Carbon movement and management: why carbon, what can it do for you and how does it (or can we) do it?

Toby Maxwell, **TMaxwell@usgs.gov**
U.S. Geological Survey, Forest & Rangeland Ecosystem Science Center, Prineville, Oregon.

Overview

1. What can carbon do for you? Harnessing carbon to improve restoration
   - Soil health
   - Resilience of native plants

2. Management to improve or preserve carbon
   - Annual grasses and fire
   - Grazing management

3. The carbon cycle: why is there so much national focus on carbon in deserts, rangelands, sagebrush steppe?
   - The carbon cycle
   - how are plant and soil carbon related to climate, climate change?

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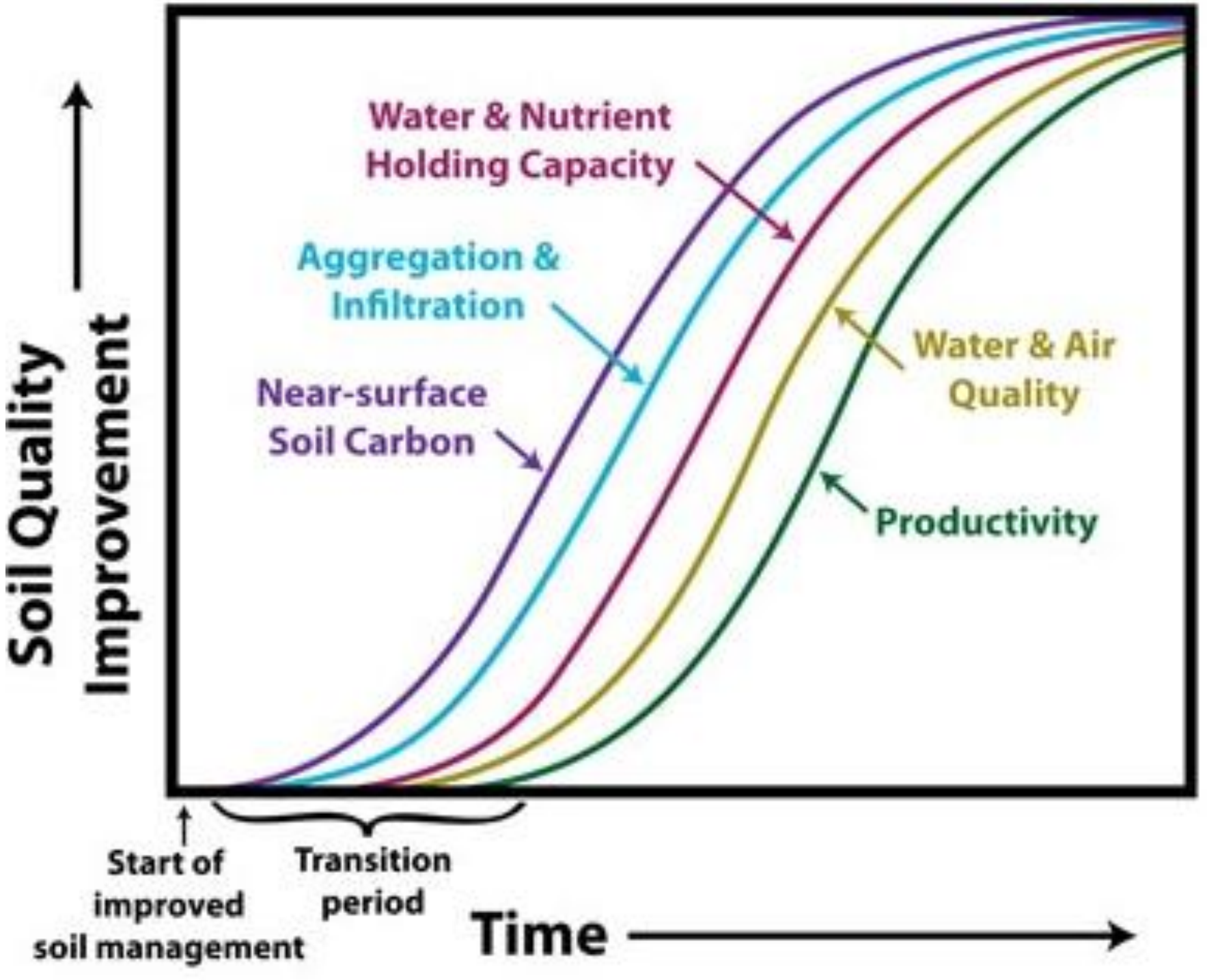
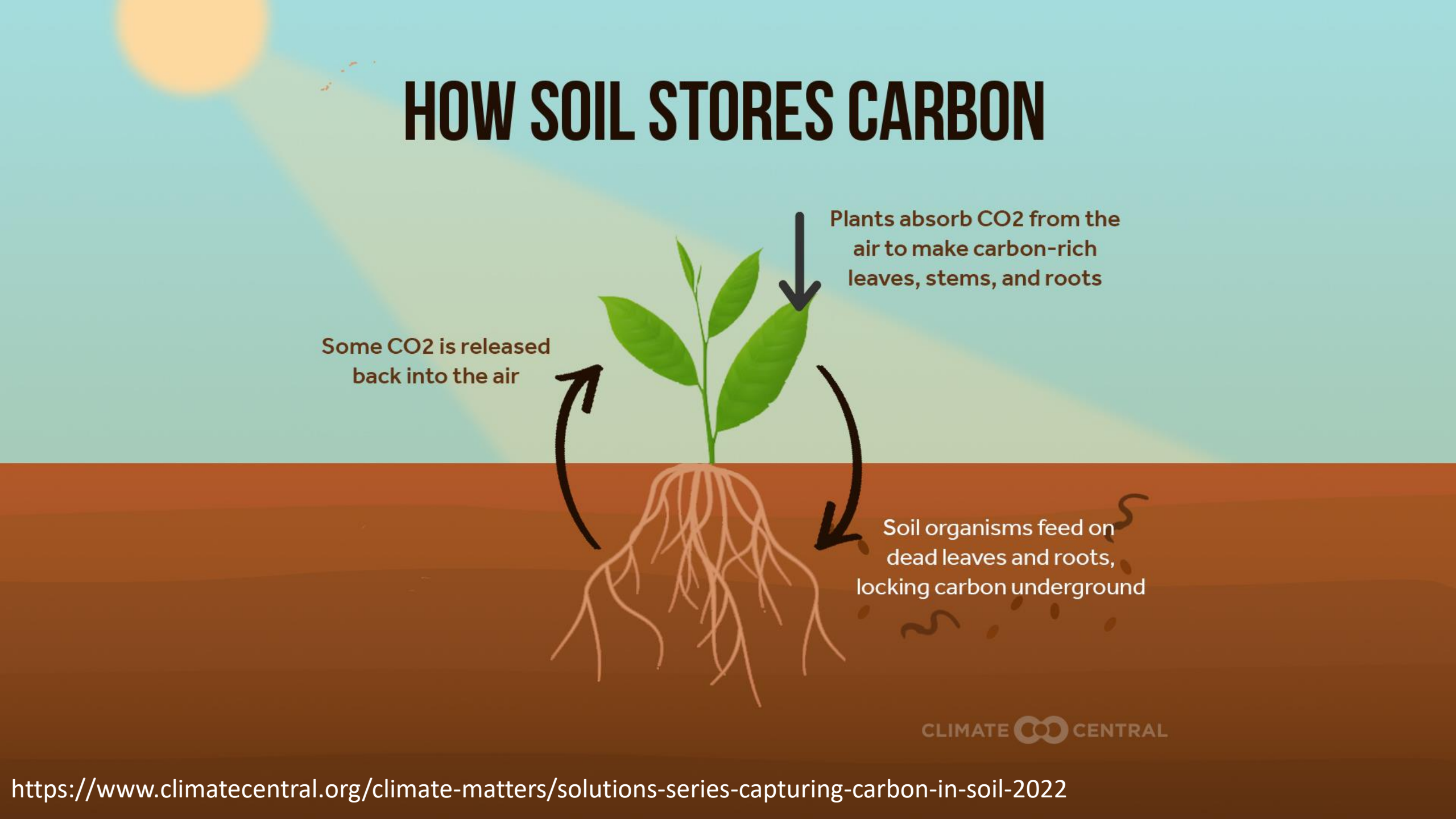
Carbon is a part of the ‘global greenhouse-gas problem’ but it is also central to many important ecosystem functions.

Investment in carbon is long-term, but with well-understood and impactful dividends

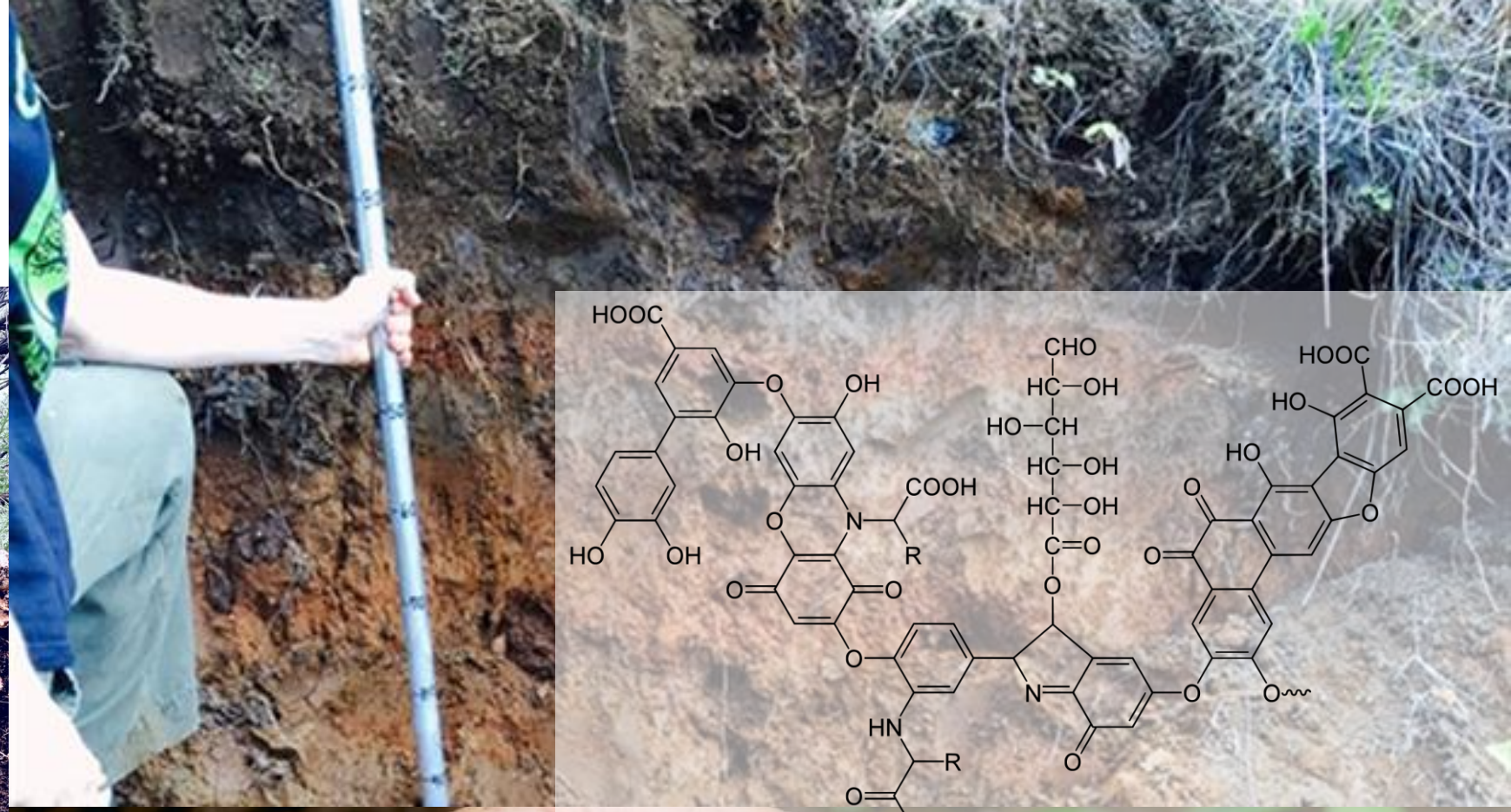


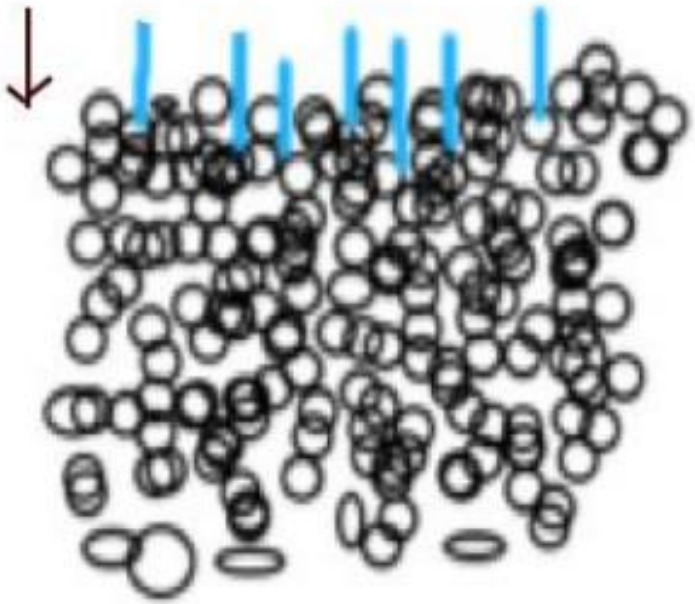
https://www.glenncountyrcd.org/carbon-farm-planning

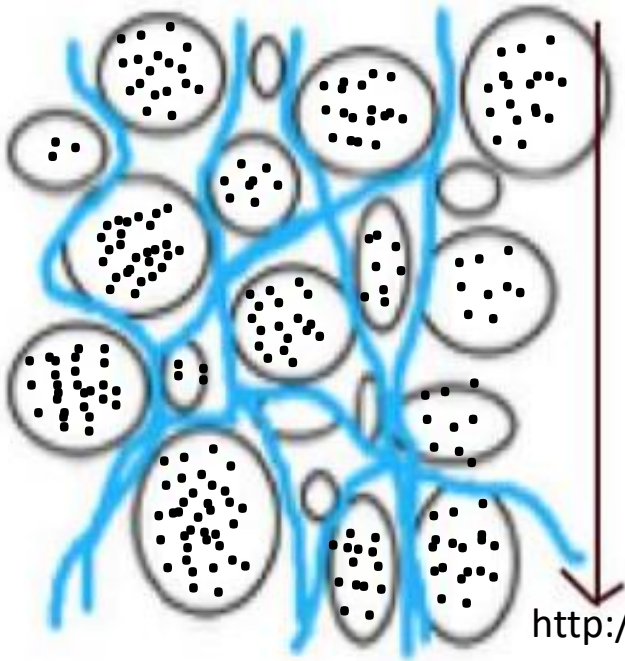


https://www.climatecentral.org/climate-matters/solutions-series-capturing-carbon-in-soil-2022

What is soil carbon?



