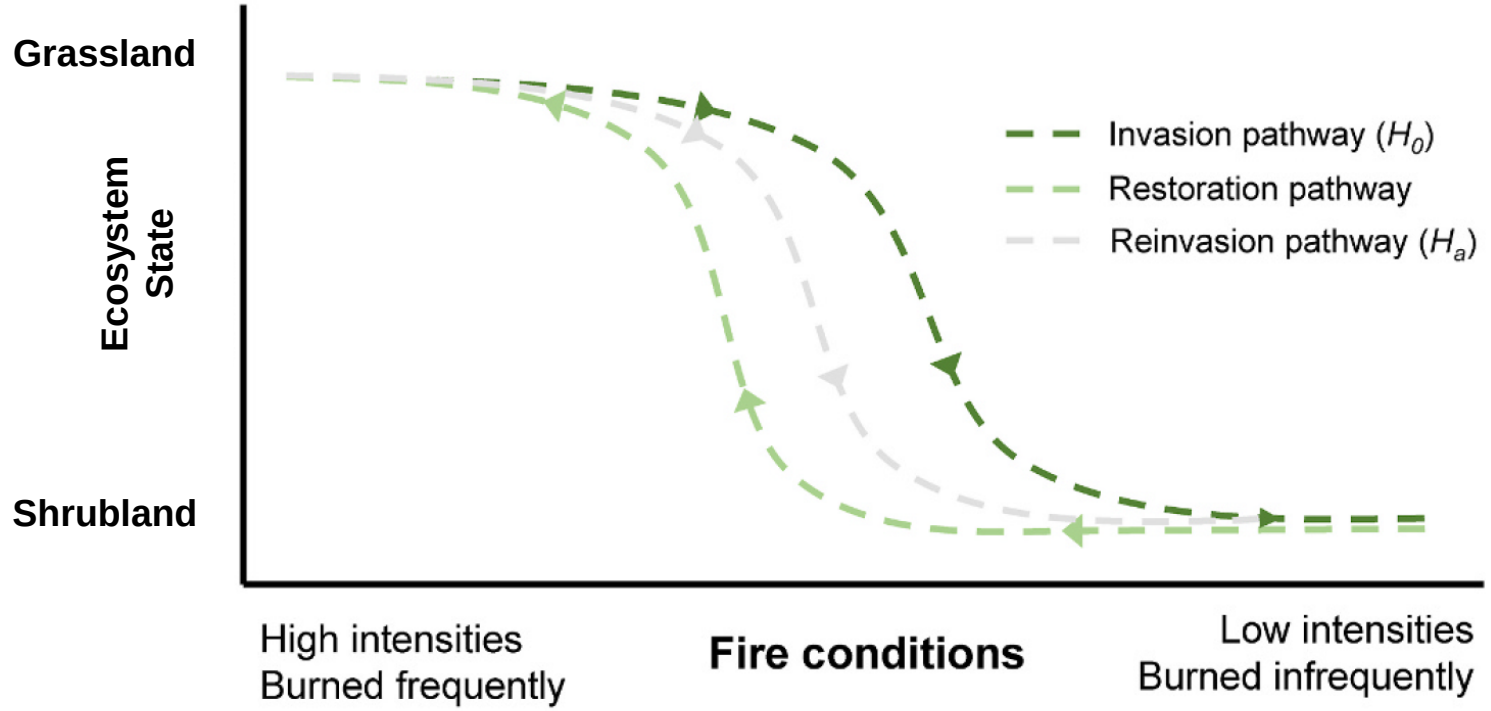
Coarse woody roots create macropores, increasing rainfall infiltration depth and reducing the soil residence time

