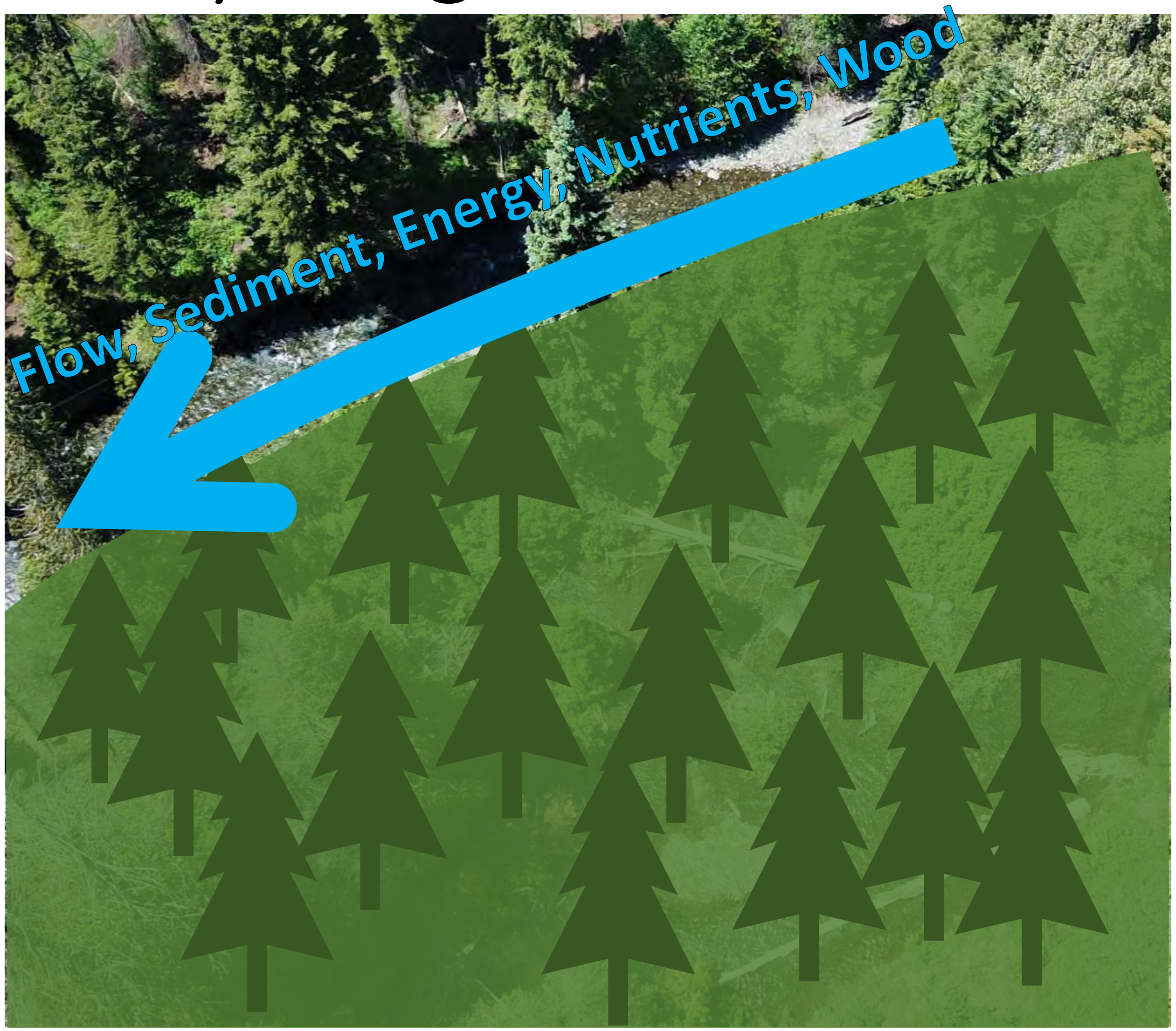
Expanding the benefits of river corridor projects by enhancing floodplain function

Dan Scott, Senior Geomorphologist, Watershed Science and Engineering

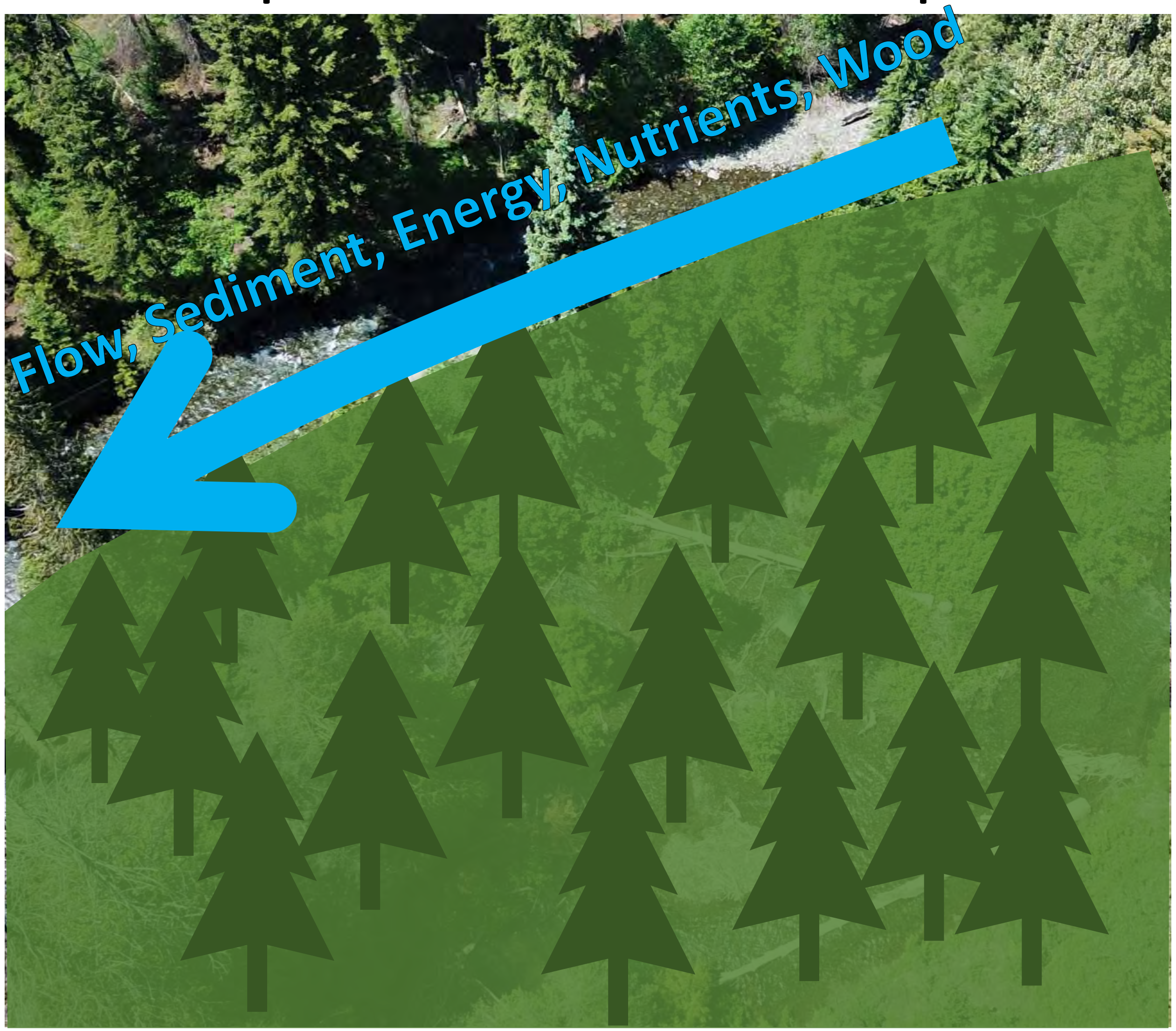
Katherine B. Lininger, Assistant Professor
Department of Geography, University of Colorado Boulder

Lateral Connectivity – the Source of Most Floodplain Function

A laterally disconnected floodplain keeps everything in the channel



Enhancing Lateral Connectivity Allows the Floodplain to Soak Up Mass and Energy



Implications of Redistributing Mass and Energy

- Water escapes the channel and resides on the floodplain
- Water carries sediment, wood, nutrients, and carbon, some of which remains on the floodplain for long periods of time
- Diverting water out of the channel can reduce stress on channel bed and banks during floods, potentially reducing geomorphic risk locally and downstream



Outline

What can floodplains do for the river corridor?

1. Floodplains distribute energy and reduce geomorphic risk
2. Floodplains store sediment
3. Floodplain wood redistributes energy and sediment
4. Carbon storage in floodplains: floodplain wood and soil carbon

Summary and considerations when restoring floodplain function

Group discussion: reflection and brainstorming about restoring floodplain function

Floodplains Provide an Energy Sink

$\Omega = \gamma Q S \quad \omega = \Omega / w$ unit stream power = flow's ability to do work

$w_1 < w_2$ increase total flow width

$\omega_1 = \frac{\Omega}{w_1}$ unit stream power with narrow width

$\omega_2 = \frac{\Omega}{w_2}$ unit stream power with wider width

$\omega_1 > \omega_2$ widening effective flow drops unit stream power

Hydraulic Model

Ongoing bank erosion breached a revetment

Can floodplain reconnection mitigate mainstem erosion risks while restoring salmonid habitat?