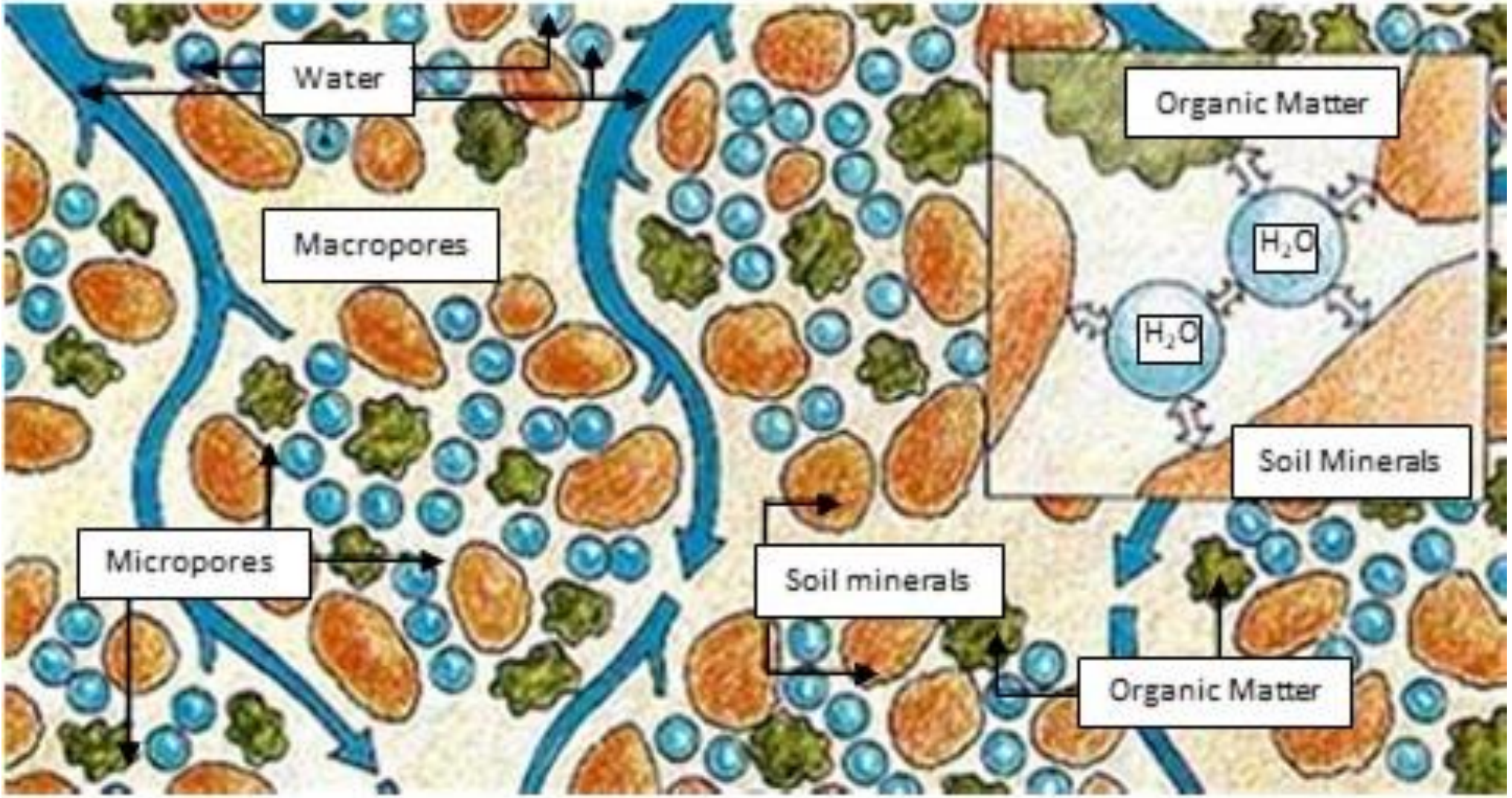


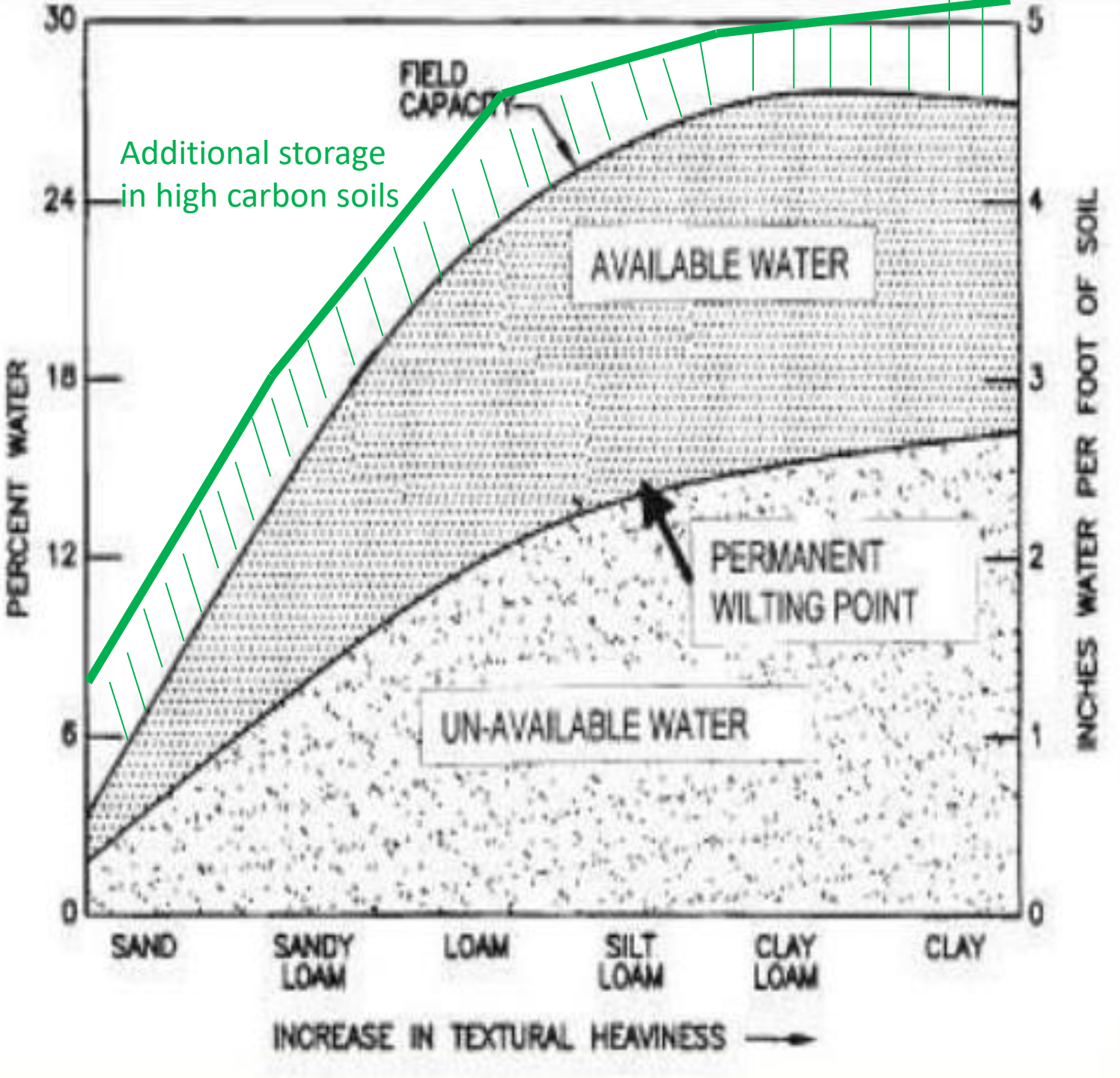


Soil carbon improves ‘soil structure’, leading to aggregation and improved water infiltration and storage

http://nmsp.cals.cornell.edu/publications/factsheets/factsheet95.pdf

Soil carbon not only helps water flow, it helps retain water that is available to plants

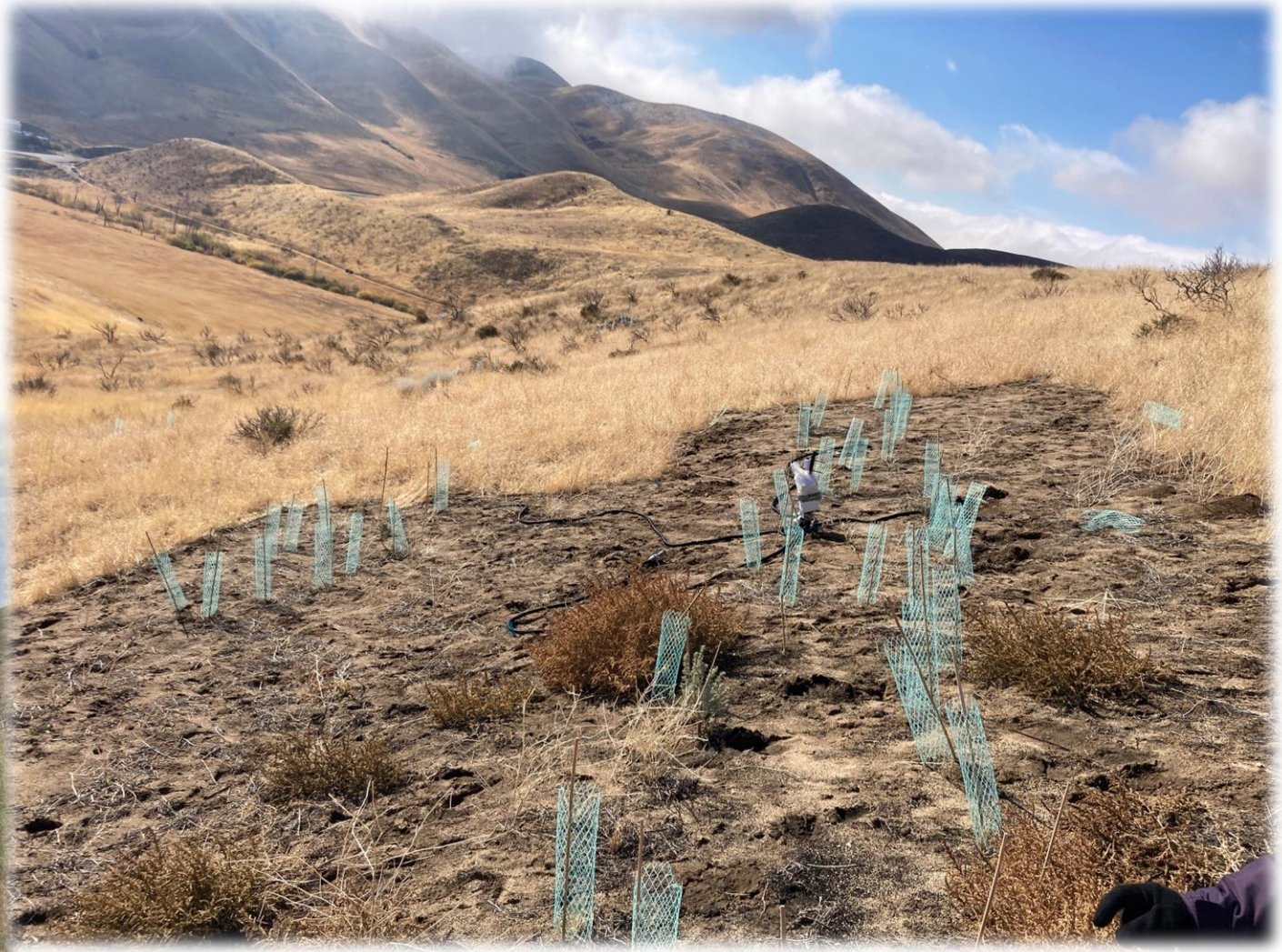




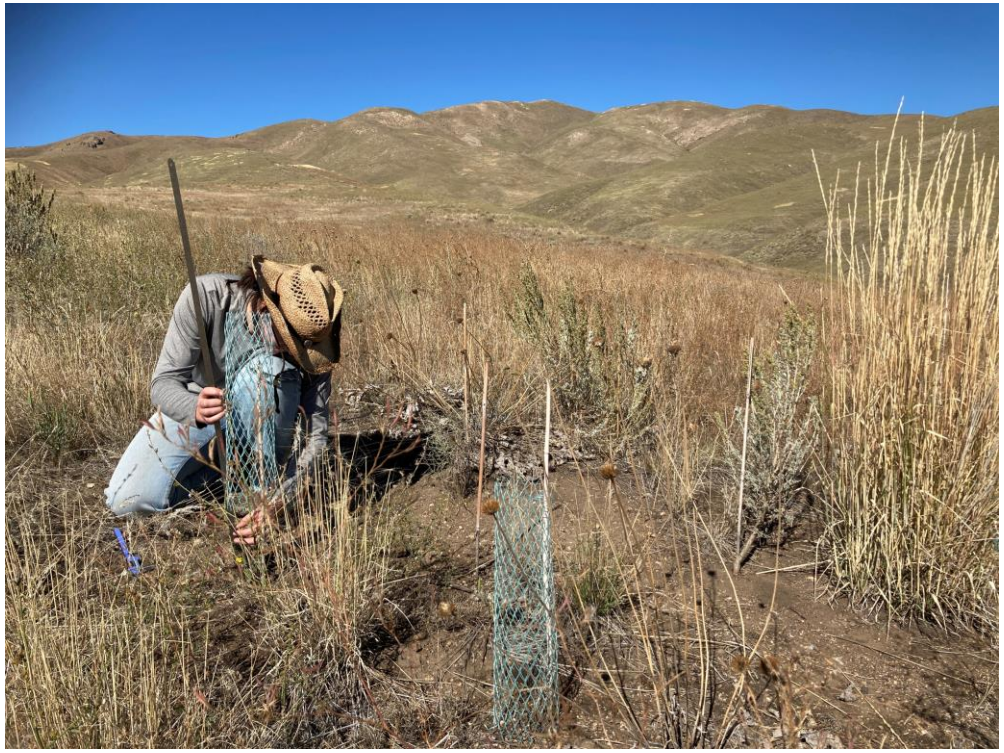
Soil carbon adds soil water storage in the form of plant available water to all soil types

Case study: soil carbon impacts on soil functions are associated with improved biomass production and restoration success in the Boise River Wildlife Management Area

Setting – burned, then invaded sagebrush steppe, rush skeletonweed, cheatgrass are the main invaders
Goal: establish native perennials
Treatment: +Indaziflam, +imazapic, +aminopyralid
Planting: Yarrow, Bluebunch wheatgrass, squirreltail, rabbitbrush, sagebrush