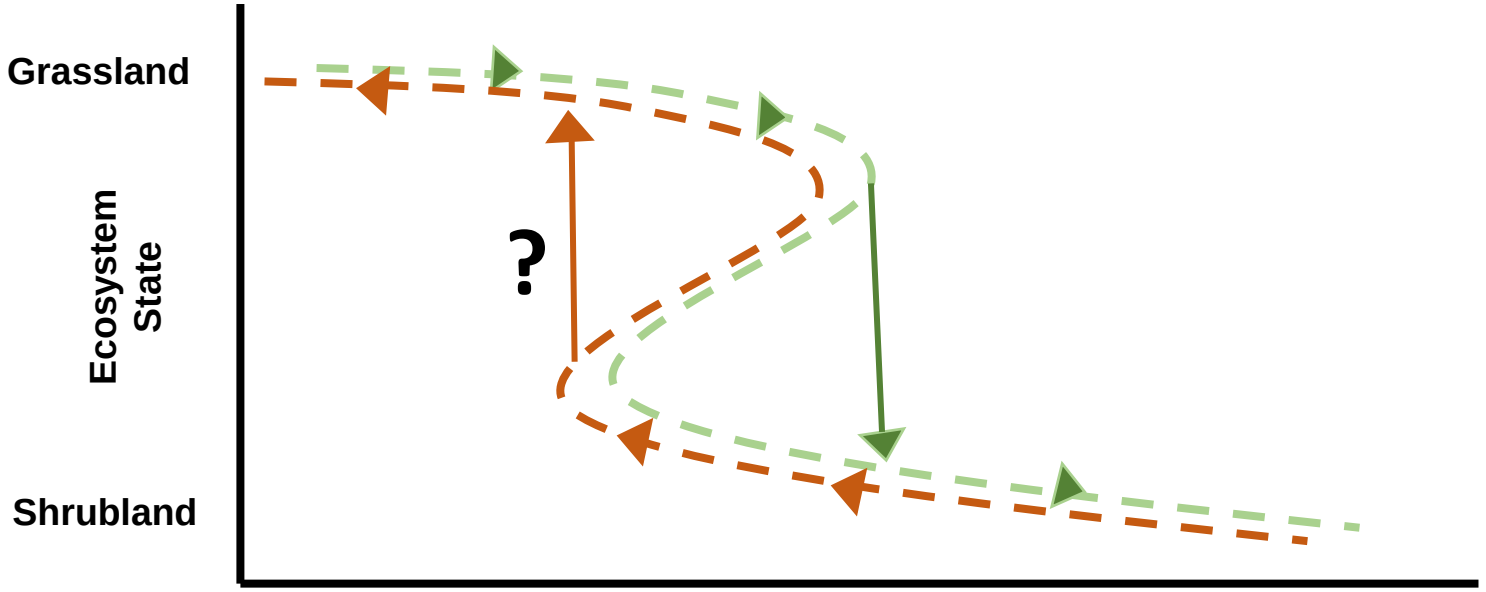


Jarecke et al., 2024 *Ecohydrology*



- Soil macropores leave legacies, even if woody shrubs are removed aboveground
  Altered infiltration pathways → water moves deeper, faster
- Carbonate weathering happens deeper, associated with bedrock and not soils →
  resulting in accelerated kastification of the ecosystem
- These changes modify bedrock composition, groundwater recharge, and alluvial systems





State transitions can vary based on antecedent conditions, as well as legacies in the system.

Fogarty et al. 2025 JEnvMgt

Systems with fold bifurcation exhibit hysteresis. If these changes occur belowground, legacies may impede a state transition back to the starting conditions.