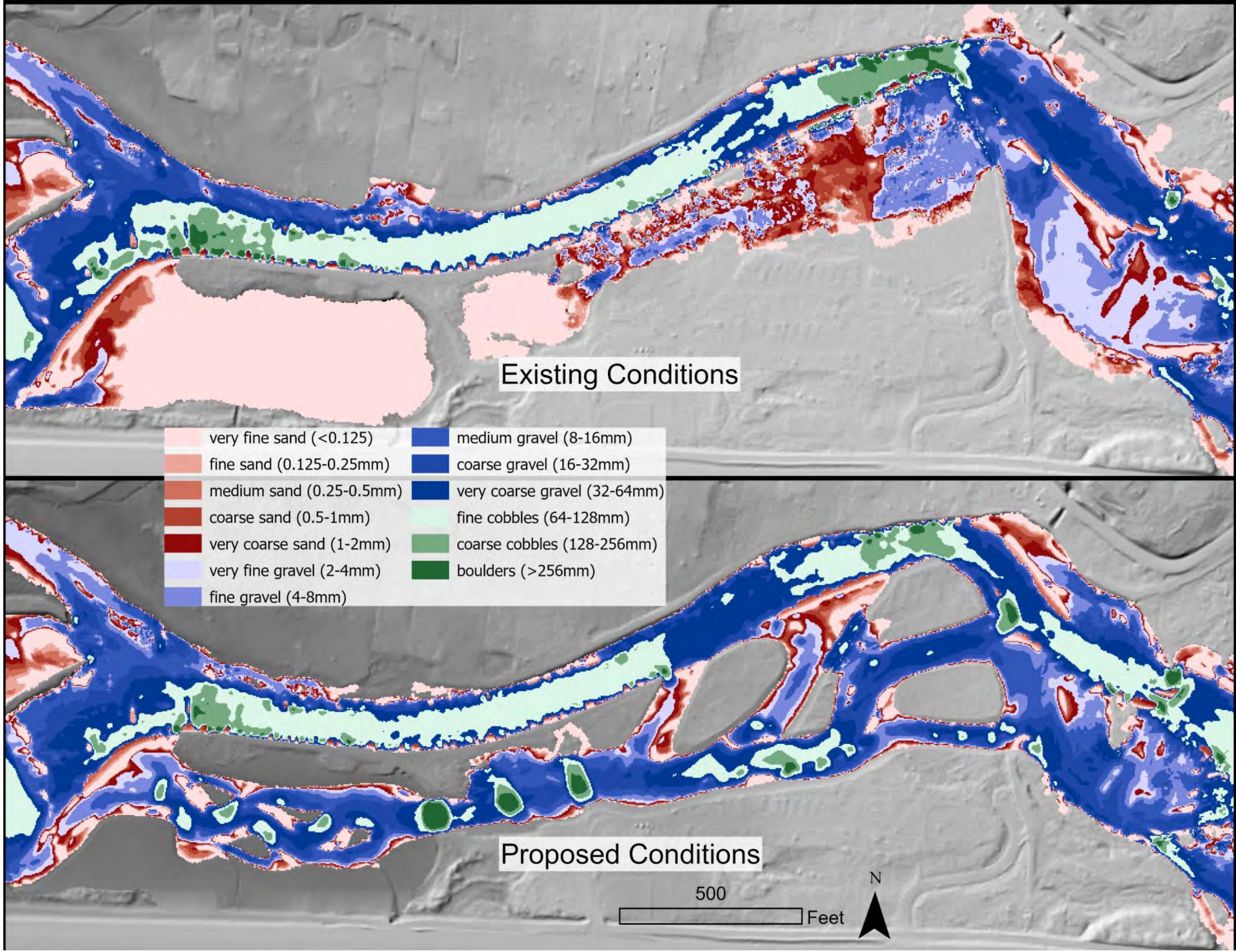
Hydraulic Model

Can floodplain reconnection mitigate mainstem erosion risks while restoring salmonid habitat?

Divert flow through side channels and engage floodplain

Hydraulic Model

Diverting flow reduces predicted incipient motion particle size in mainstem



Reality

Problem:

- Ongoing incision
- Exposed bedrock, cobbles, boulders (lacks spawning habitat, refuge)

Solution:

- Loose wood roughening
- Flow deflectors for lateral hydraulic connectivity

Result:

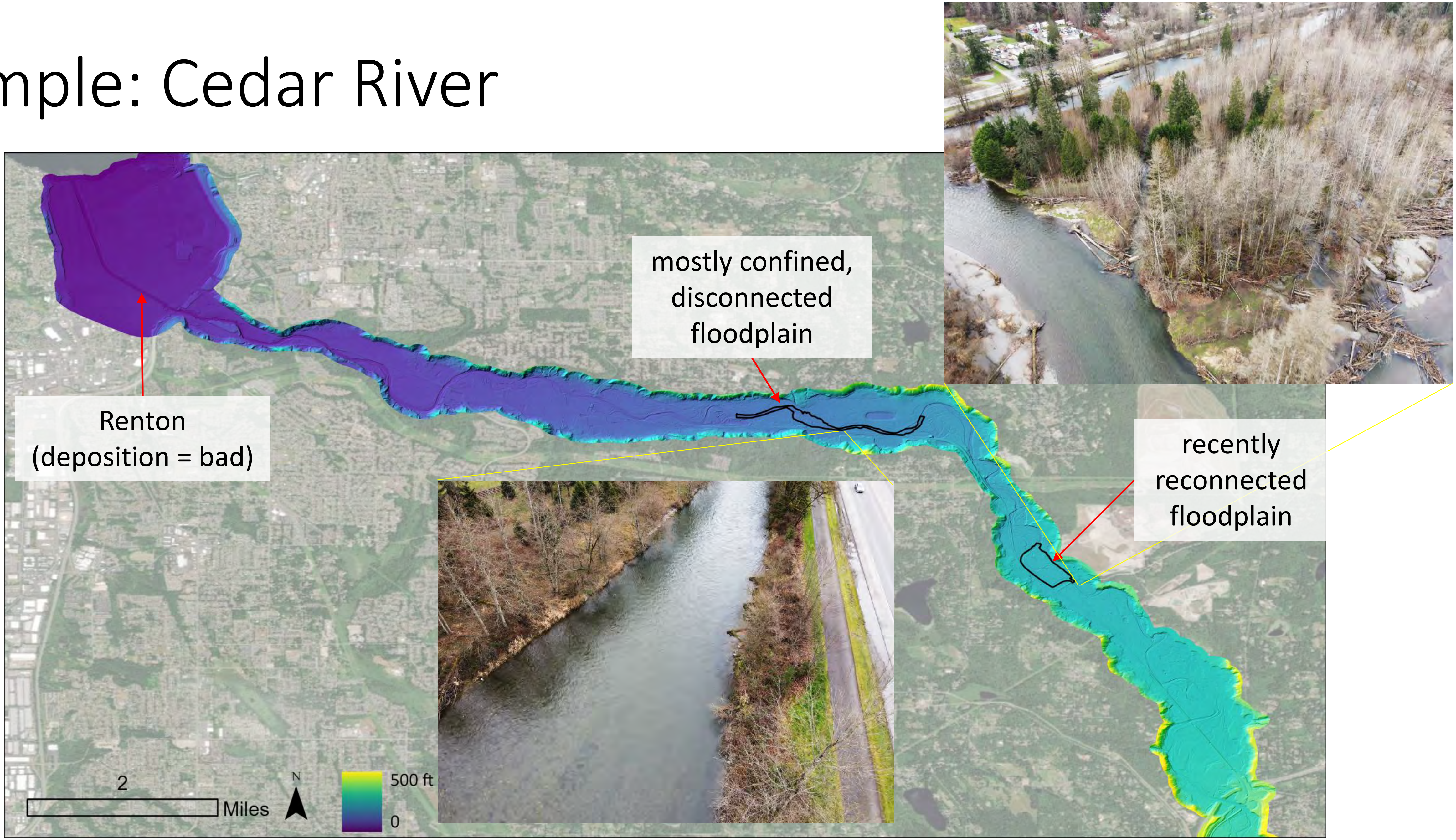
- Fining
- Incision halted (for now…)

Floodplains store sediment

Floodplains keep sediment from going downstream

- Can improve water quality (e.g., may slow down post-fire sediment yield; Wilson et al., 2021)
- Can keep it out of places where it aggravates humans, such as where it exacerbates flood risk (Anderson & Jaeger, 2020; Collins et al., 2019)

Example: Cedar River



How do connected floodplains affect sediment export during floods?

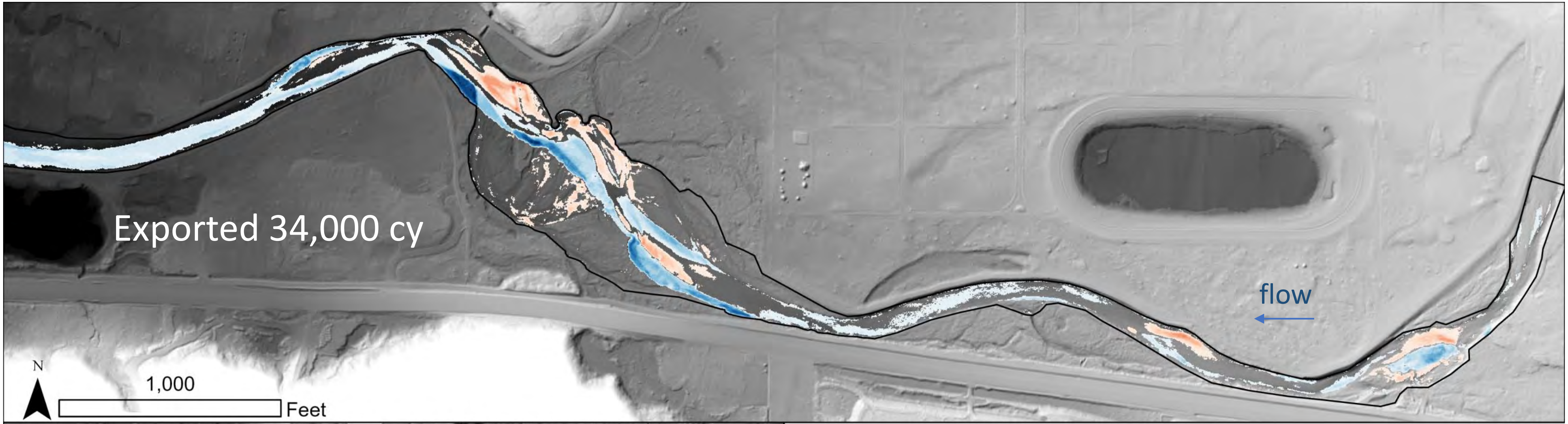
Driver:

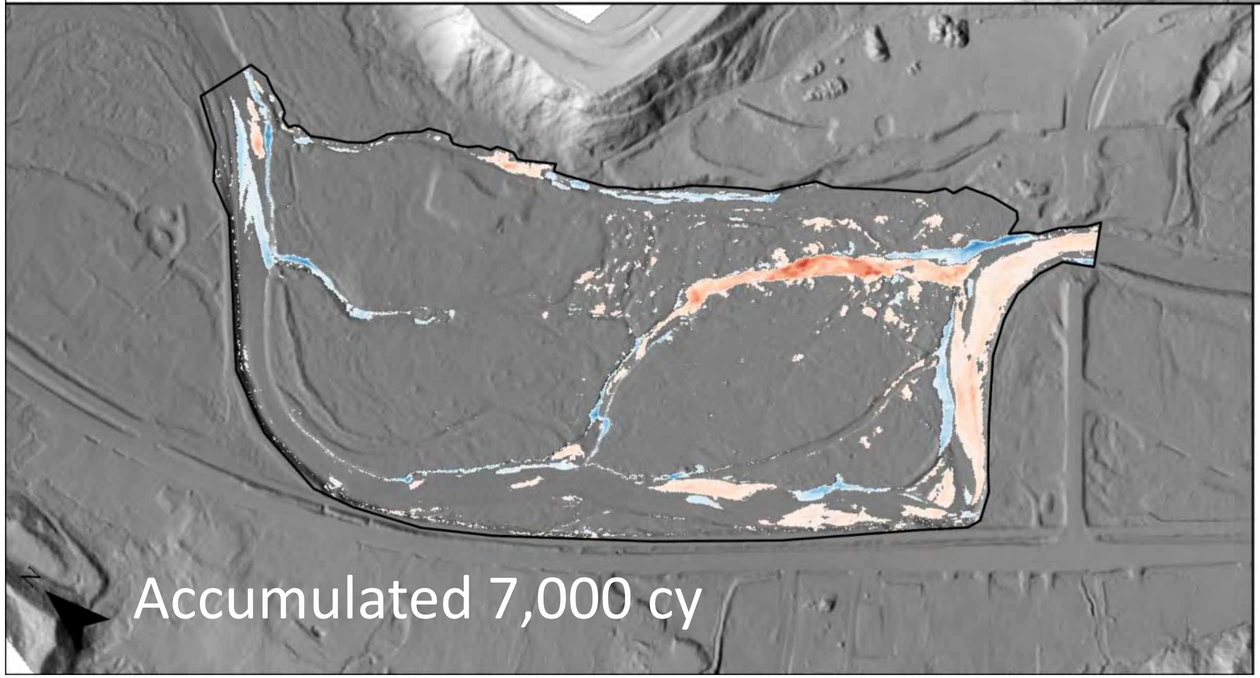
- ~50-year flood with unusually long duration near peak

River-scale result:

- Widespread incision, likely caused by long duration at peak without corresponding sediment supply
- 14,100 cy of material made it to Renton, where it will eventually need to be dredged

Deviations from the norm? **Connected Floodplains**





connected floodplain => aggradation

disconnected floodplain => degradation

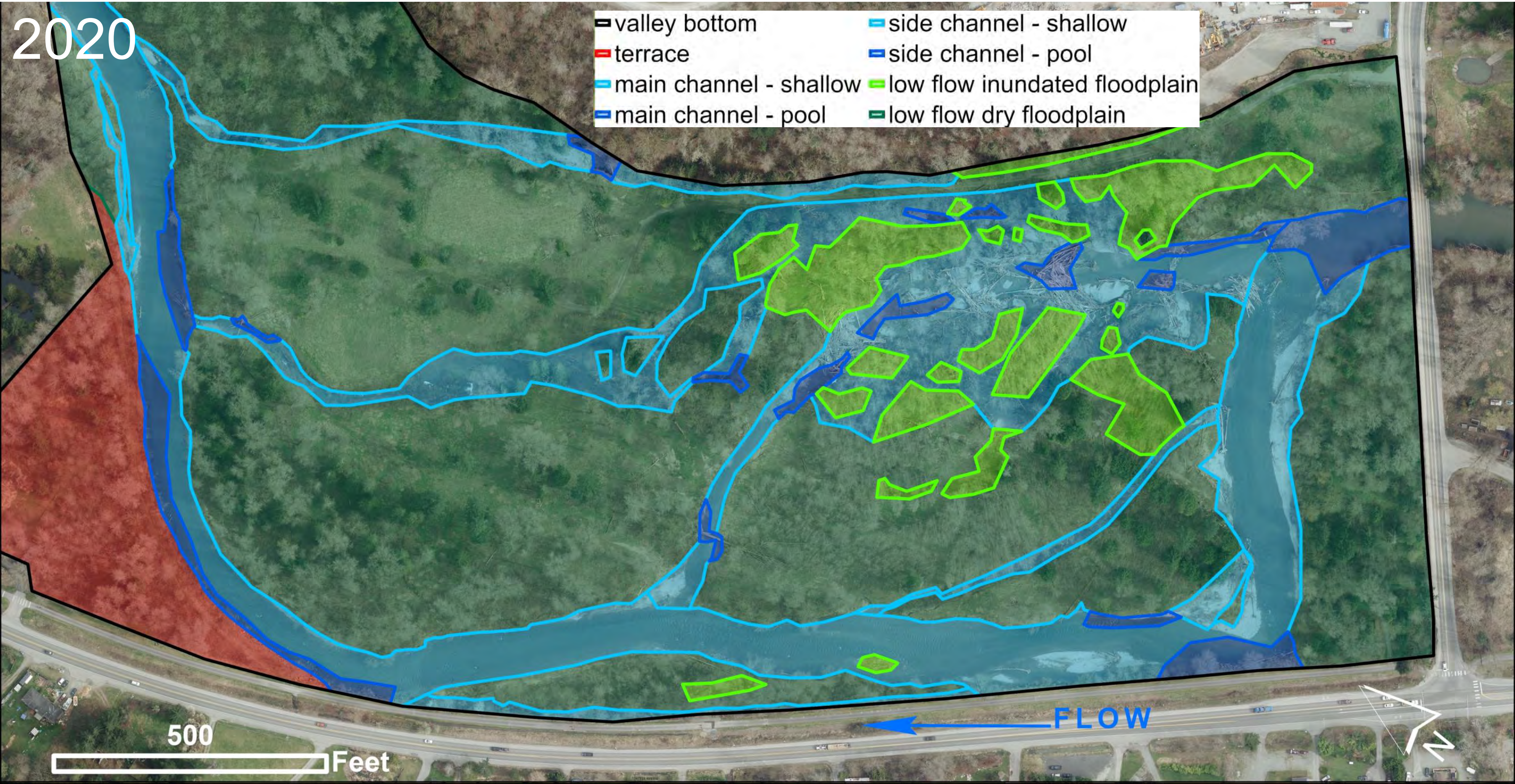
Wood can regulate sediment and energy dynamics on floodplains

- Wood in floodplains and side channels redistributes floodplain flow energy (Jeffries et al., 2003; Sear et al., 2010)

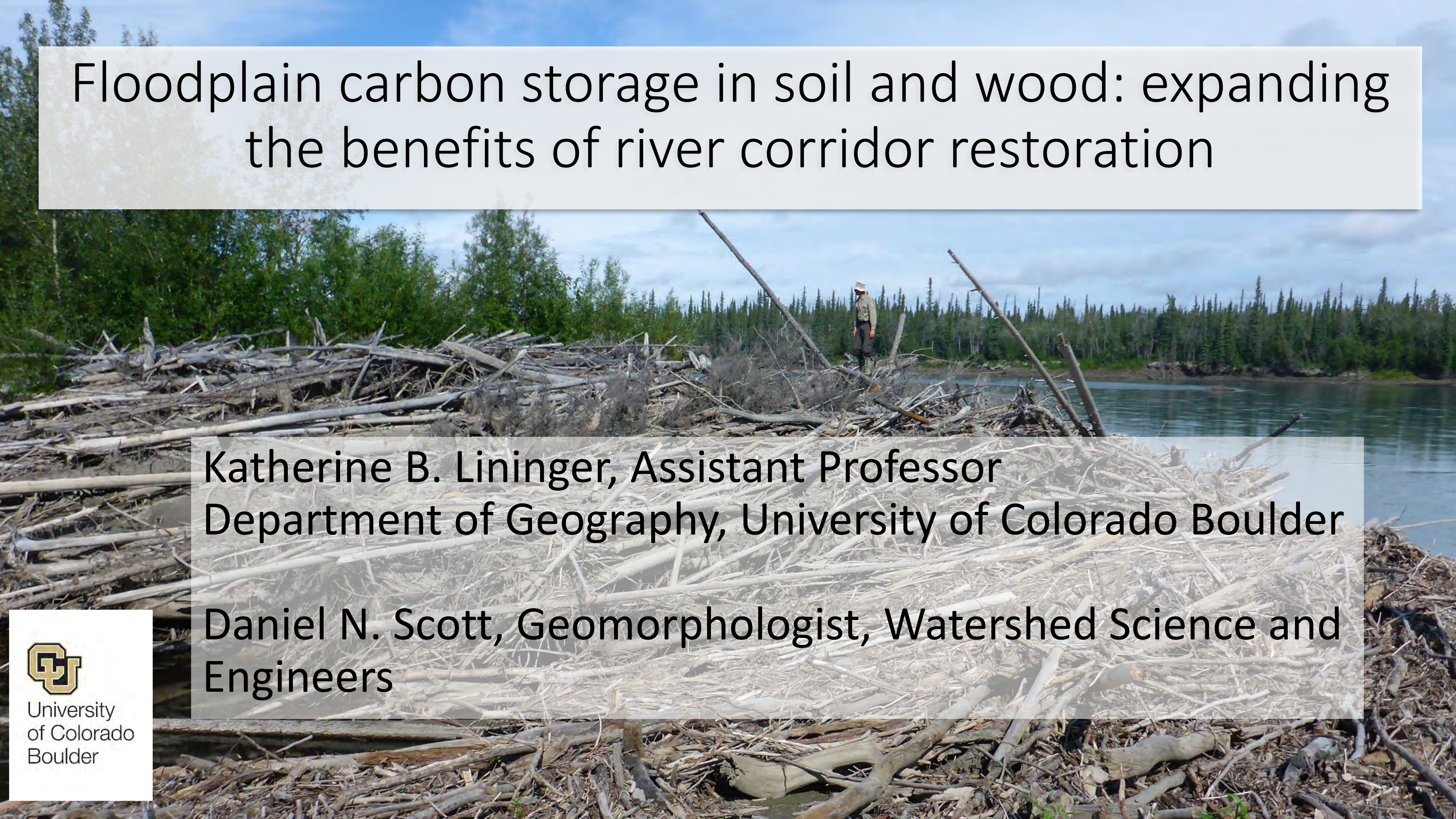
Wood regulates:

- vegetation establishment
- side channel evolution
- aggradation

Wood Magnifies the Benefits of Floodplain Reconnection



Floodplain carbon storage in soil and wood: expanding the benefits of river corridor restoration