Across sites with 0.5-3% soil carbon we found that for each 1% increase in soil carbon…



Knowing something about the carbon status of your soil could lead to improved restoration success, especially where water stress is limiting

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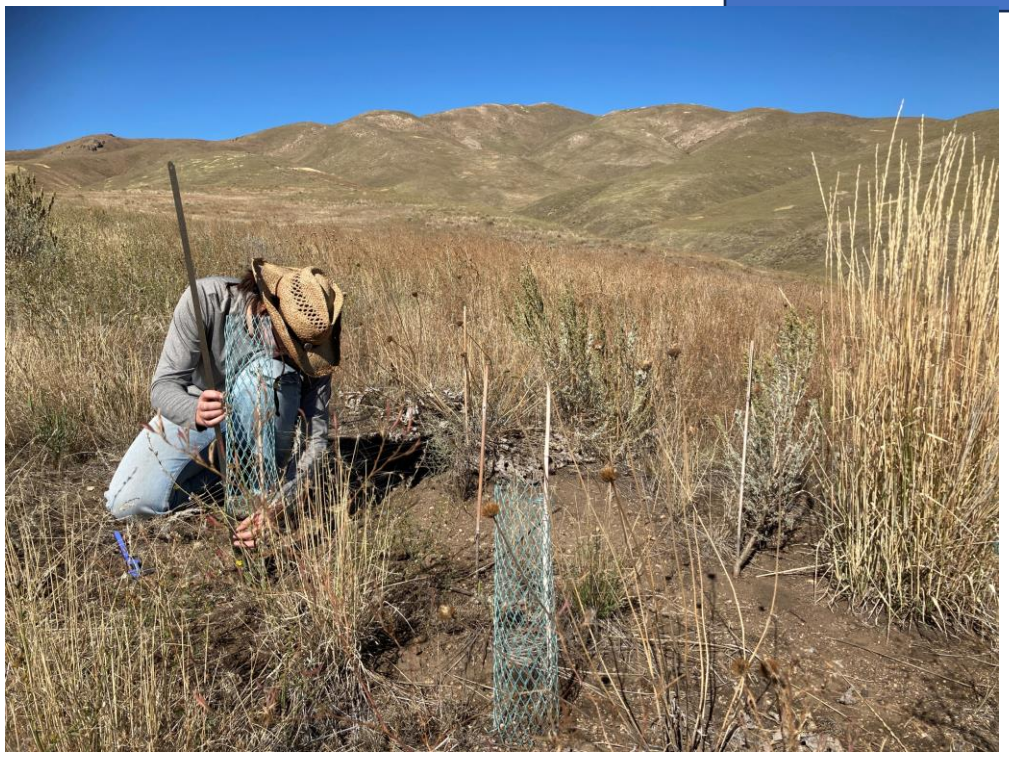
25% greater soil water holding capacity



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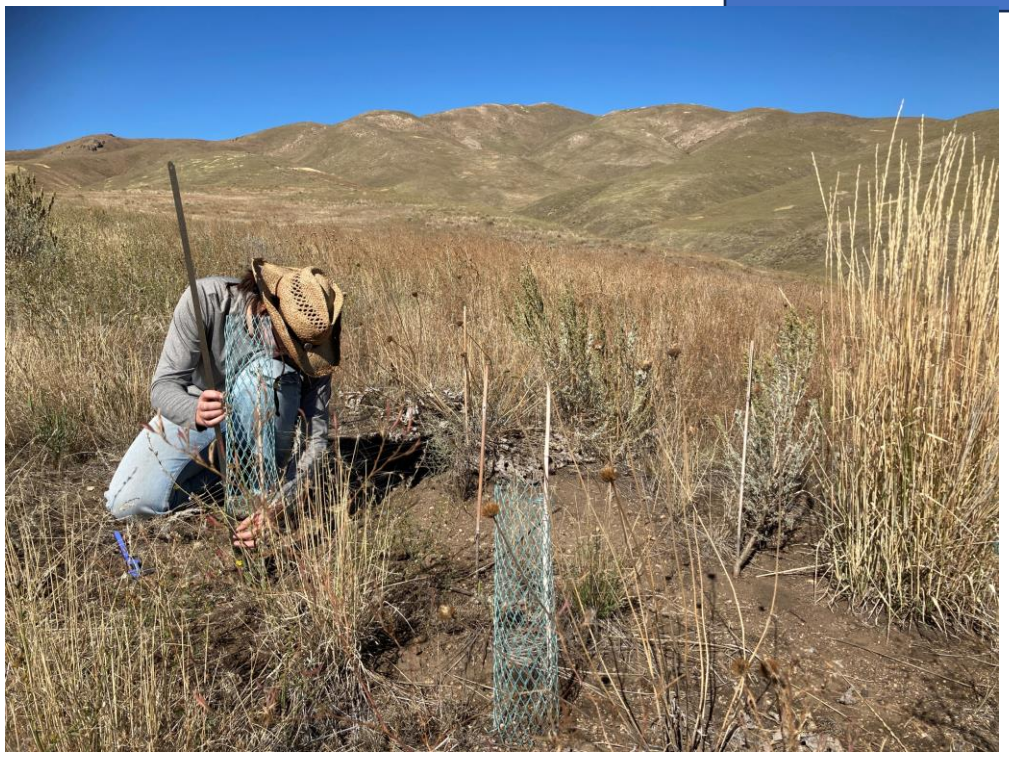

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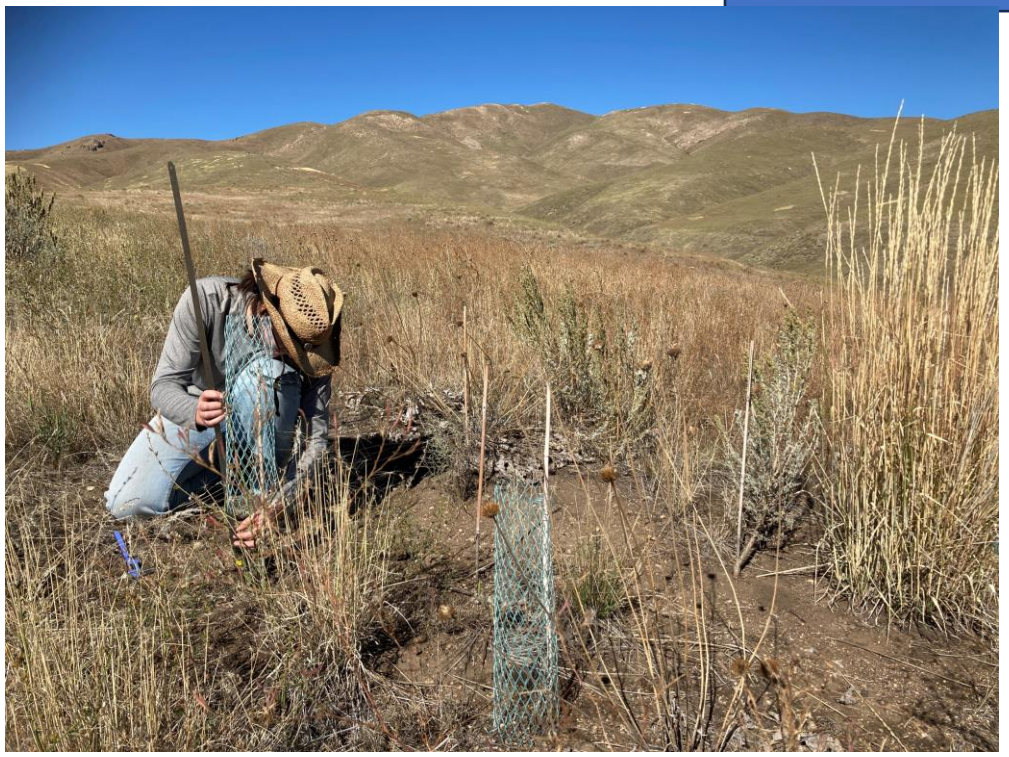
5% greater Biomass



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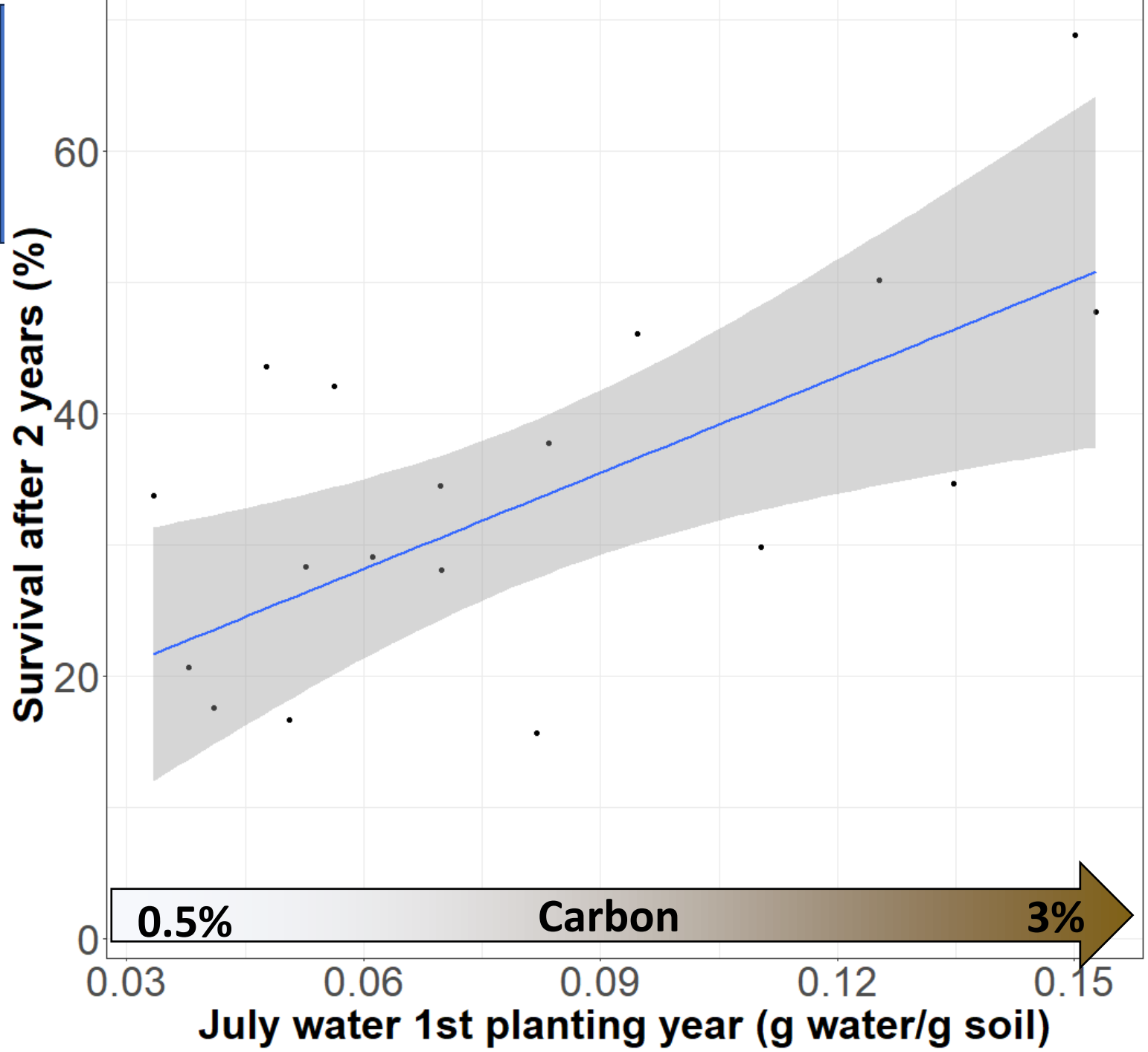

