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Quantifying ecosystem service tradeoffs in response to alternative land use and climate scenarios: Pacific Northwest applications of the VELMA ecohydrological model

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Quantifying ecosystem service tradeoffs in response to alternative land use & climate scenarios:

Pacific Northwest applications of the VELMA ecohydrological model

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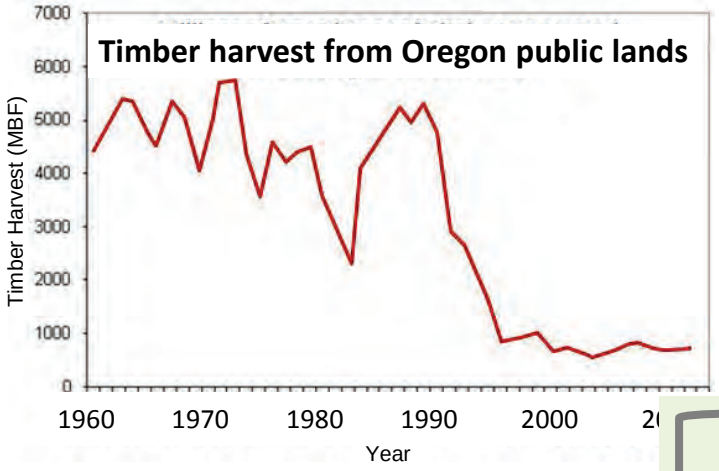
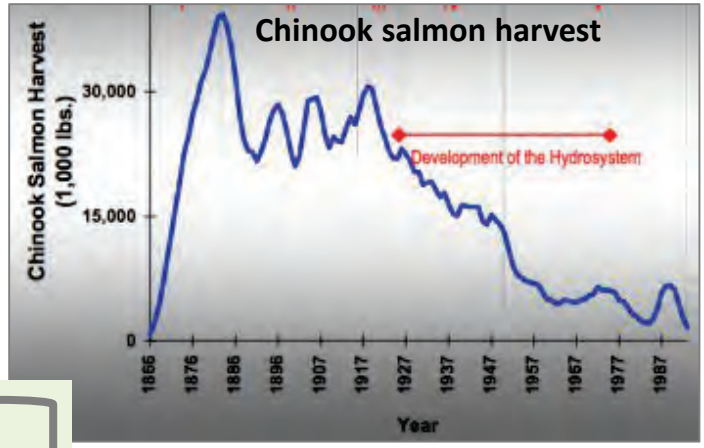
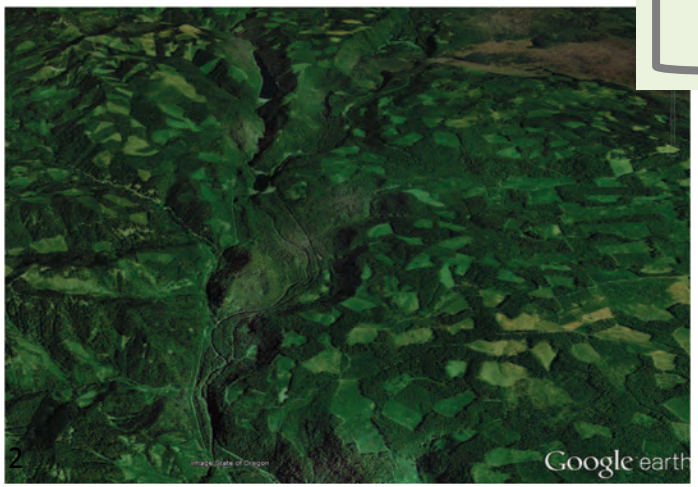




The historical pattern of resource use in the PNW has often been one of boom and bust, with unsustainable management practices leading to severe downturns in major industries, such as the once thriving salmon fishery and forest products industry.



Motivation

Communities need comprehensive approaches for meeting present needs without compromising the capacity of ecosystems to meet the economic, social and human health needs of future generations.