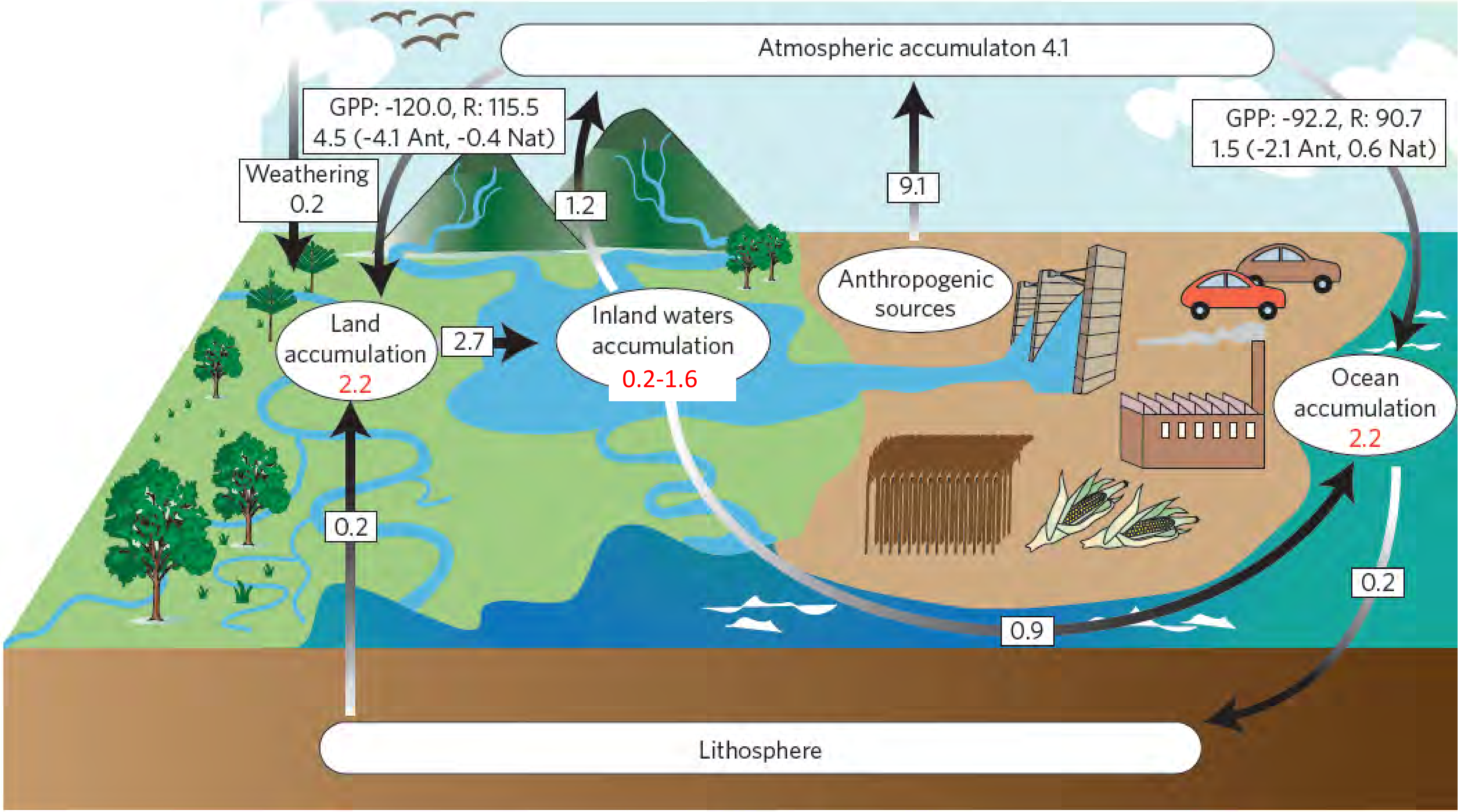


Katherine B. Lininger, Assistant Professor
Department of Geography, University of Colorado Boulder

Daniel N. Scott, Geomorphologist, Watershed Science and Engineers

University of Colorado Boulder

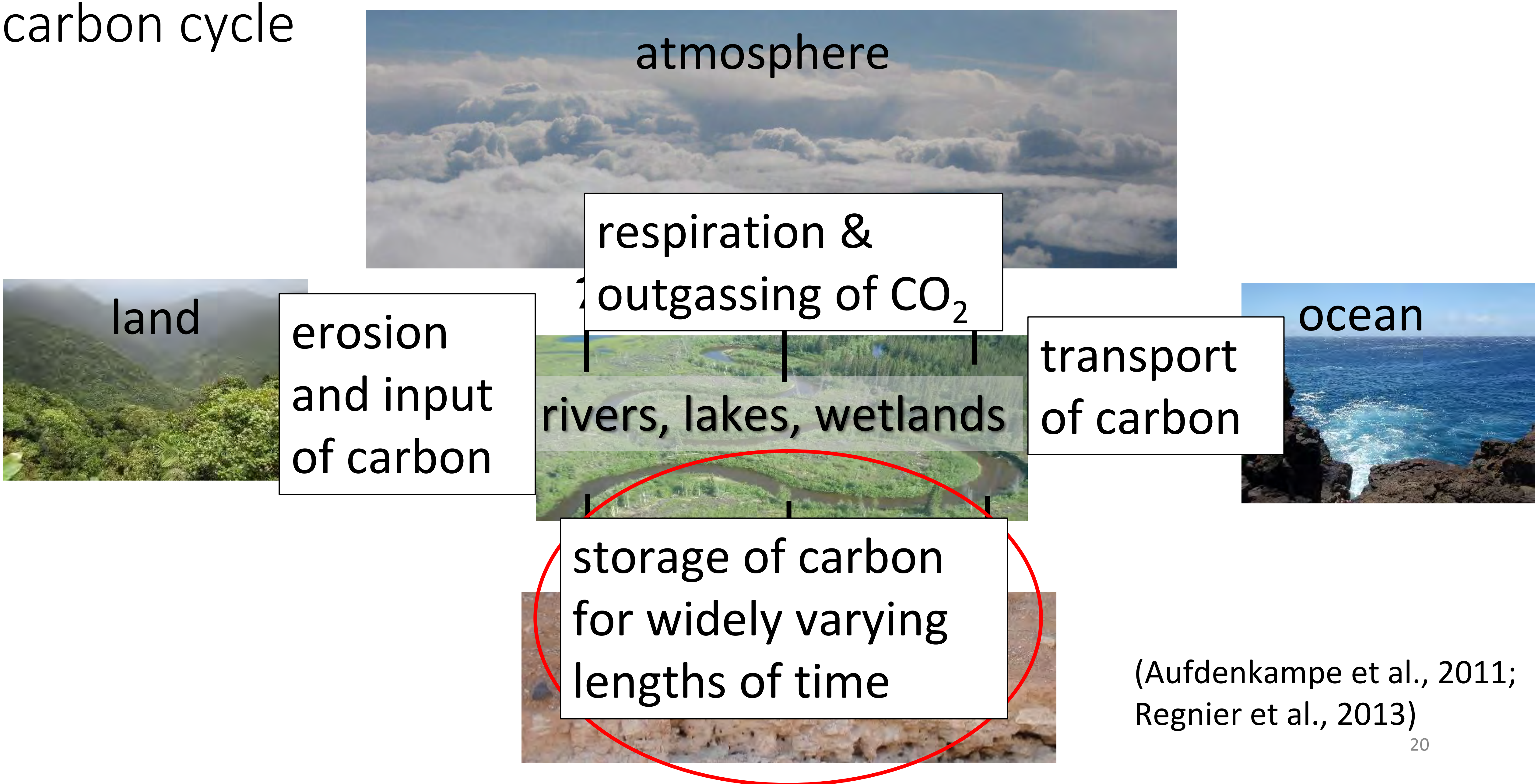
The carbon cycle



From *Battin et al., 2009*

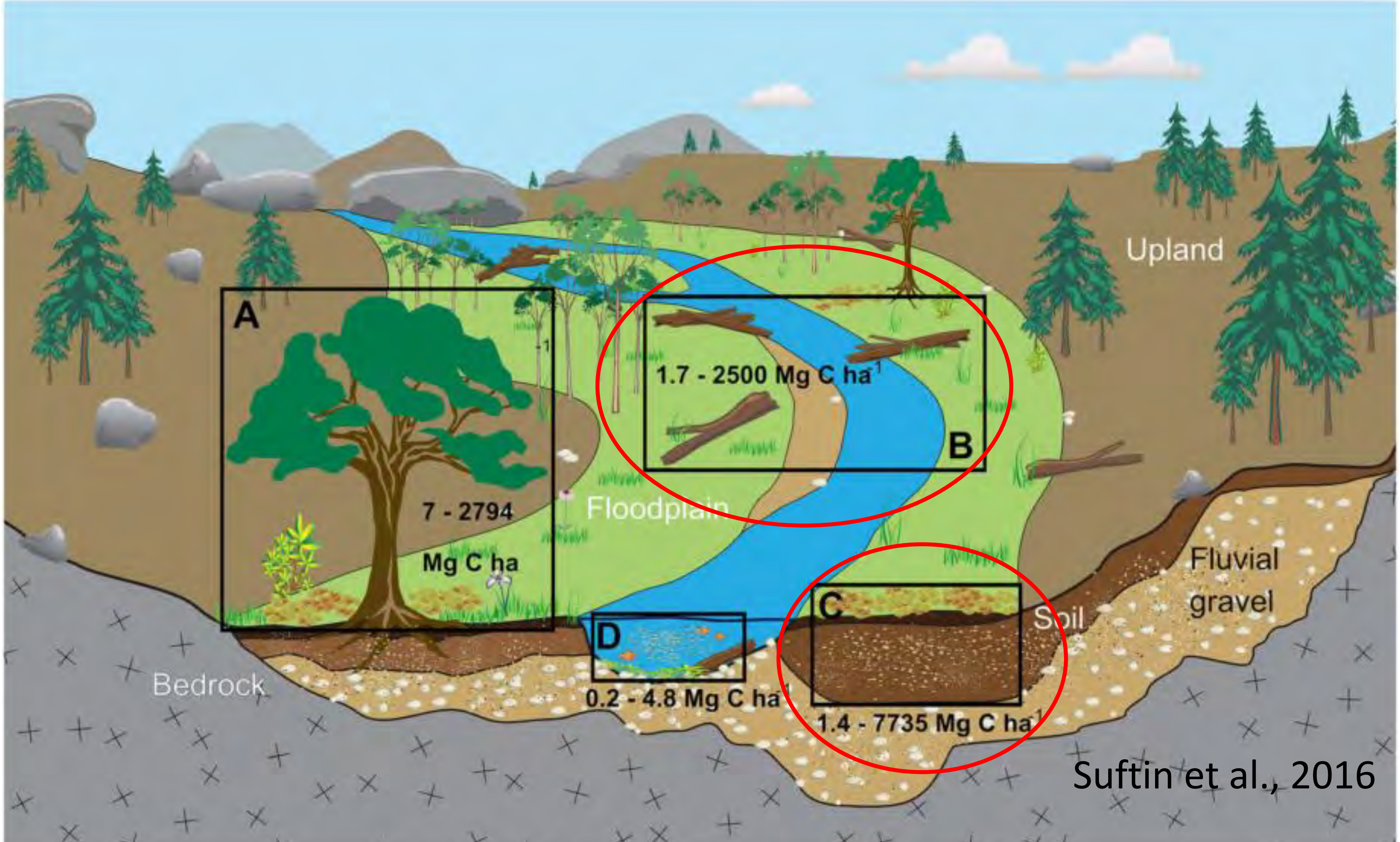
Units in Pg C yr^{-1}

Expanding the benefits of restoration: river corridors and the carbon cycle



(Aufdenkampe et al., 2011; Regnier et al., 2013)