greater plant
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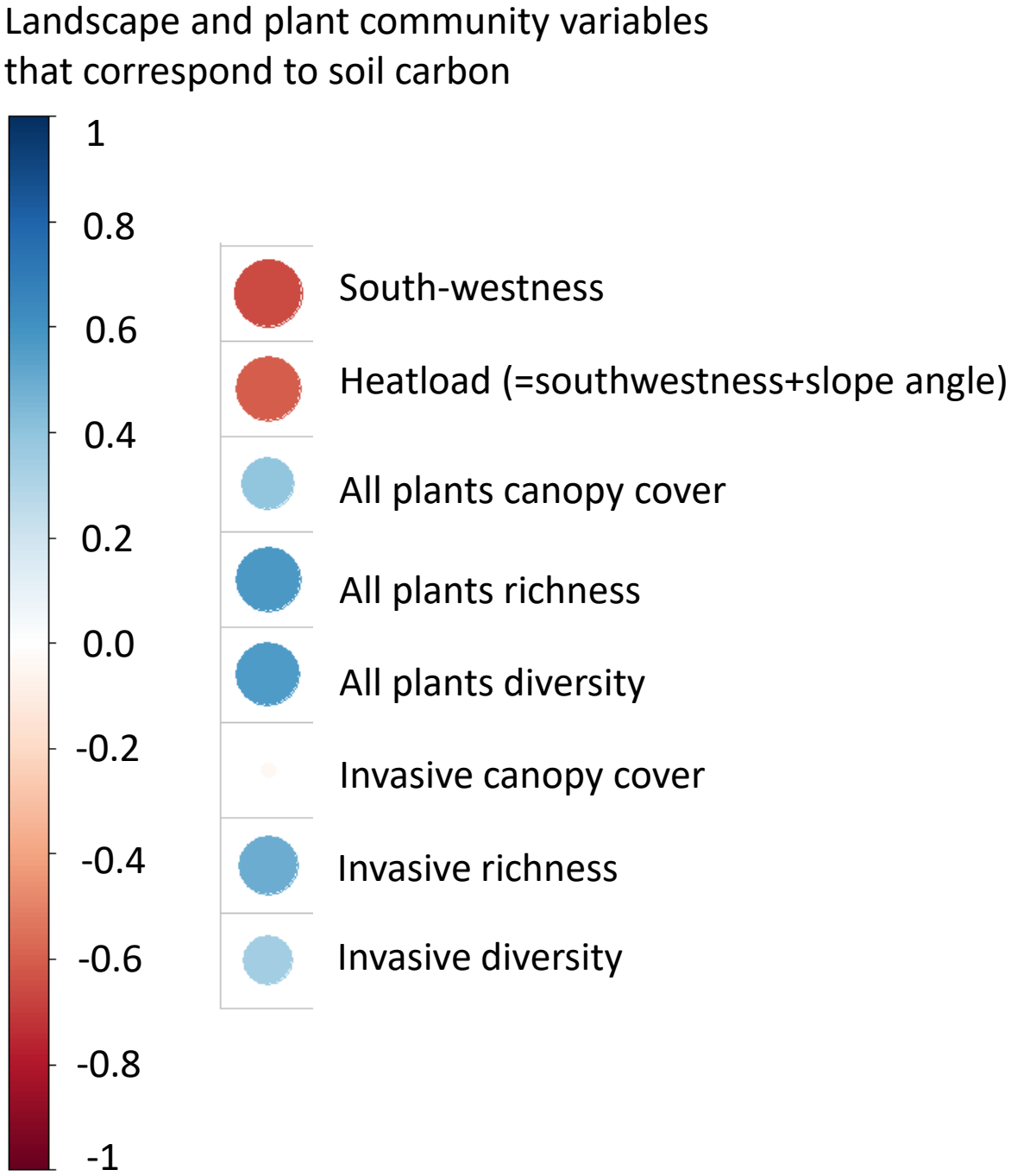
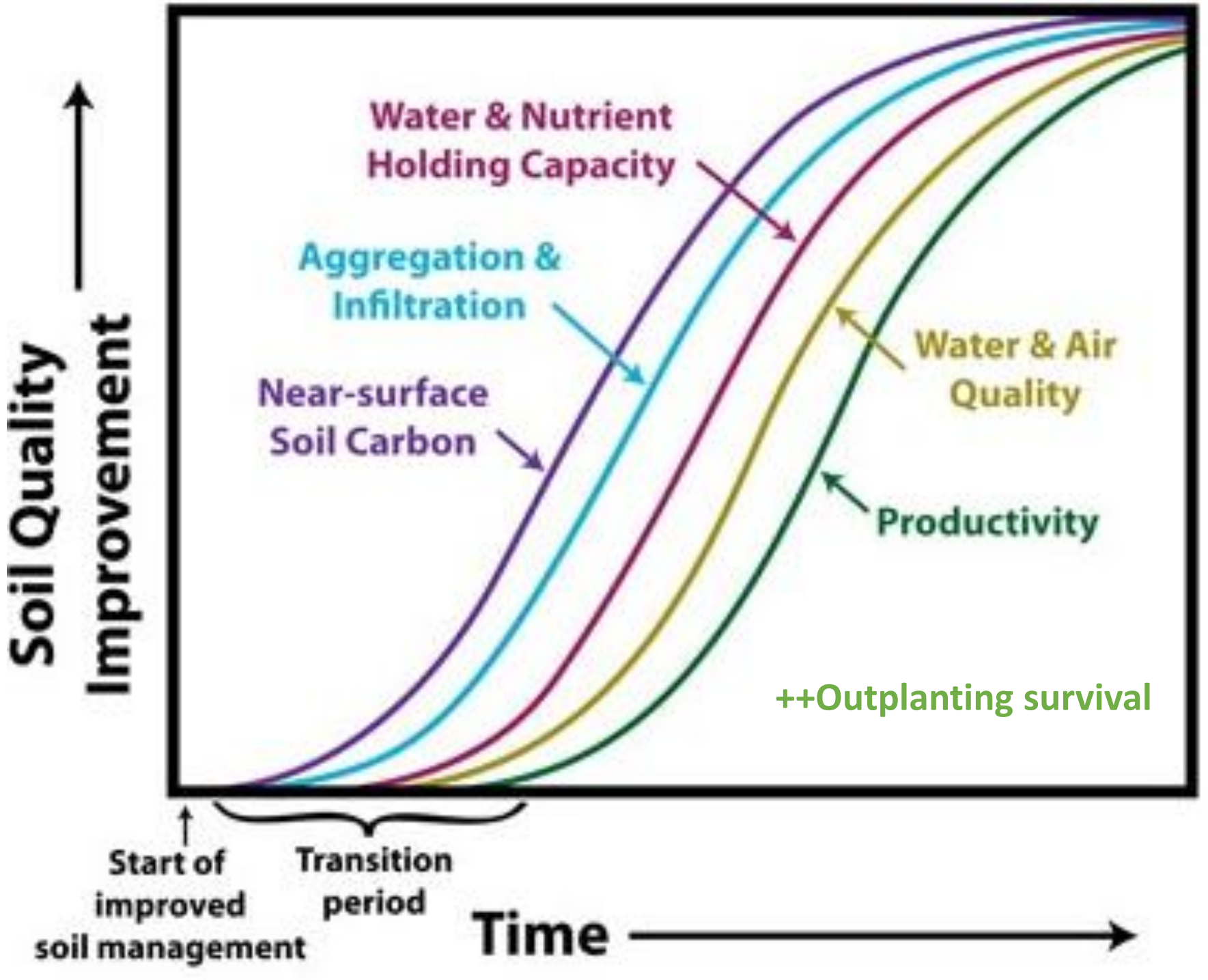


So, now that we know carbon can influence restoration success, where can we 'find' carbon?

-More north/east slopes
-more diverse sites (even if diversity is of invasives)

No significant elevation or climate gradients in this study

Storing carbon is a part of solving the ‘global greenhouse-gas problem’ but it is also central to many important ecosystem functions



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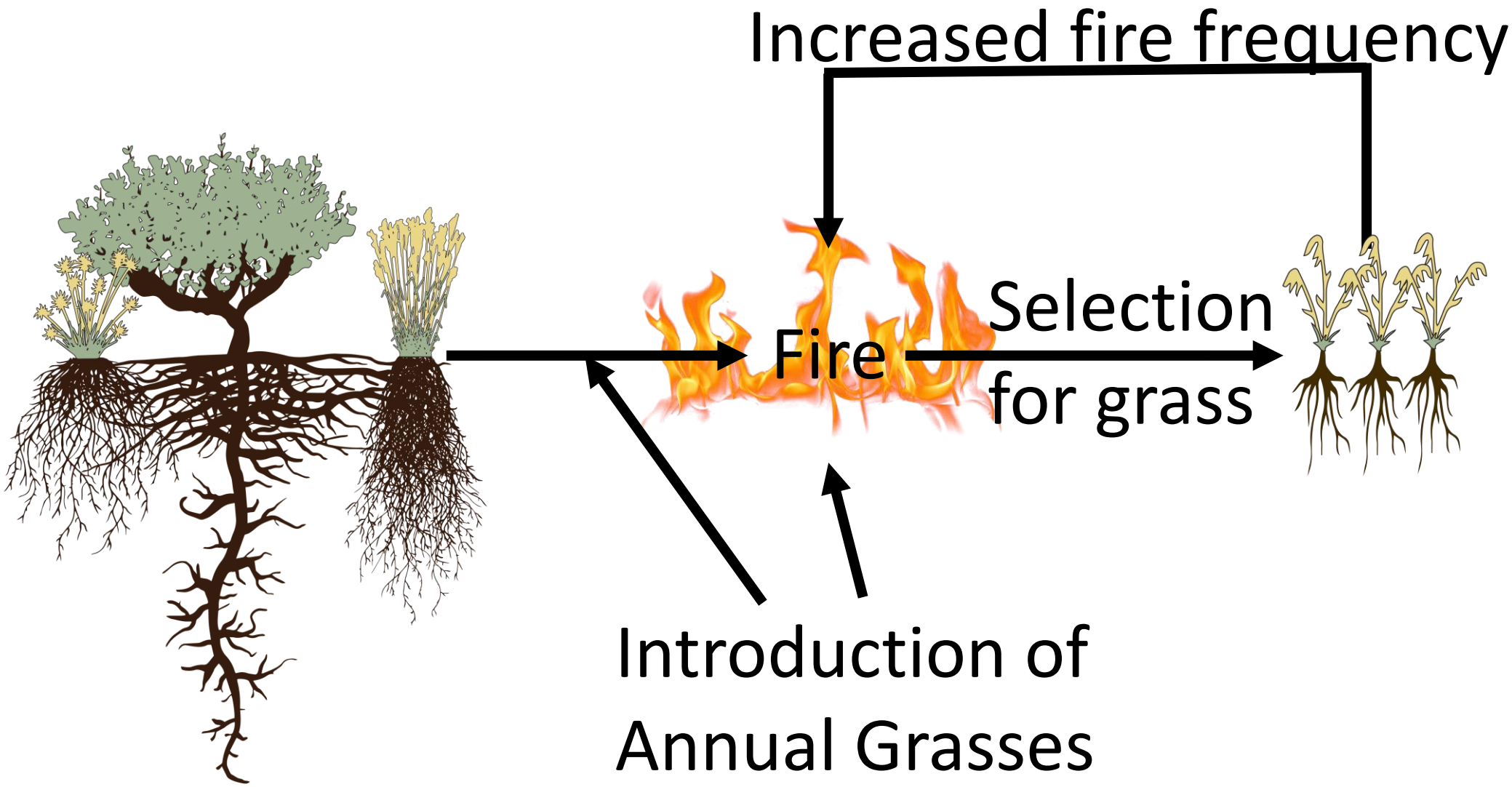
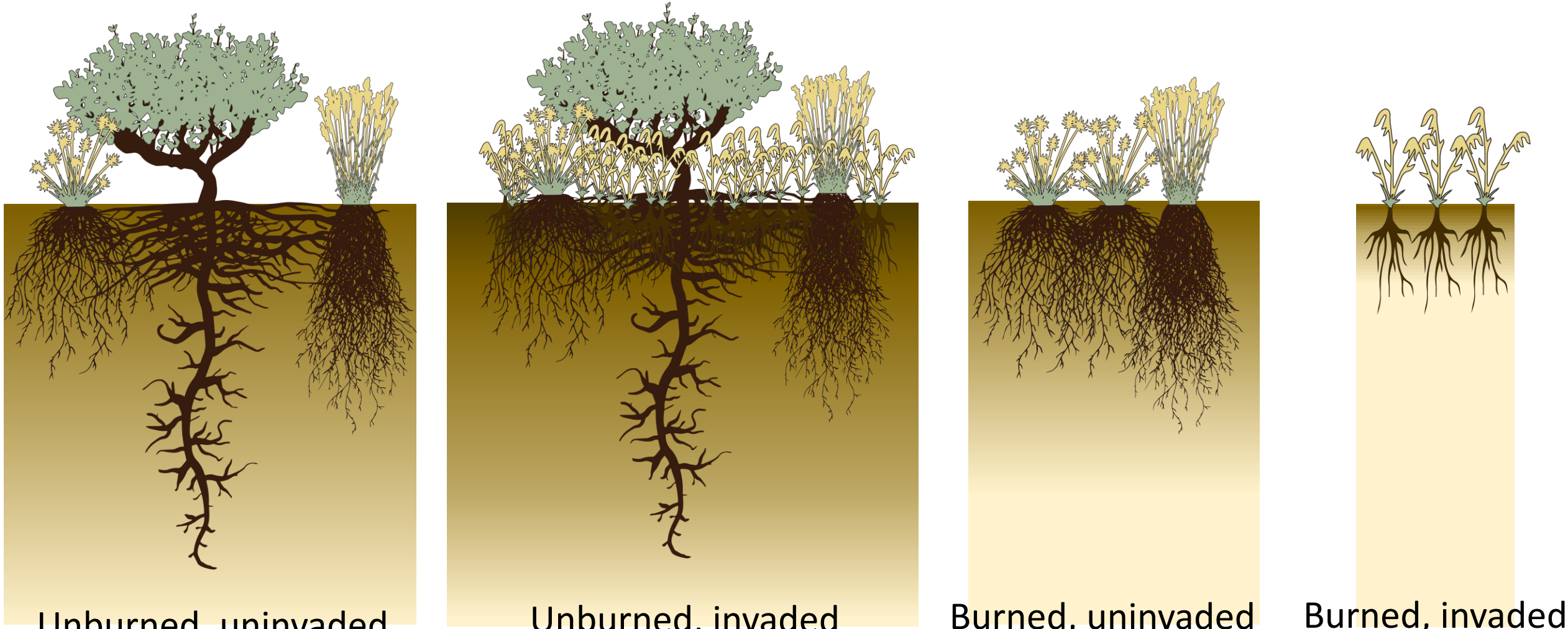
Annual Grass Fire cycle threatens perennials, carbon



Adapted from D'Antonio and Vitousek 1992

Annual Grass Fire cycle

Soil C should be affected by perennial to annual transition



Unburned, uninvaded

Unburned, invaded

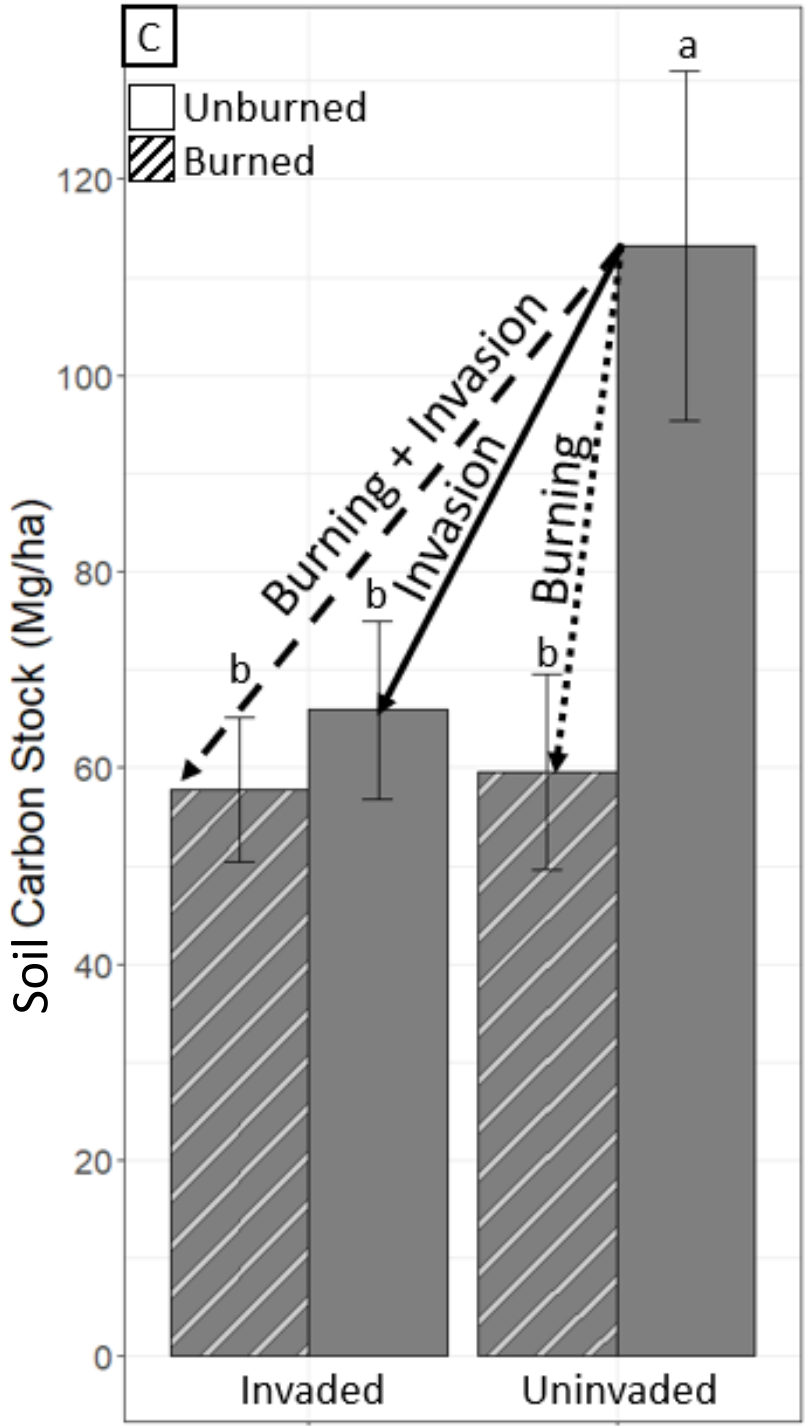
Burned, uninvaded

Burned, invaded

Exotic annual grass invasions and associated wildfire deplete soil carbon by ~50% in semiarid rangelands