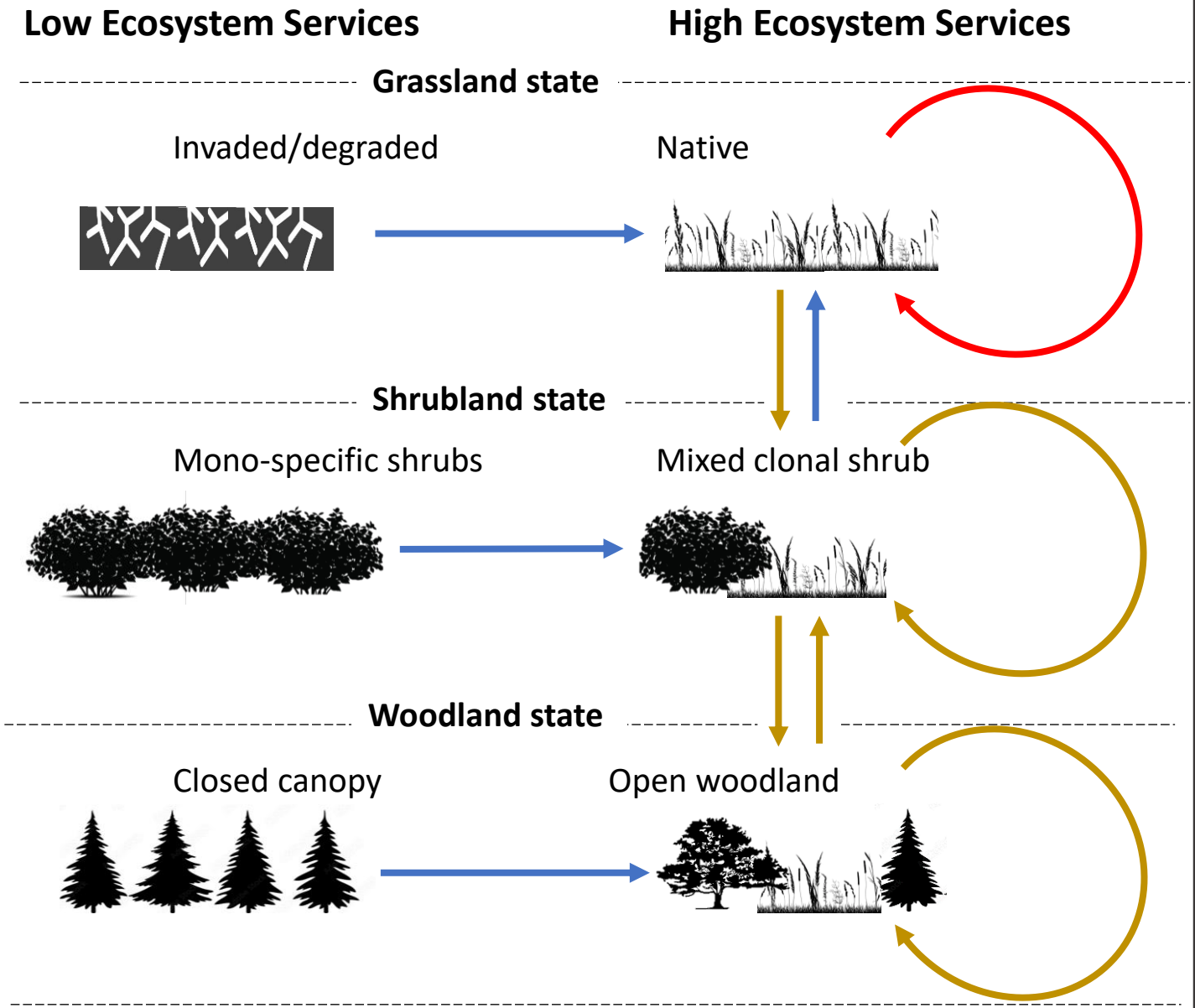
- Unclear if these conditions can be reversed

What if we are spending all this time trying to get back to starting conditions that are no longer attainable?

- *Climate change has altered the baseline conditions*
- *In the pursuit of the unattainable, what if we miss the opportunity to protect other areas?*

Do we need a new conceptual approach to this problem?

Rather than a ‘successful outcome’ being conditional on a particular state, what if our goal was maximizing high quality ecosystem services across a range of states.



This type of a framework is likely more achievable, costs fewer resources, and has broadly higher conservation outcomes than blind pursuit of the ideal.

RAD Framework

- Resist
  - Use management options to resist changes to undesirable state or conditions
- Accept
  - If management goals cannot succeed (cost, time, or efficacy), accept the change
- Direct
  - Apply conservation methods to direct state changes to conditions with higher value ecosystem services

Significant consequences

1. Shrubs transpire a lot more water than grasses
2. Greater depth of soil drying, removing moisture surplus

Potentially irreparable

3. Roots modify soil structure, infiltration pathways,
4. Modify bedrock composition, groundwater recharge, and alluvial systems

Nuanced approach

5. RAD provides a decision-tree style to evaluating option for success, seeking maintenance of ecosystem services rather than an idealized state.

More humility, less hubris