Major stocks of carbon in river corridors



Suftin et al., 2016

Wood and organic matter in river corridors

- large wood (LW): >1m in length and > 0.1m in diameter

- coarse particulate organic matter (CPOM): material > 1mm in diameter

- significant amounts of attention on in-channel large wood since the 1970s

Dall River, AK, USA

(Montgomery et al., 2003; Jones et al., 2014; Wohl et al., 2019)

Wood and organic matter in floodplains

- much less attention on *floodplain* wood and organic matter dynamics

Importance of floodplain wood and organic matter

- floodplain LW influences geomorphic processes (sedimentation, erosion) and floodplain development
- little knowledge of transport and deposition of CPOM and LW in floodplains

(Jeffries et al., 2003; Pettit and Naiman, 2006; Sear et al, 2010; Collins et al., 2012; Sutfin et al., 2016; Lininger et al., 2017)

Importance of floodplain wood and organic matter

Ecological importance of floodplain LW and CPOM:

- significant organic carbon stock
- sites of seedling establishment
- habitat for biota
- enhances soil nutrients

Floodplain wood as an opportunity for restoration/management

(Jeffries et al., 2003; Pettit and Naiman, 2006; Sear et al, 2010; Collins et al., 2012; Sutfin et al., 2016; Lininger et al., 2017)

Human have likely reduced OC storage and large wood in river corridors

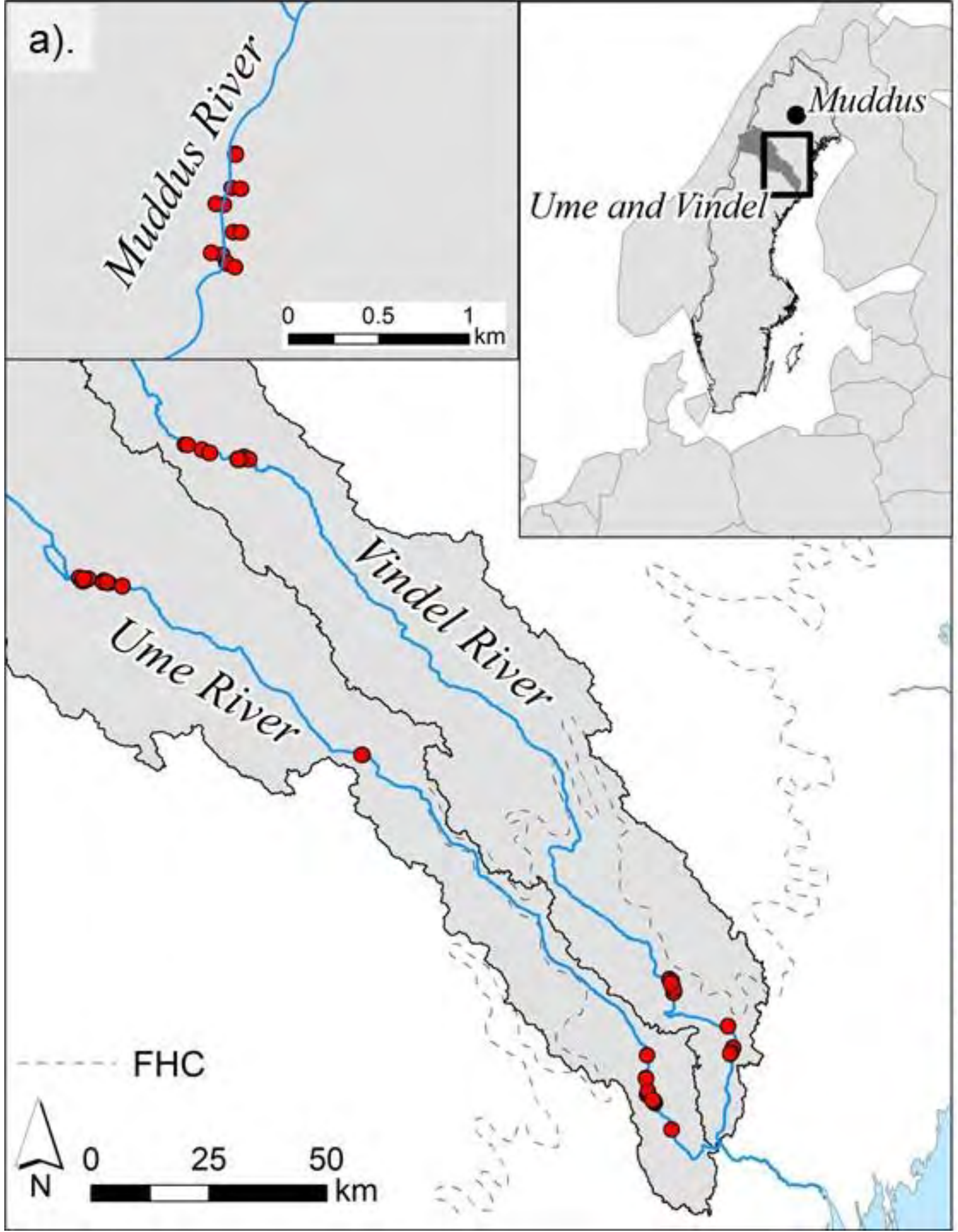
- Example: Lower Mississippi River Valley (Hanberry et al. 2015)


Danube River, photo by Ellen Wohl

Vs.

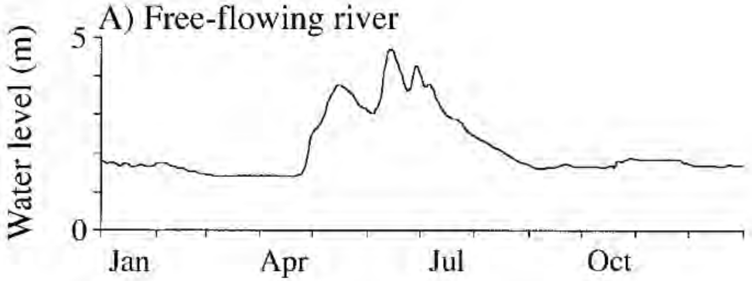

Preacher Creek, Alaska

(Wohl, Hall, Lininger et al. 2017, *Ecological Monographs*)