The more quickly we intervene to interrupt invasion, the less carbon will be lost, fire cycle will be limited

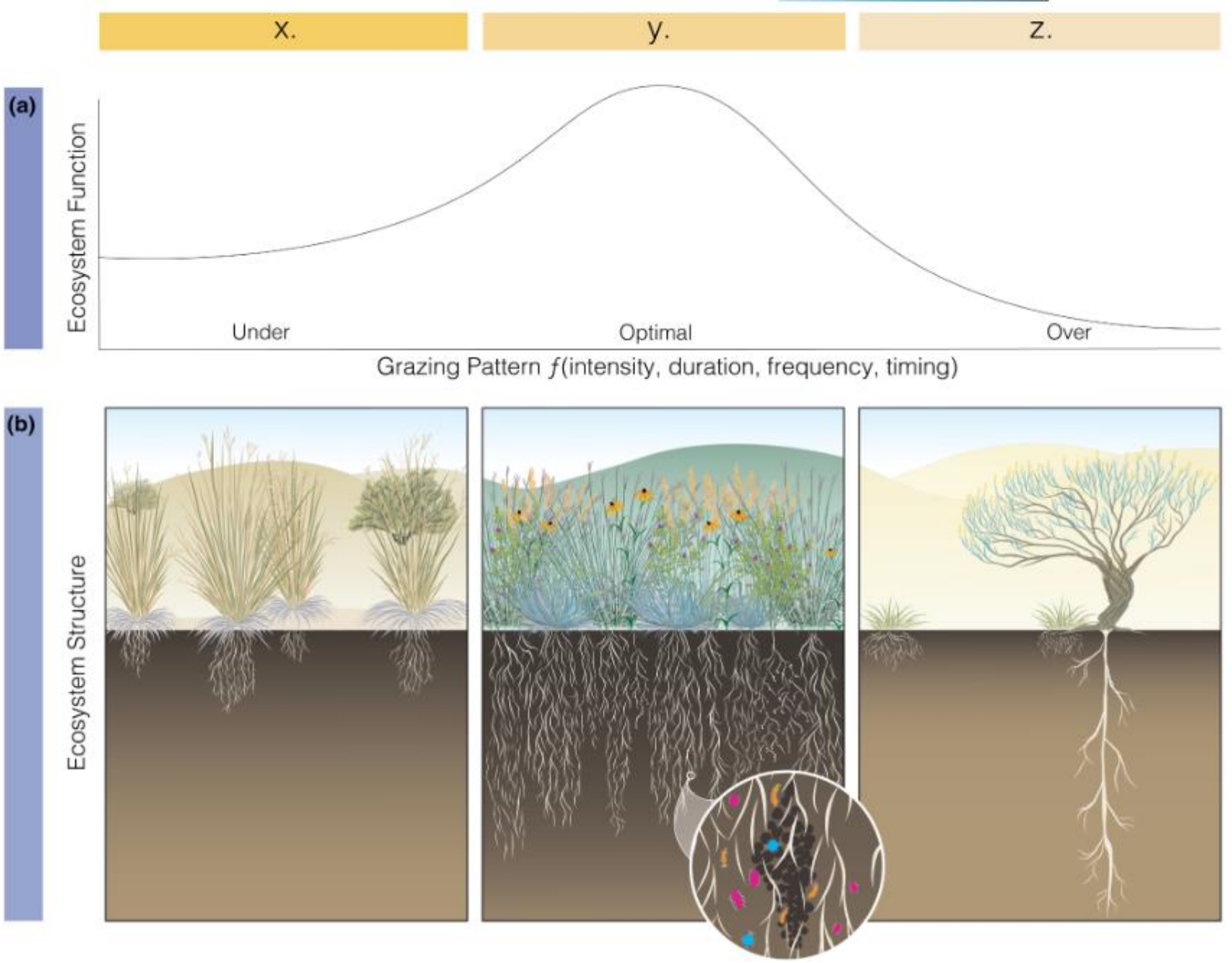
Maxwell, Quicke, Price and Germino, in review, Communications Earth and Environment



Grazing effects on soil carbon

There may be an optimal moderate level of grazing that can stimulate soil carbon accumulation

Depends on grazing management, climate, fertility, plant community composition



Stanley PL, Wilson C, Patterson E, et al (2024) Ruminating on soil carbon: Applying current understanding to inform grazing management. Global Change Biology 30:e17223. https://doi.org/10.1111/gcb.17223

Grazing effects on soil C – AUs don't tell it all

Grazing system example	Stocking rate (AU/acre)	Pasture quantity and size (# | acres)	Stocking density (AU/acre)	Duration (days/year)
A: Continuous	0.1	1 | 1000	0.1	365
B: Low rotational	0.1	5 | 200	0.5	73
C: High intensity, short duration	0.1	100 | 10	10	4 *

Short duration, high intensity 'Adaptive multi-paddock – AMP' grazing can improve soil carbon compared to similar stocking rates <u>at the same site.</u>

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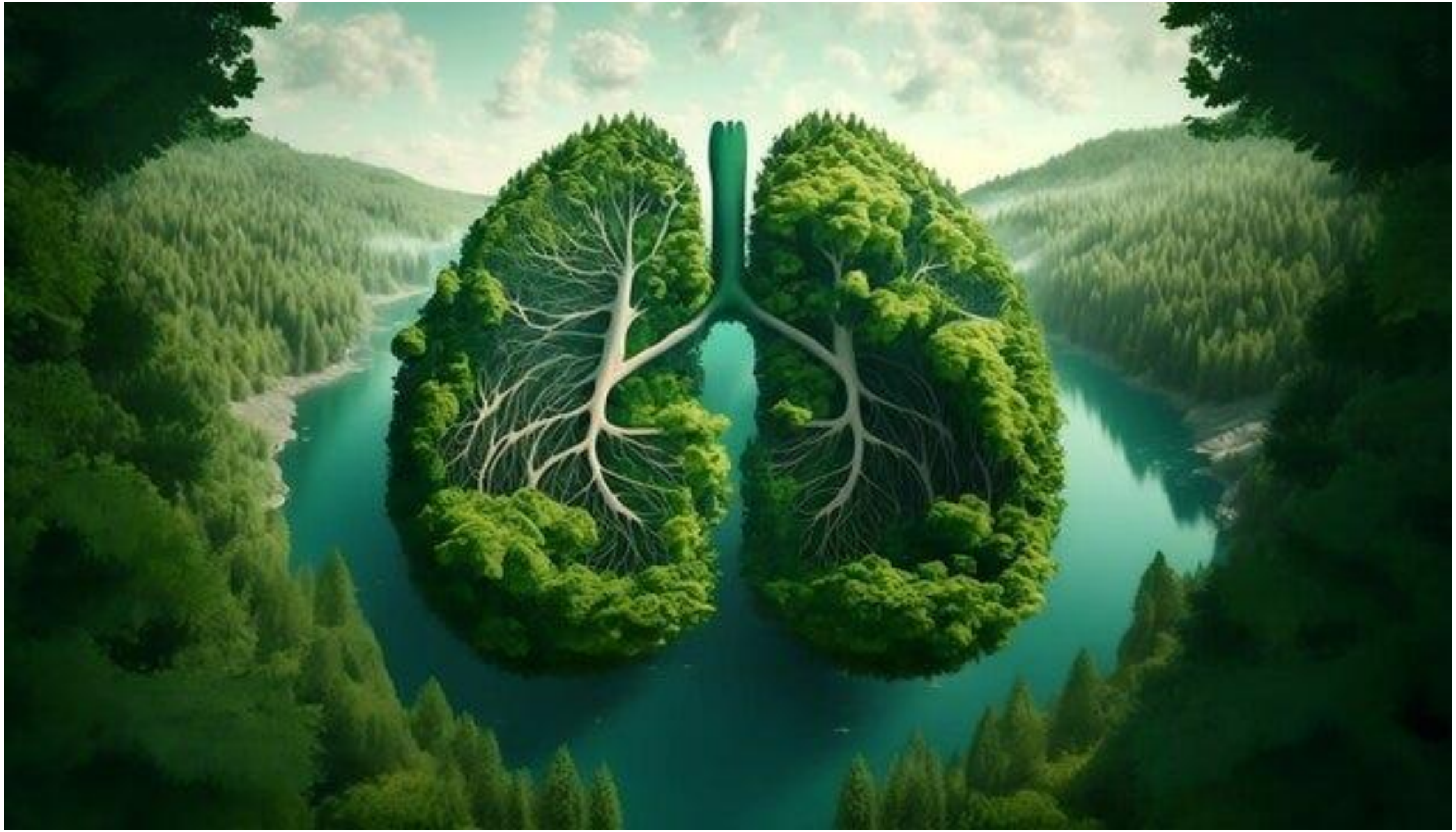
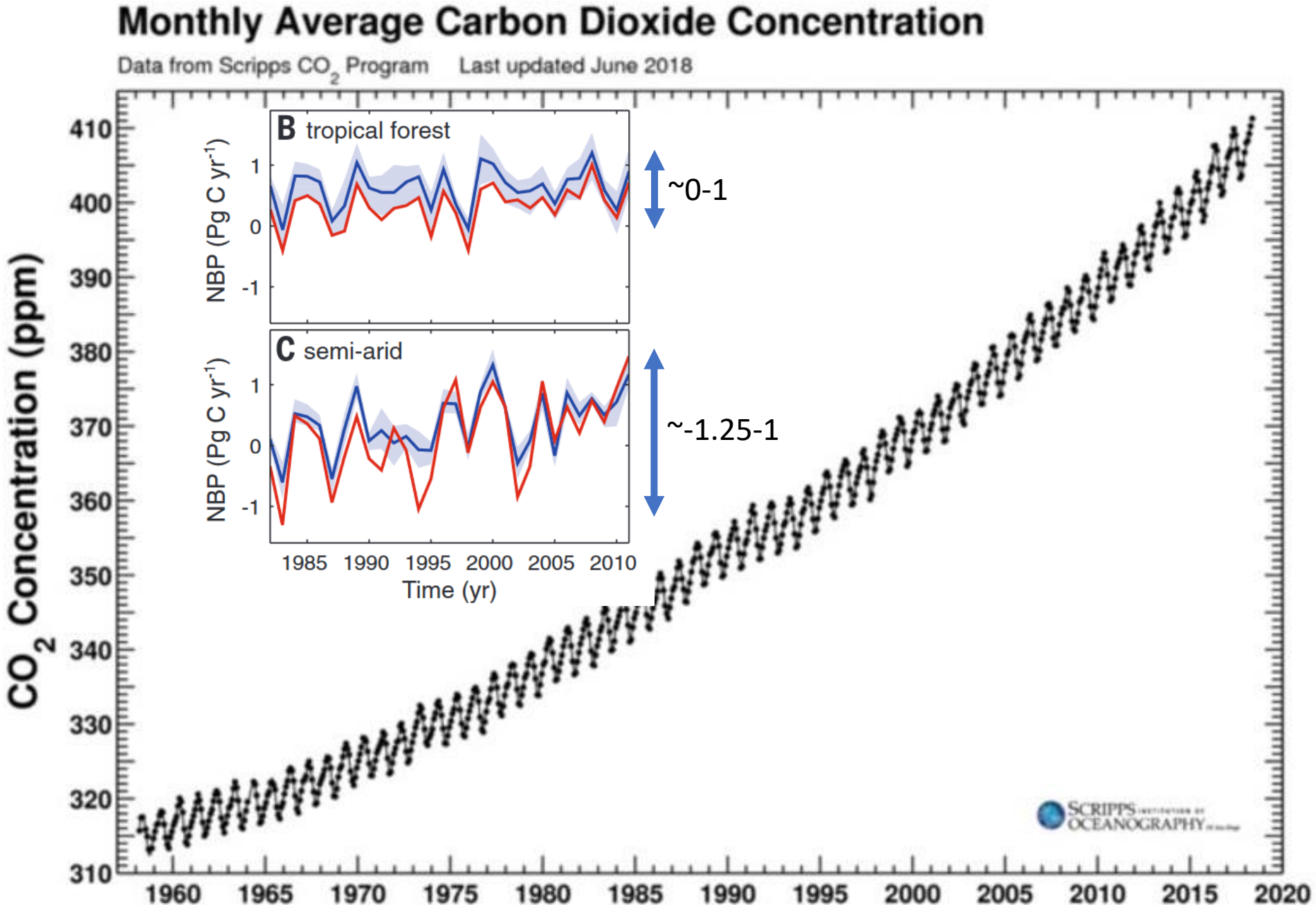
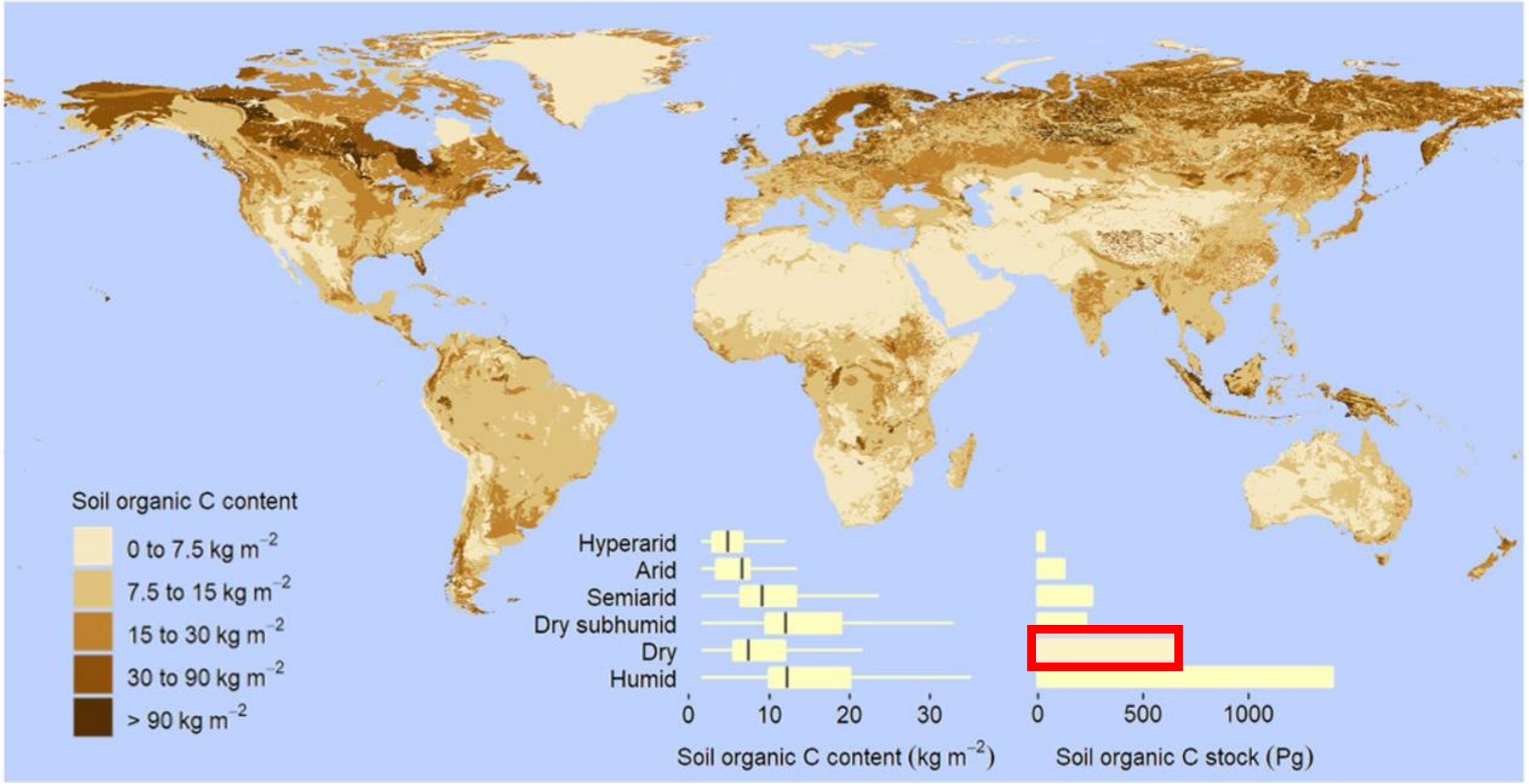