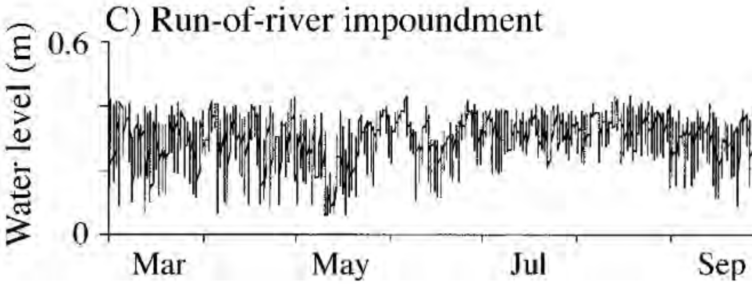


Muddus River: unaltered

Vindel River: Not dammed, but logged

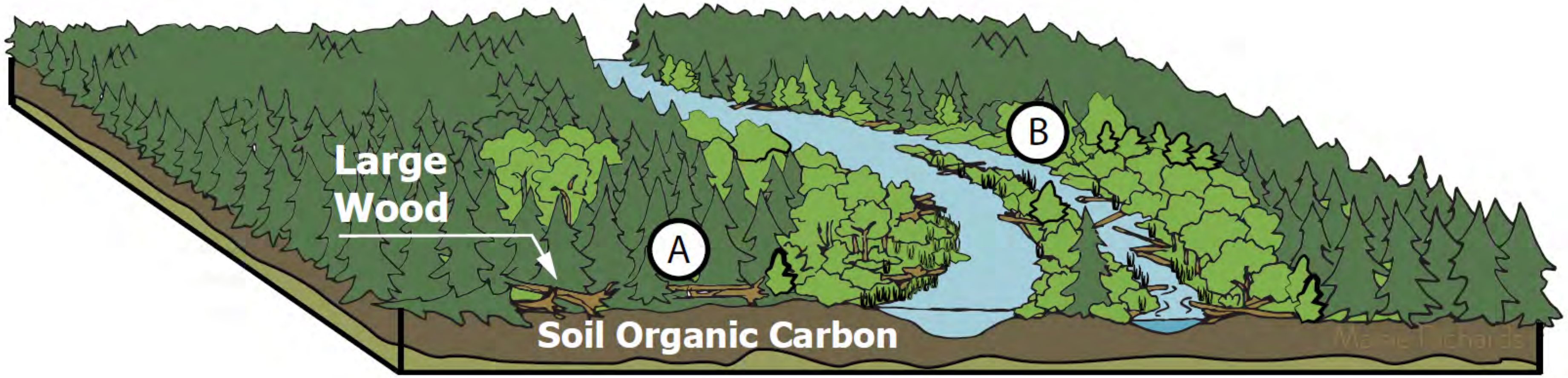


Ume River: Dammed and logged



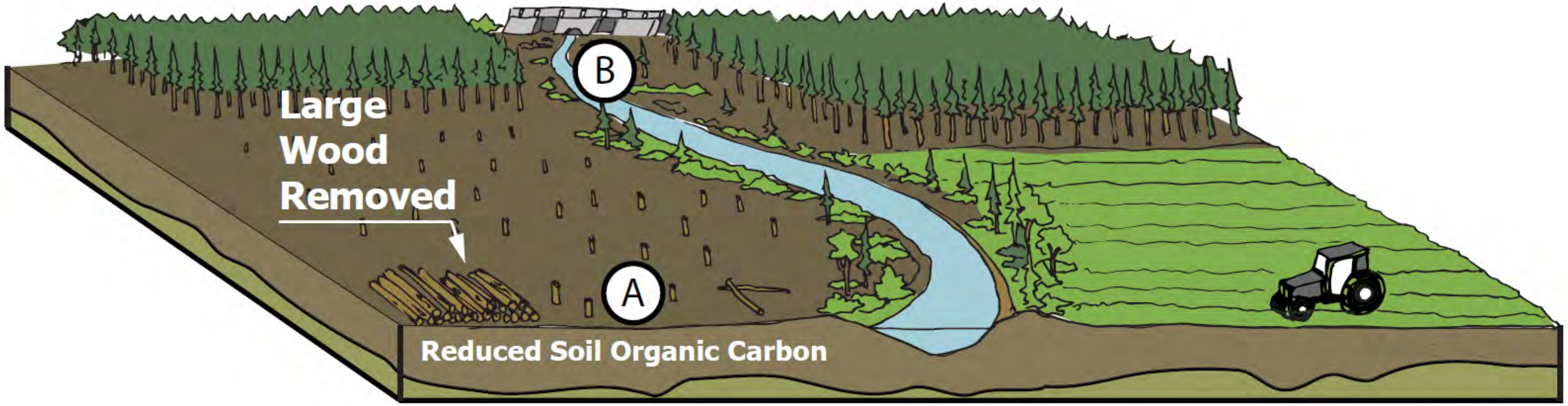
Unaltered vs. altered river corridors in northern Sweden

Unaltered river corridor:



Human alterations
(logging/land-use change, dams)

Altered river corridor:



(A) organic carbon in large wood and soil comes from standing vegetation in floodplains

human activities reduce this

(B) flooding delivers fine sediment, organic material, large wood, and moisture to floodplains

dams reduce this

(Lininger and Polvi, 2020, *Geomorphology*)

We have reduced floodplain soil OC storage and floodplain wood loads.

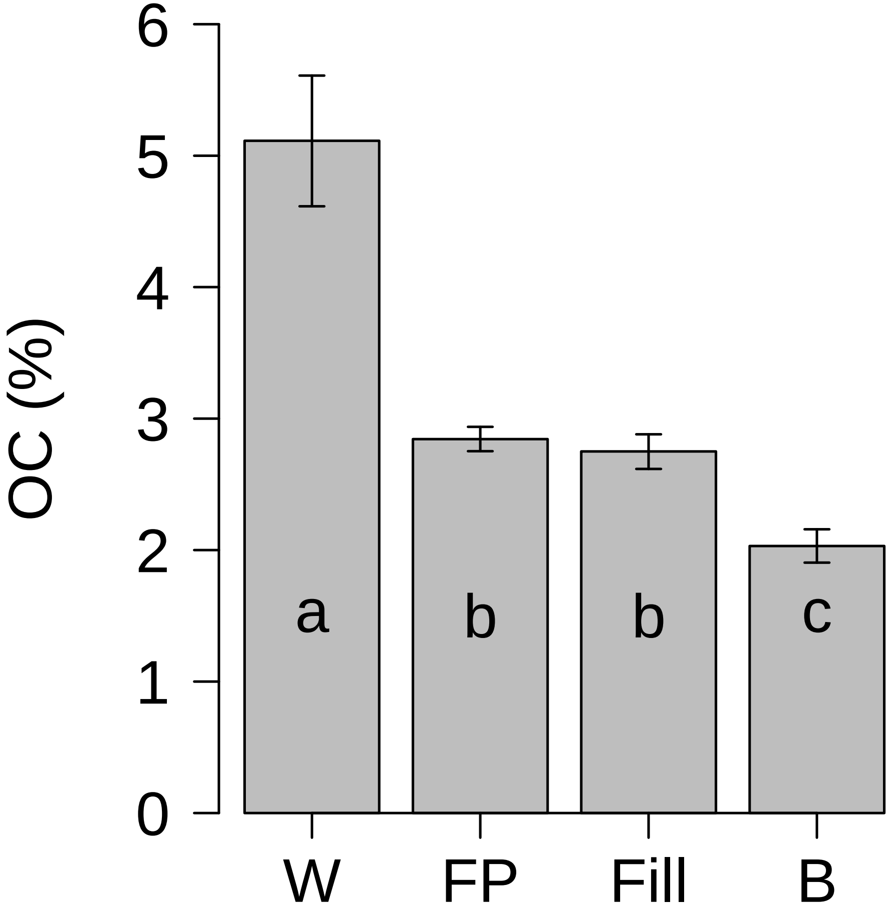
So:
What processes result in high soil OC and high floodplain wood loads?

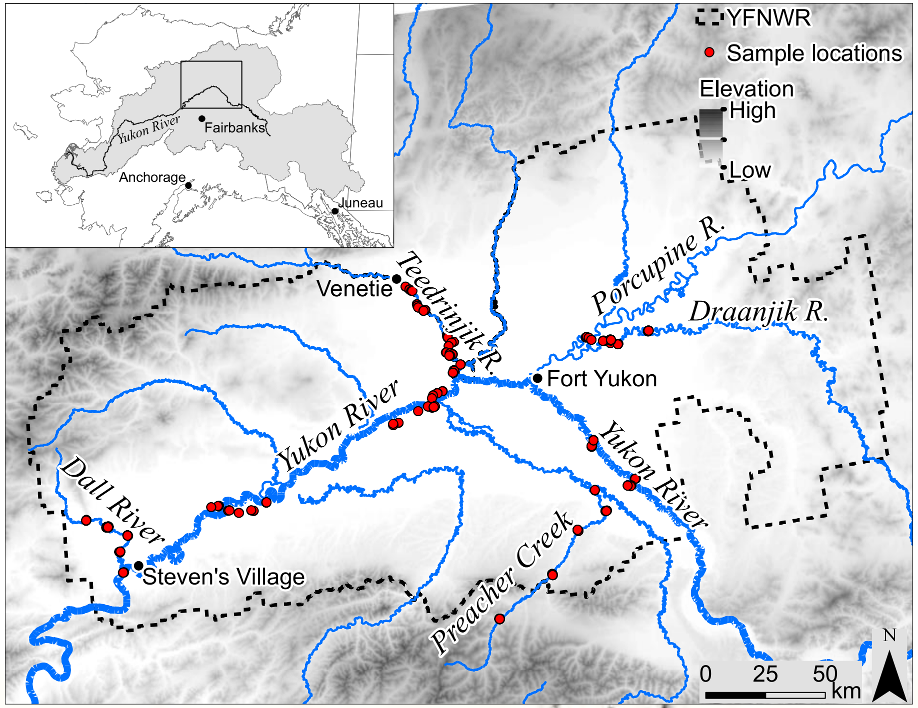
What promotes high soil organic carbon storage in floodplains?

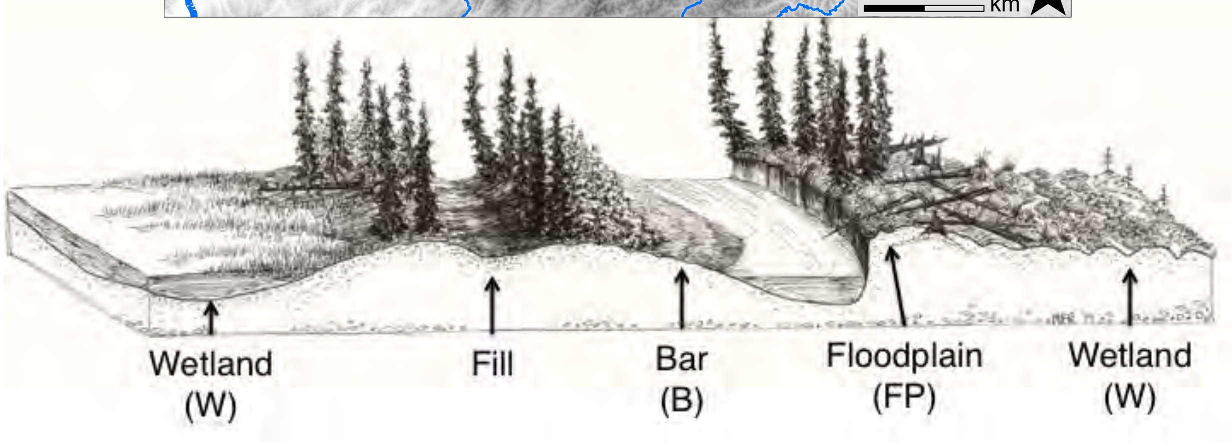
- higher concentration of soil OC in floodplains compared to uplands
- soil OC varies with:
  - temperature
  - vegetation
- geomorphic factors

(Appling et al. 2014; Jobbágy & Jackson 2000; Pinay et al. 1992; Sutfin et al. 2016; Lininger et al. 2017, 2018, 2019; Sutfin et al., 2021)

Floodplain soil OC varies with geomorphic factors: moisture, grain size, geomorphic unit