https://medium.com/@giussepeantonio910/the-green-lung-of-the-earth-understanding-the-importance-of-the-amazonian-forest-903e86923661



Ahlström A, Raupach MR, Schurgers G, et al (2015) The dominant role of semi-arid ecosystems in the trend and variability of the land CO_2 sink. Science 348:895–899.

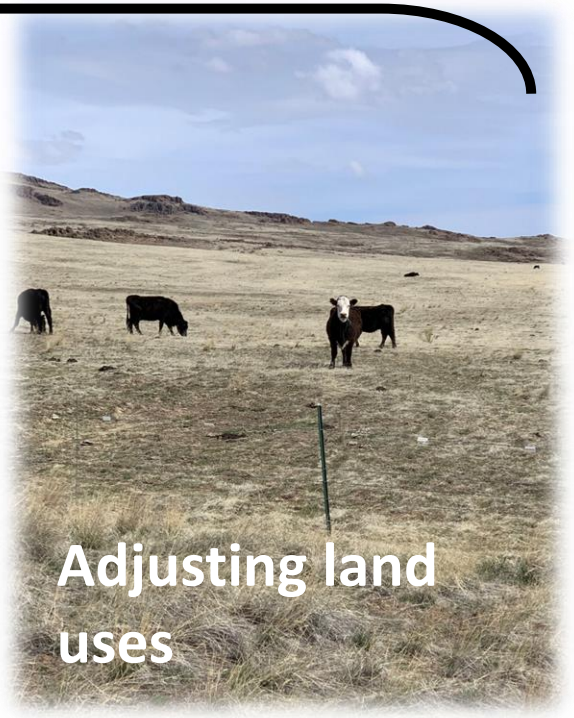
Drylands are relatively carbon-poor, but vast, and thus store massive amounts of carbon. Carbon could be accumulated, or lost relatively efficiently in response to management, climate



Plaza C, Zaccone C, Sawicka K, et al (2018) Soil resources and element stocks in drylands to face global issues. Sci Rep 8:13788.

We can adapt AND mitigate.

Reduce fire and annual grass invasion
to conserve carbon, assist native veg and wildlife



Thank you!

Matt Germino, Harry Quicke, Brynne Lazarus, Allison Simler-Williamson
The FIRESS Team at USGS FRESC

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North Central Climate Adaptation Science Center

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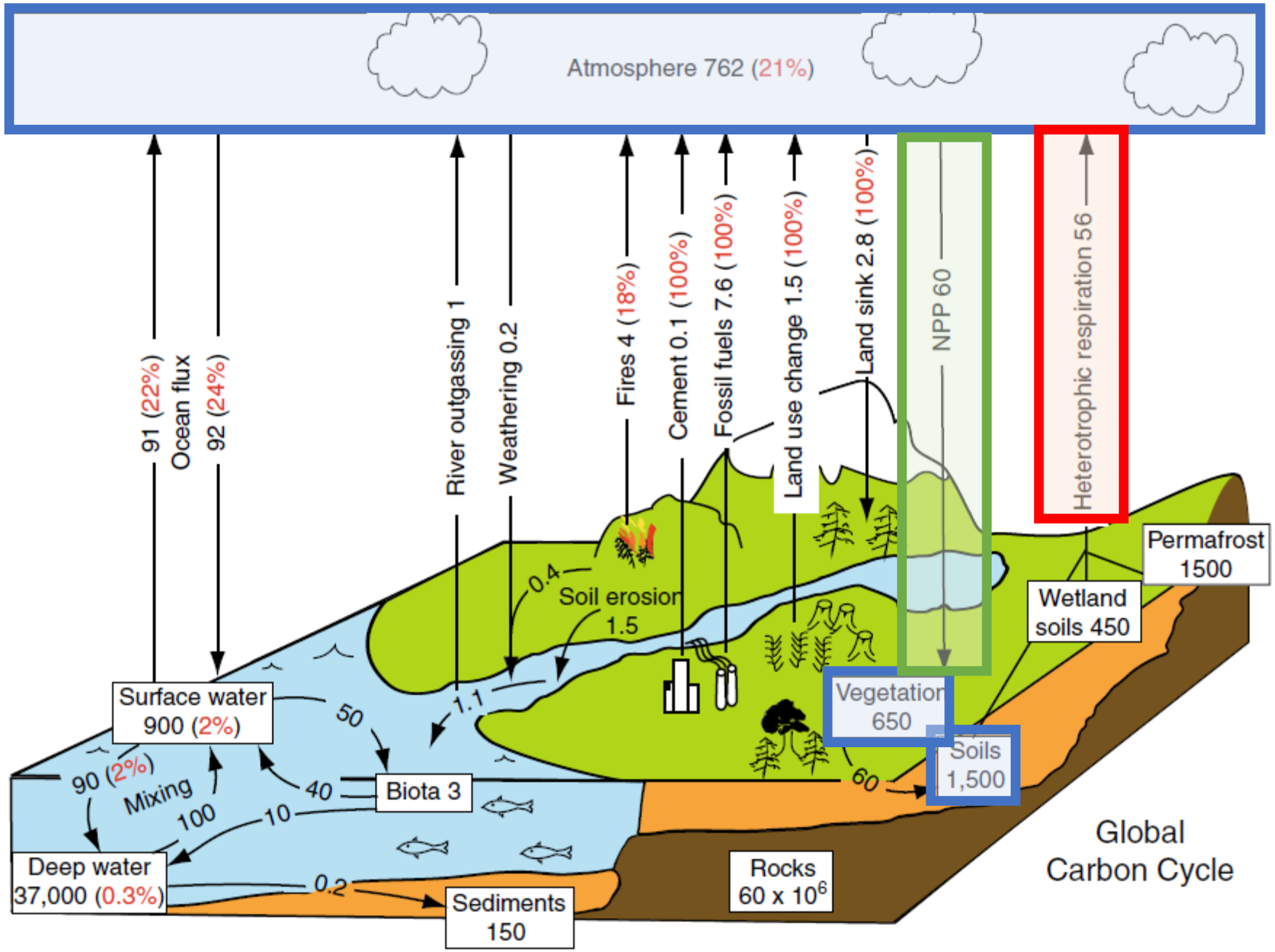
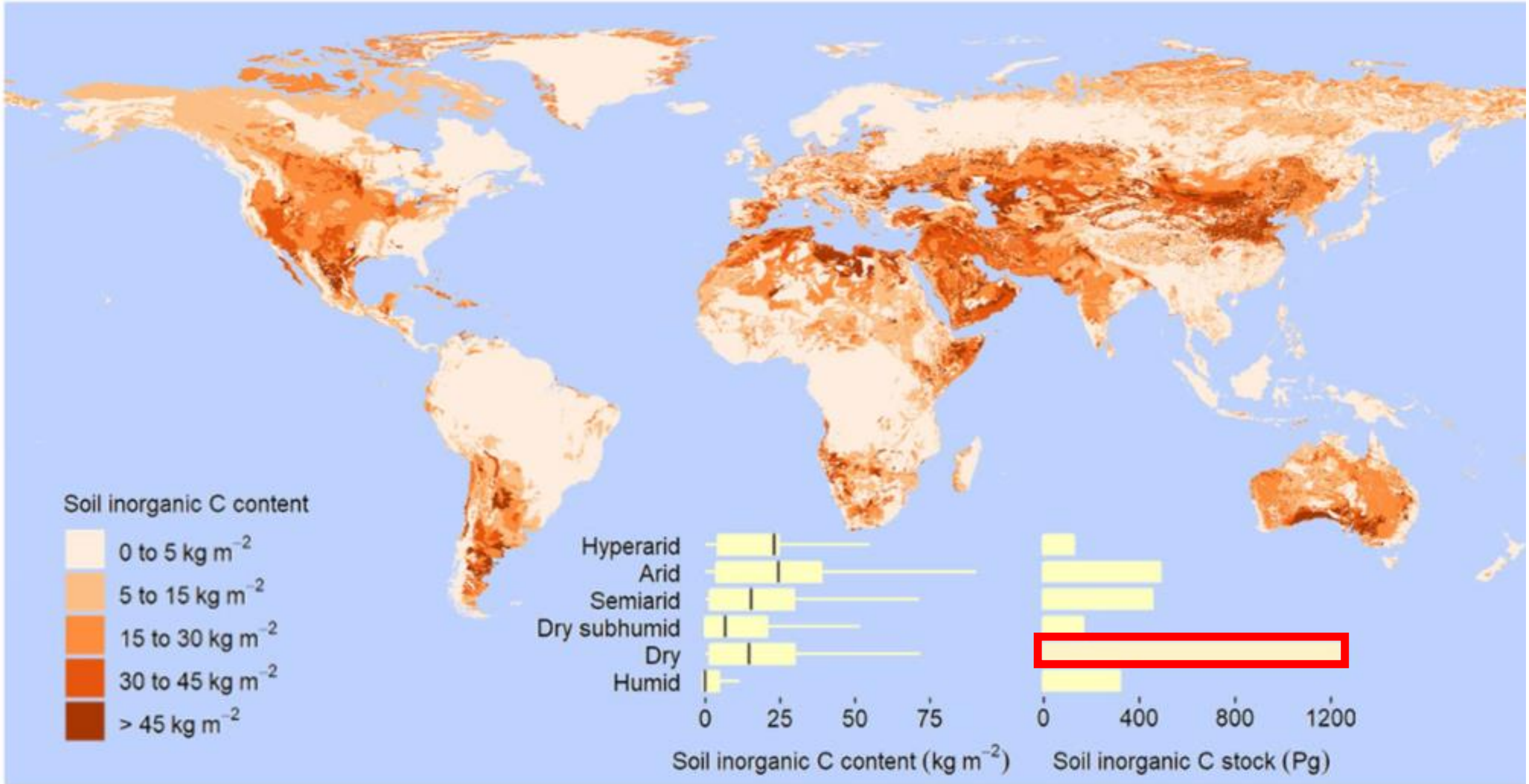

Atmosphere 762 (21%)
91 (22%)
Ocean flux
92 (24%)
River outgassing 1
Weathering 0.2
Fires 4 (18%)
Cement 0.1 (100%)
Fossil fuels 7.6 (100%)
Land use change 1.5 (100%)
Land sink 2.8 (100%)
NPP 60
Heterotrophic respiration 56
0.4
Soil erosion
1.5
Permafrost
1500
Wetland
soils 450
Surface water
900 (2%)
50
1.1
Vegetation
650
Soils
1,500
90 (2%)
Mixing
100
40
Biota 3
10
60
Deep water
37,000 (0.3%)
0.2
Sediments
150
Rocks
60 x 10^6
Global
Carbon Cycle



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385 ppm | 535 ppm | 685 ppm | 835 ppm

Atmospheric CO_2 concentration

Plant productivity is limited by CO_2, thus rising CO_2 drives increased production.

Warmer temperatures can benefit plant production, but more is not always better

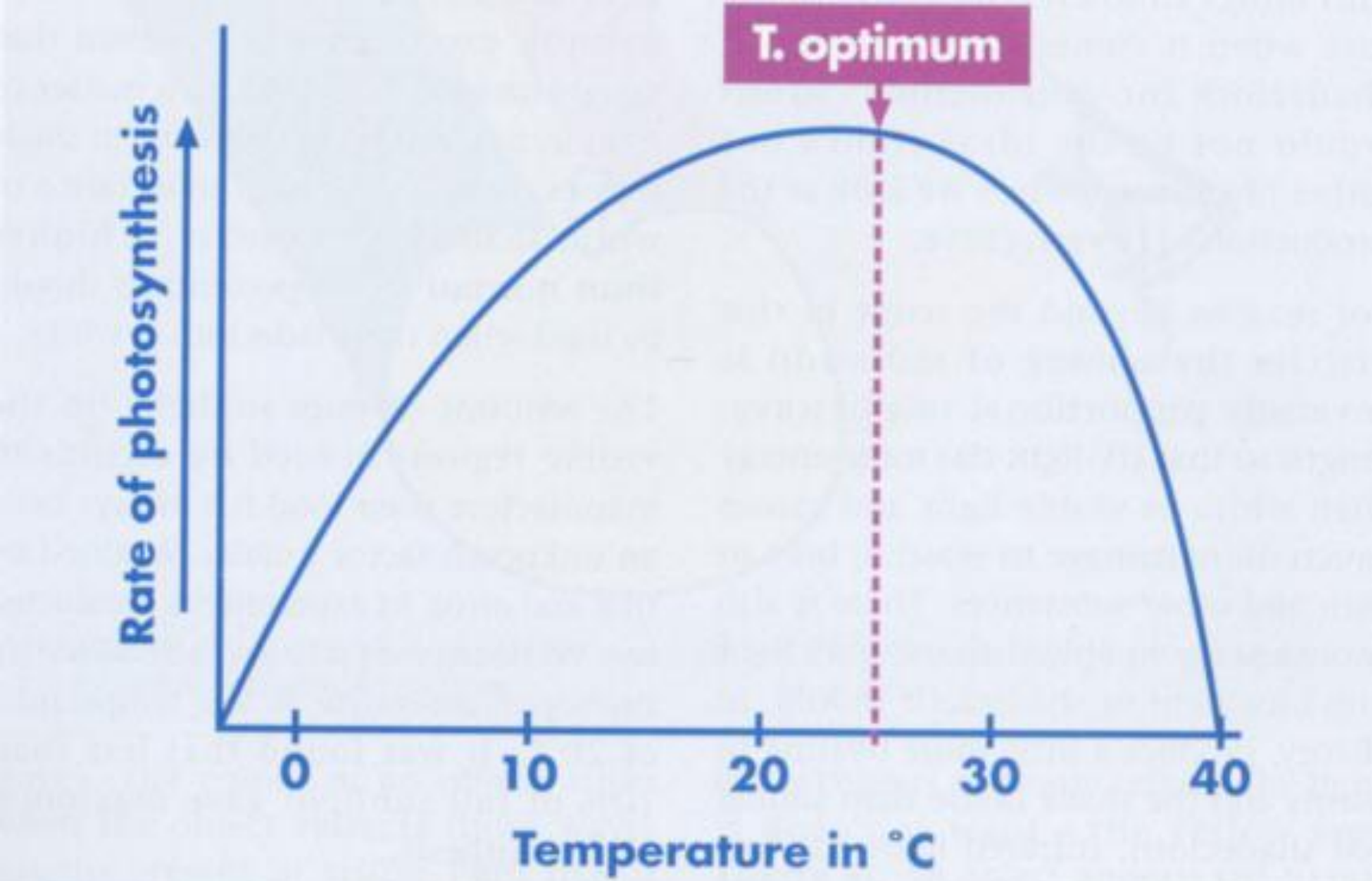
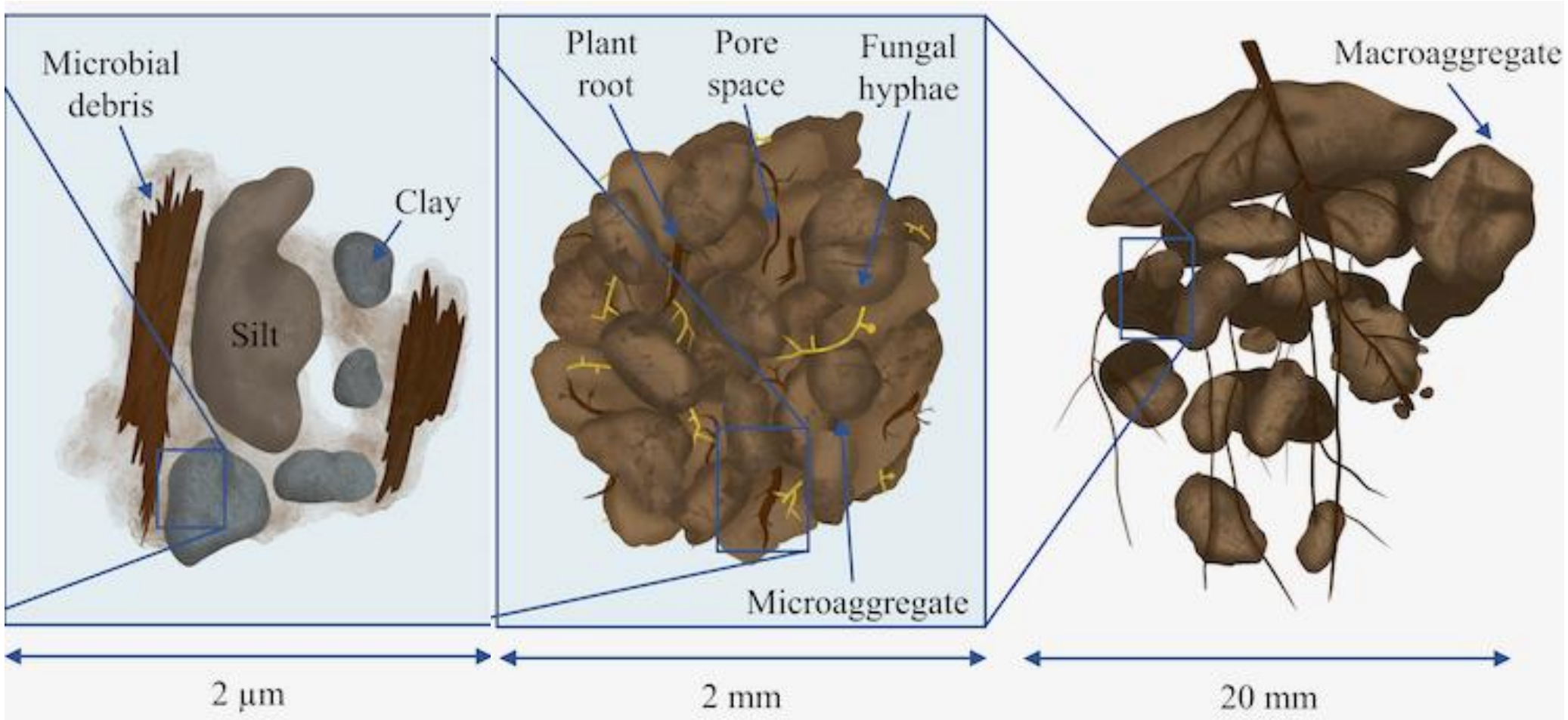


FIGURE 6: Effect of temperature on photosynthesis.

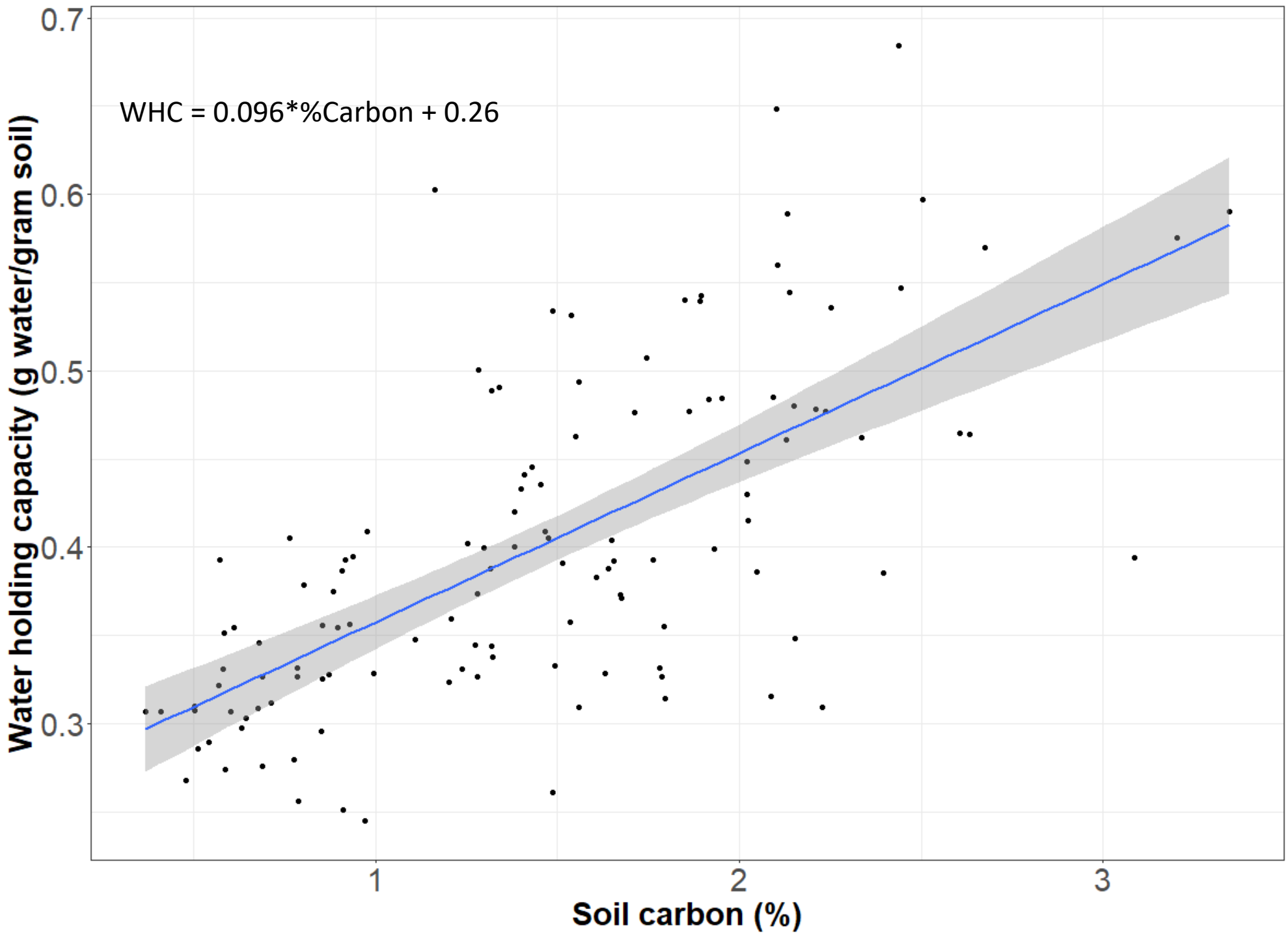
http://fhs-bio-wiki.pbworks.com/w/page/12145771/Factors%20effecting%20the%20rate%20of%20photosynthesis



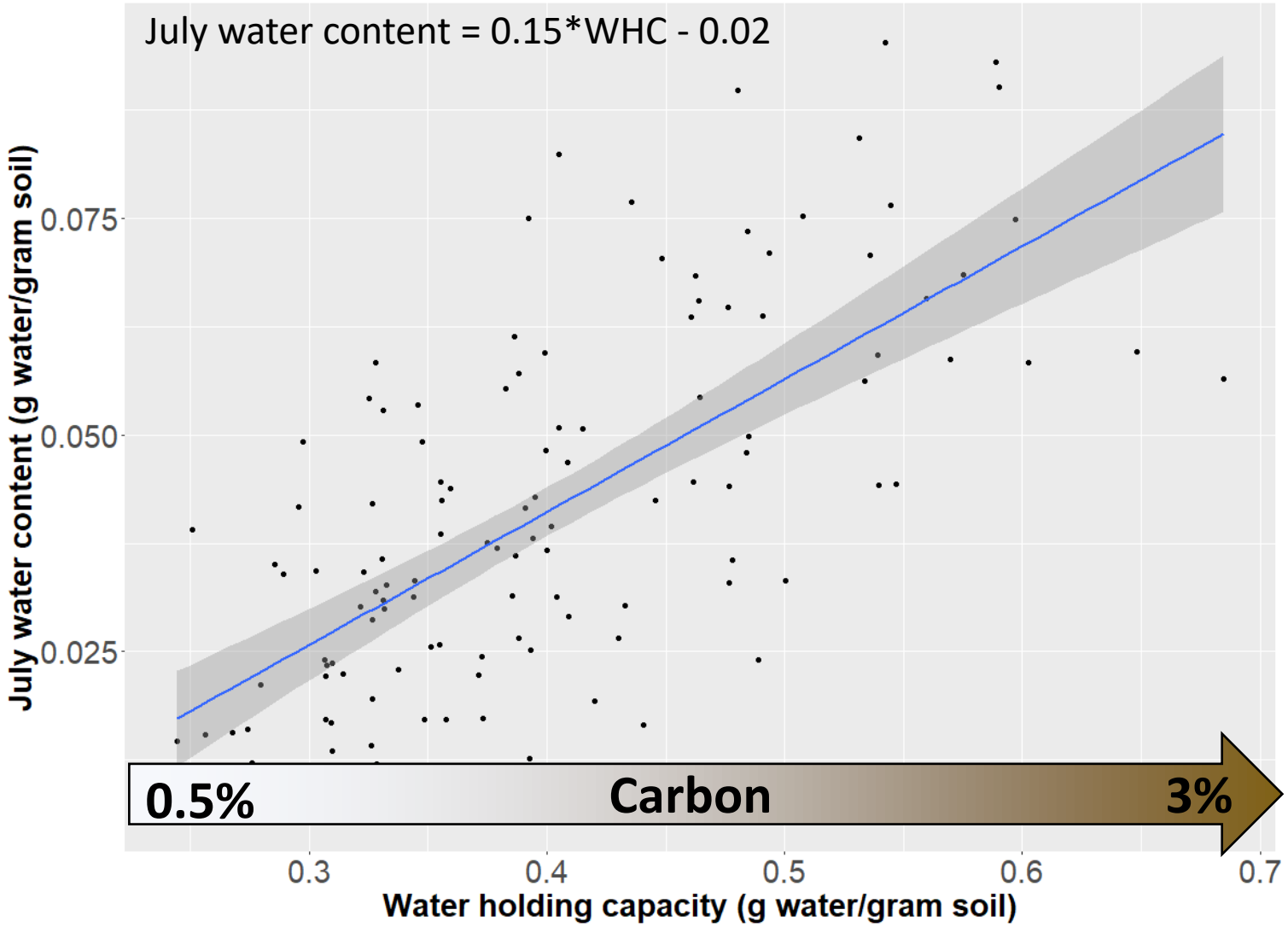
At this scale, clay-organic matter complexes contribute to flocculation.

Macroaggregate – formed from many microaggregates bound together by roots and hyphae.