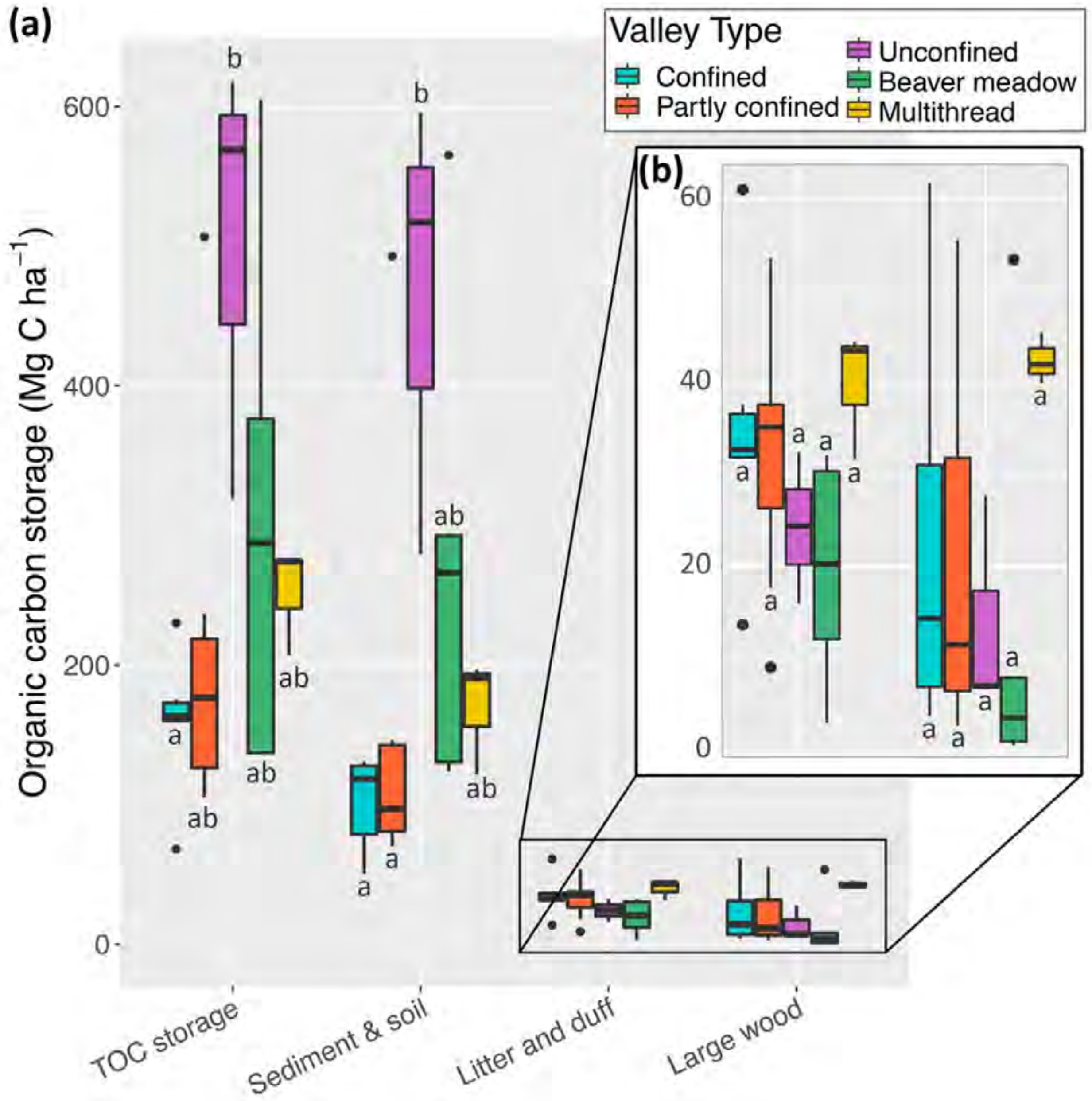




(Lininger et al., 2018, *Water Resources Research*)

Floodplain soil OC varies with valley geometry

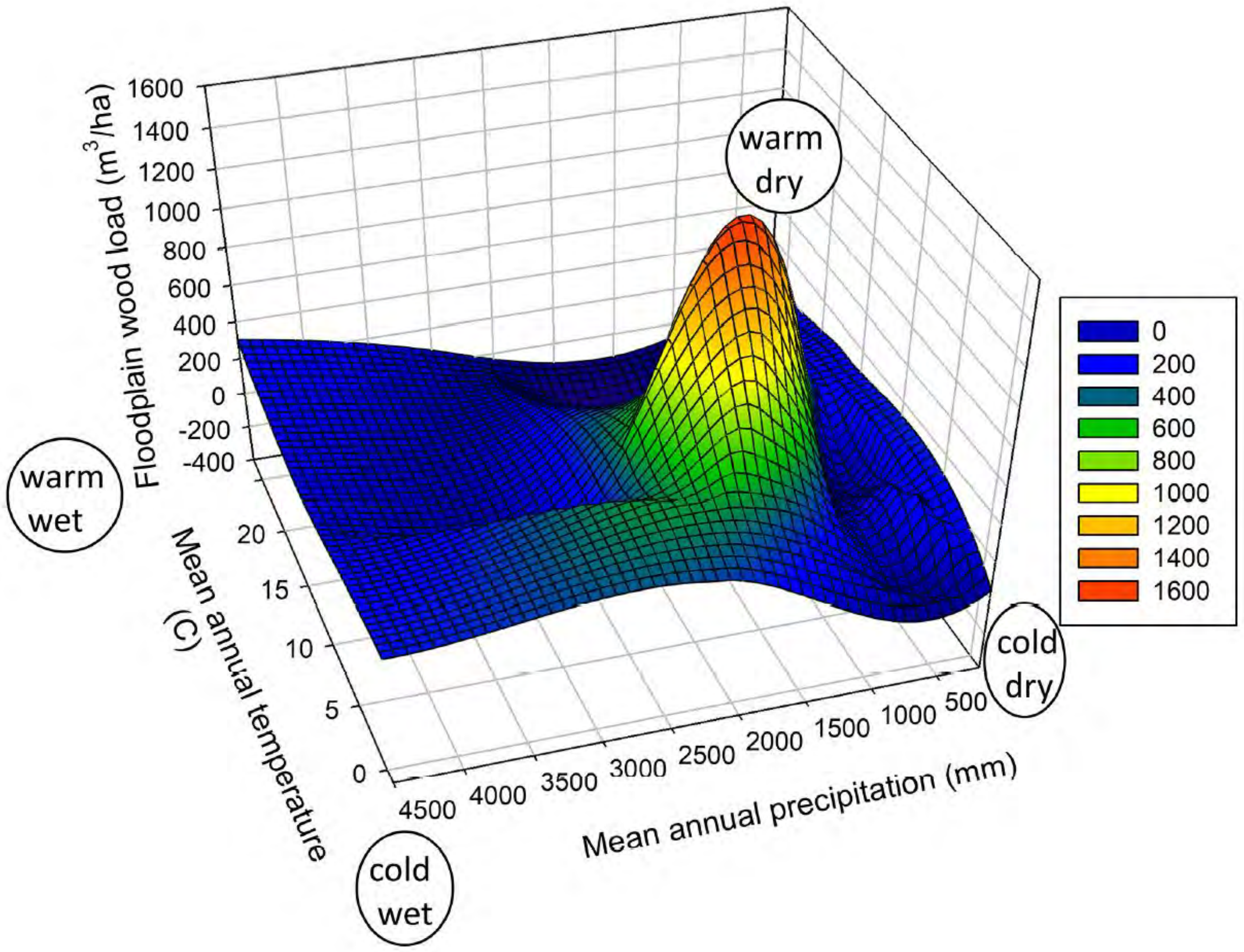
- Unconfined (wider floodplain relative to channel width) valley segments store more soil organic carbon



Sutfin et al., 2021, *Water Resources Research*

What promotes high wood loads on floodplains?

- Floodplain large wood loads vary with:
  - climate/biome



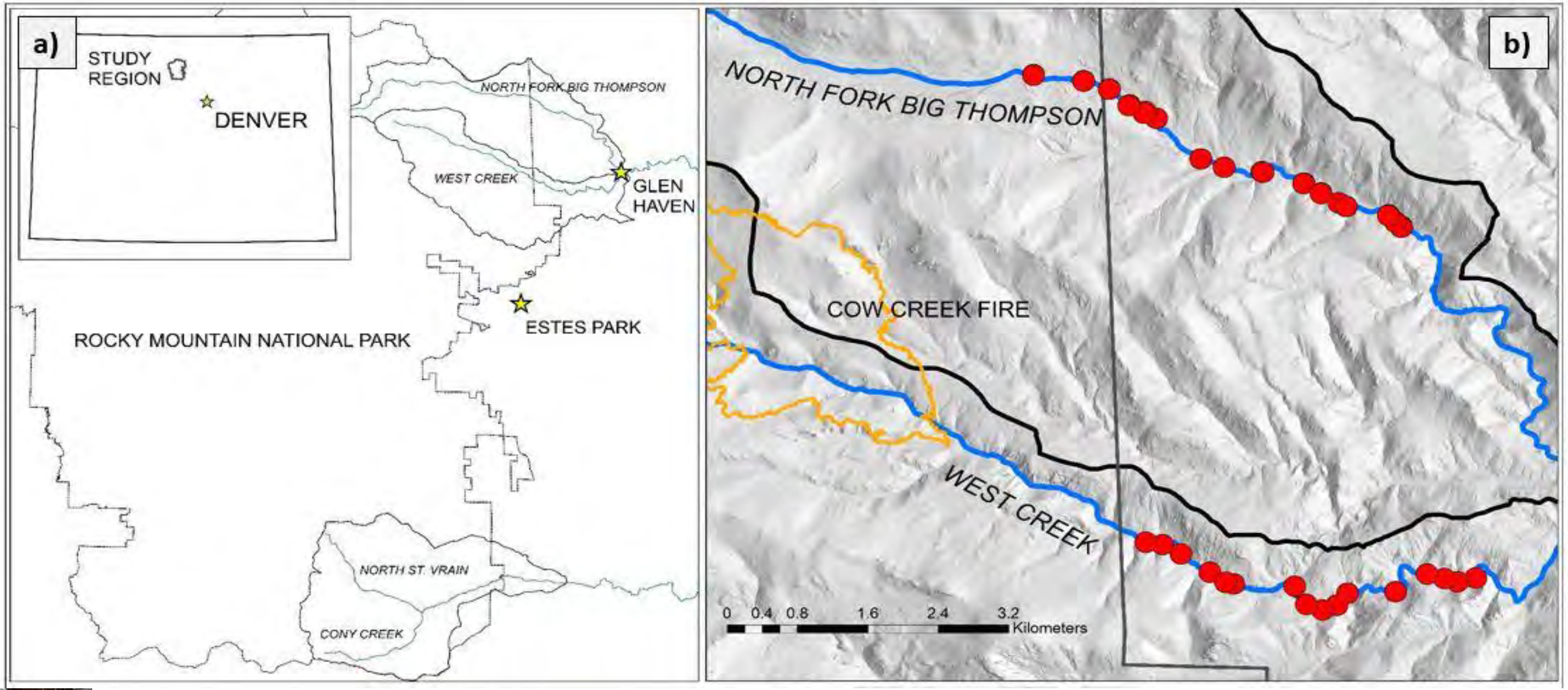
(Lininger et al. 2017, Wohl 2020)

What promotes high floodplain wood loads?
disturbance regime, geomorphic and forest stand characteristics

West Creek, CO, USA

How does wood and organic matter get onto floodplains?

- disturbance history
- tree stand density
- geomorphic characteristics



(Lininger et al., 2021, *JGR: Earth Surface*; Guiney and Lininger, in review, *Earth Surface Processes and Landforms*)

LW and CPOM delivery onto floodplains from a large flood

Fieldwork

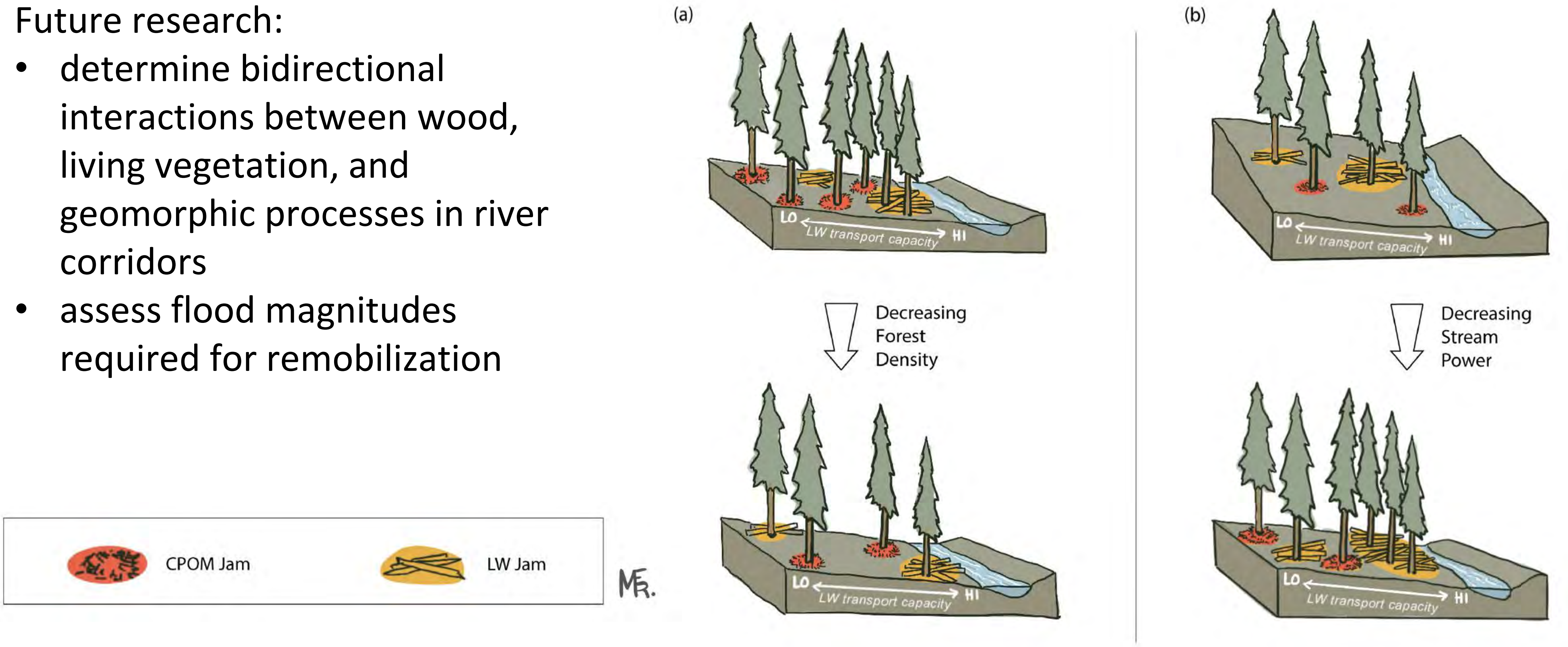
- measured jams of large wood (>1m length and 0.1m diameter) and CPOM (material > 1mm in diameter)

(Lininger et al., 2021, *JGR: Earth Surface*; Guiney and Lininger, in review, *Earth Surface Processes and Landforms*)

Forest stand density and geomorphic characteristics influence frequency and load of floodplain jams

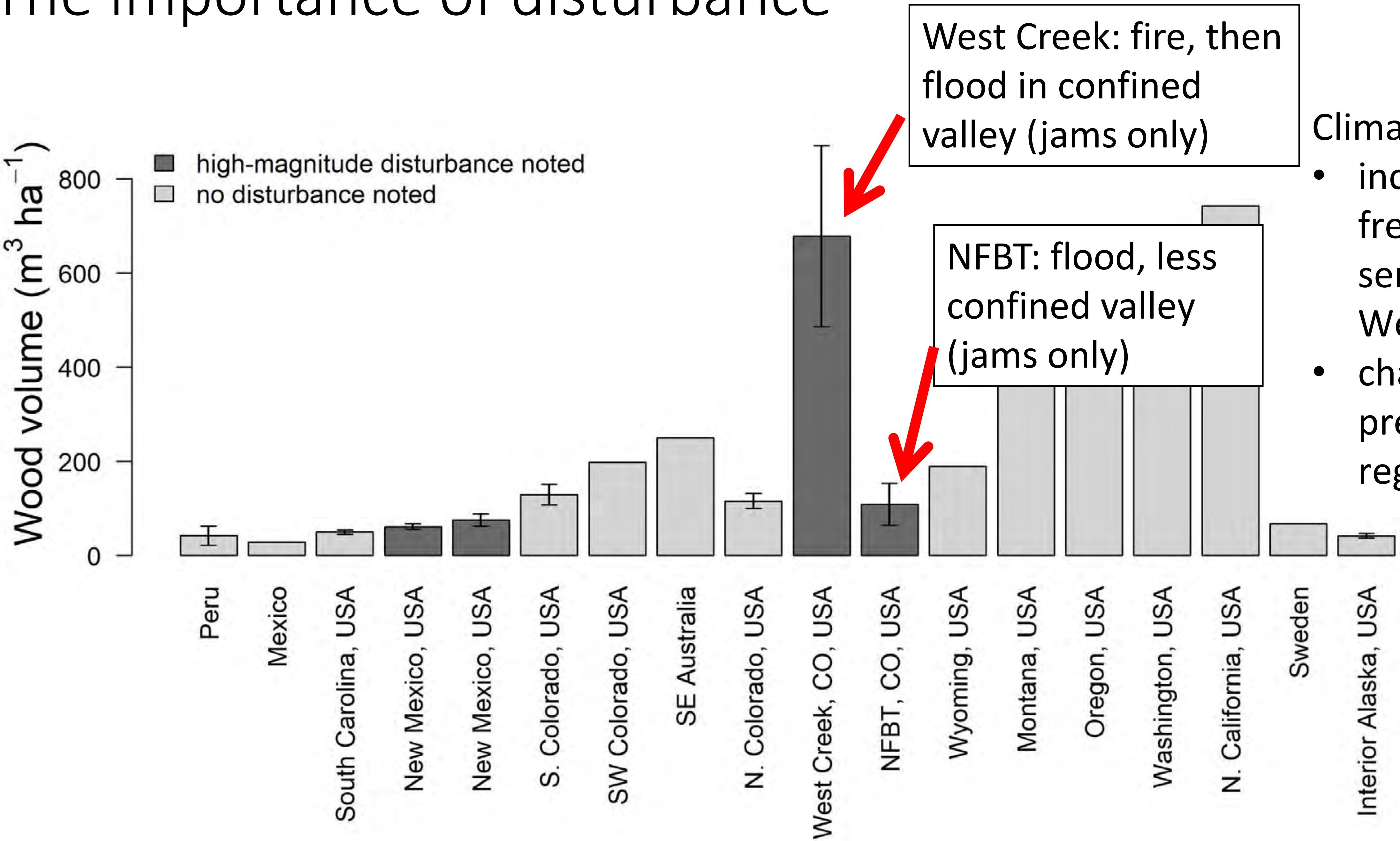
Future research:

- determine bidirectional interactions between wood, living vegetation, and geomorphic processes in river corridors
- assess flood magnitudes required for remobilization



(Lininger et al., 2021, *JGR: Earth Surface*)

The importance of disturbance



Climate change:

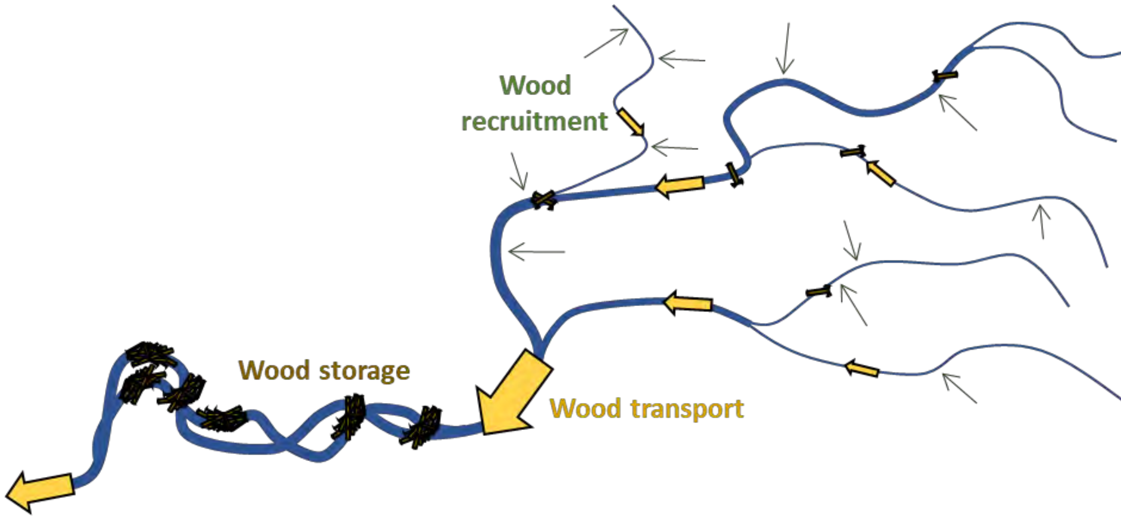
- increased fire frequency in semiarid Western USA
- changes in precipitation regimes?

Conclusion: Floodplain soil carbon and wood can provide additional benefits during river corridor projects

West Creek, CO

Preacher Creek, AK

Considerations



- Must consider ecogeomorphic context:
  - Wood, sediment, flow regime
  - Floodplain ecology, invasives, etc.

- Hard to assign a design life to floodplain function, but timescale of function determines long-term benefits
  - How long will reconnection and function last?
  - Are ingredients (context) present to sustain reconnection and function?

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- Colorado Water Institute

Questions?

Wood along the Yukon River, AK

Discussion Questions (pick one or more to discuss):

1) How can you integrate floodplain function into your projects?

2) Are there floodplain functions we discussed today that you don’t typically consider?

3) How can you overcome barriers to restoring floodplain function?

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