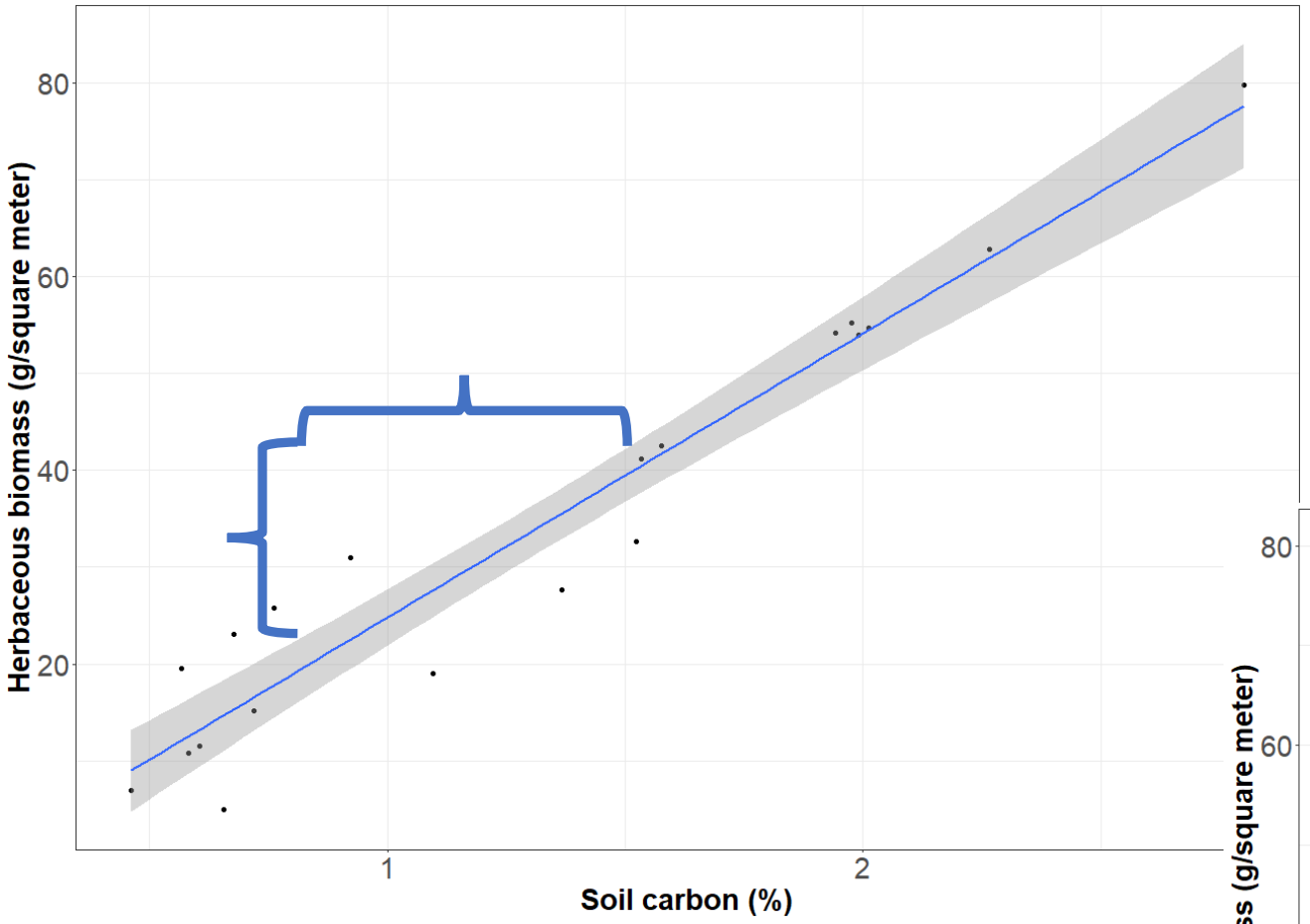
Several macroaggregates held by a root.



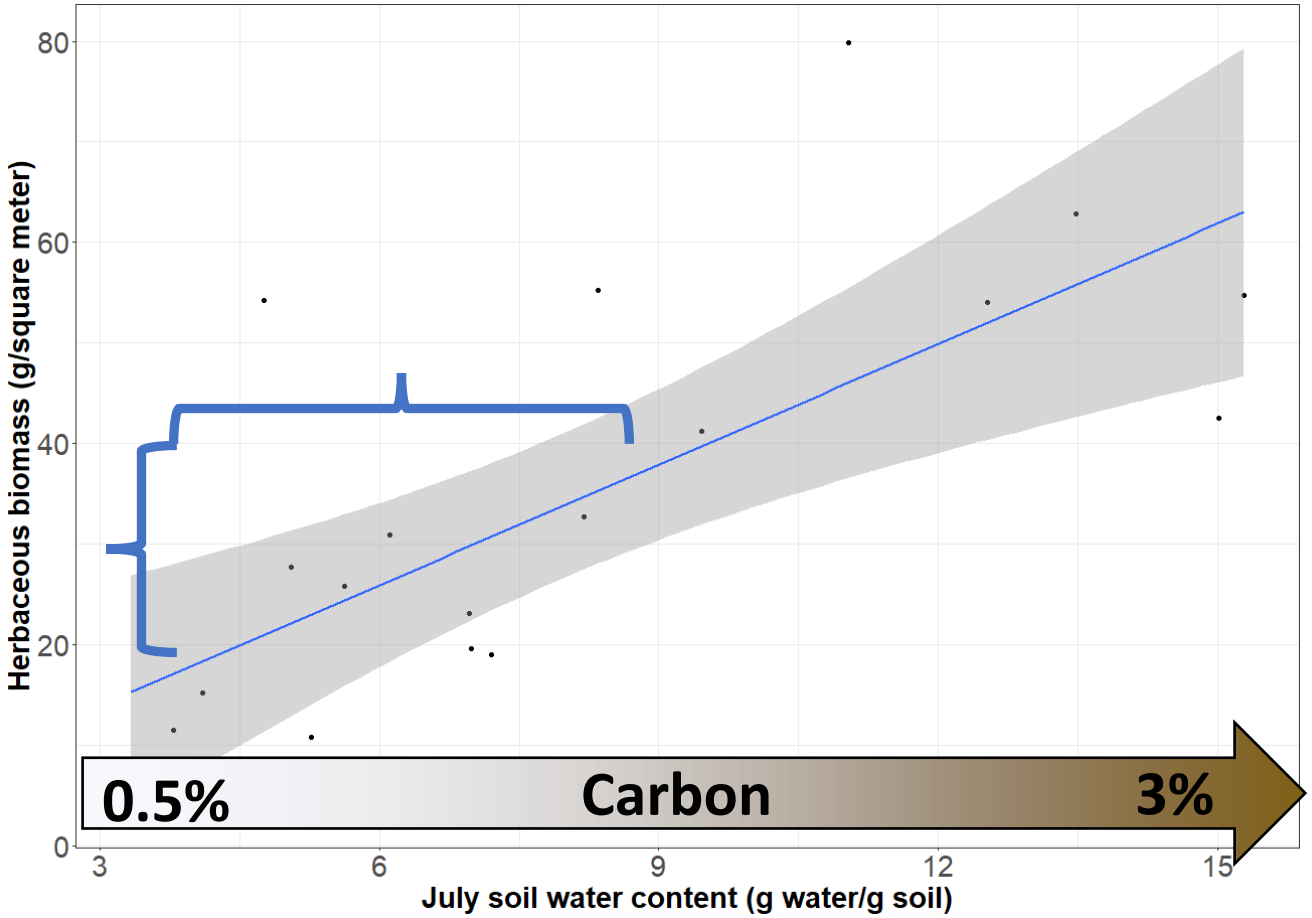
Soil carbon increases how much water soil can hold



When soils store more water, the growing season is functionally extended for perennial plants.



Biomass doubles with ~+5% greater soil water content, which could be attributed to ~1% increase in soil carbon!!



Conclusions

Areas with more carbon are likely to have greater restoration success due to its impact on soil water storage and movement

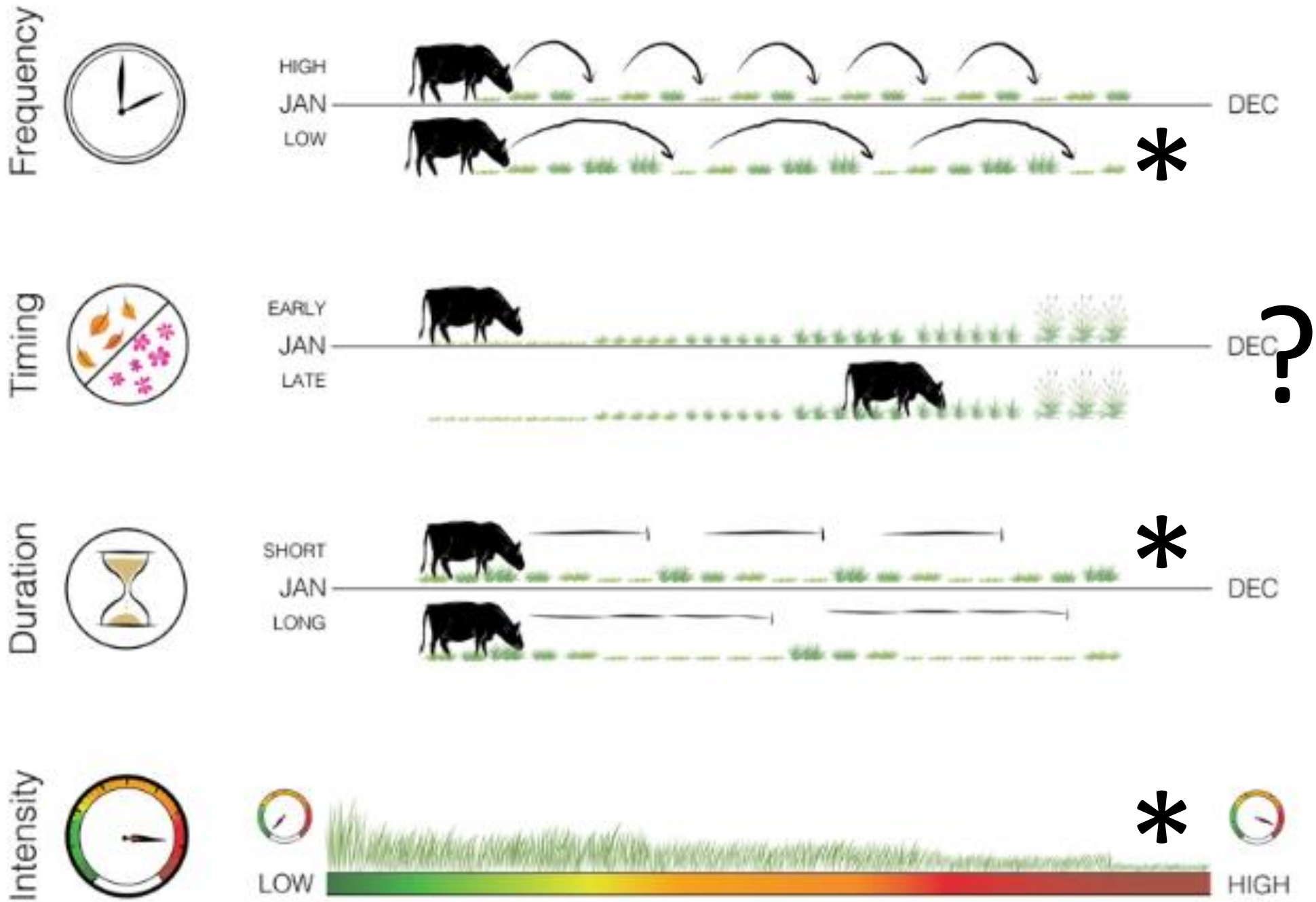
-carbon tends to be in greater on north/east slopes and in areas with greater diversity (even if totally invaded!)

Limiting annual grass invasions will conserve carbon, improving resilience of sagebrush stands, likely affecting fire intensity and success of restoration/ recovery after fire.

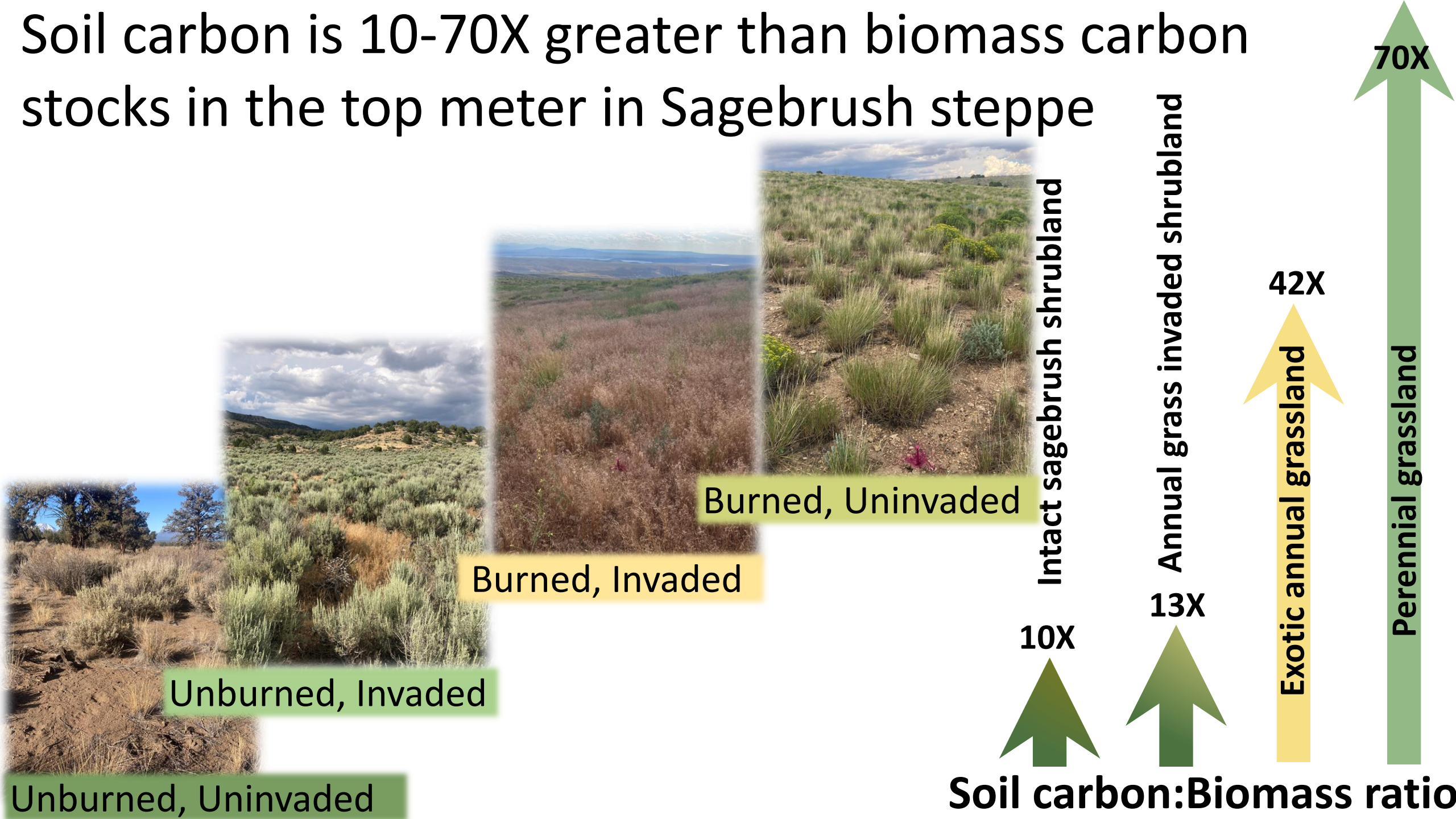
Short duration, high intensity grazing has shown promise for improving soil carbon, quality, more research is needed.

Sagebrush steppe and all arid lands are globally important, opportunity to be leaders that can impact carbon at a scale that matters globally

Grazing effects on soil carbon



Soil carbon is 10-70X greater than biomass carbon stocks in the top meter in Sagebrush steppe



The effect of fire and invasion is less pronounced in shallow soils (roots restricted)