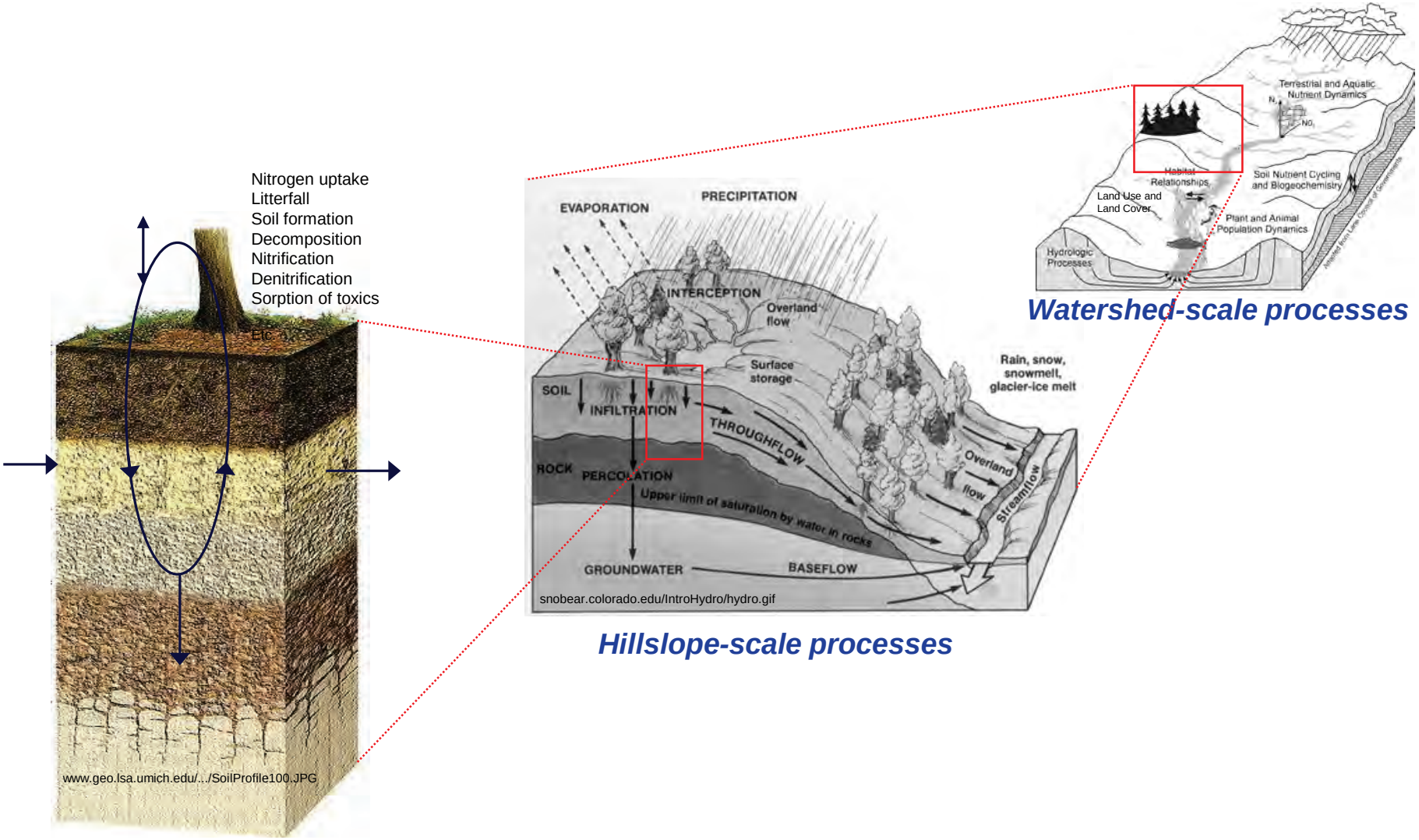
Our Goal

Develop & demonstrate nationally applicable decision support tools for quantifying the production and value of ecosystem goods and services for achieving sustainable and healthy communities.

Questions

- **How will alternative land use and climate scenarios affect ecosystem services vital to human well-being?**
  - Food & fiber
  - Water quality (nutrients, sediments, toxics, temperature…)
  - Water quantity (peak & low flows)
  - Climate regulation (carbon sequestration, GHGs)
  - Habitat for fish & wildlife populations
  - Recreational opportunities
- **Can such ecosystem services be managed sustainably?**
- **To what extent does emphasizing one service result in tradeoffs with others?**
- **Can models reliably address these questions at the scales required by resource managers & communities?**

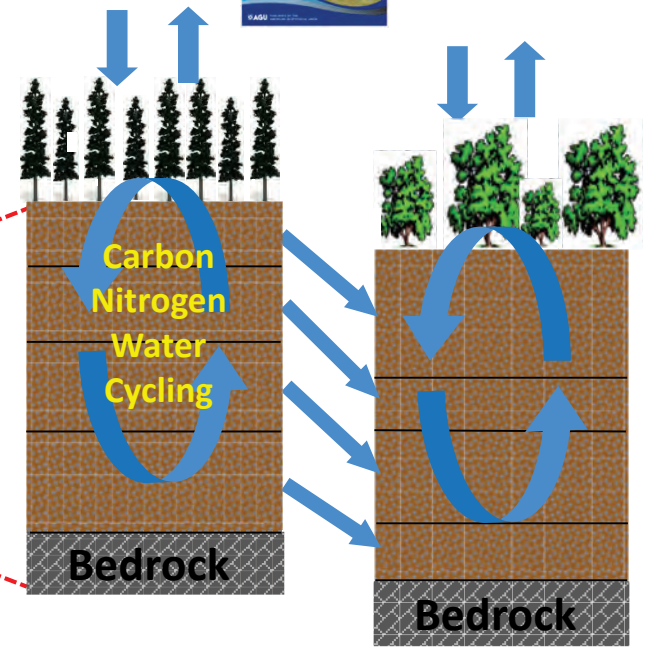
Premise: provisioning of food, clean water and other ecosystem services is strongly regulated by hydrological and biogeochemical processes that interact across multiple scales



VELMA Eco-hydrological Model

Abdelnour, Stieglitz, Pan & McKane, 2011

Abdelnour, McKane, Stieglitz & Pan, 2013



Interaction of hydrological & biogeochemical processes:

- ***Hydrological:*** *streamflow, ET, vertical & lateral flow, …*
- ***Biogeochemical:*** *plant & soil C and N dynamics, transport of NH_4, NO_3, DON, DOC, Hg and other contaminants*
- ***Drivers:*** *daily temperature, precipitation and disturbances (fire, harvest, fertilization…)*

VELMA Eco-hydrological Model

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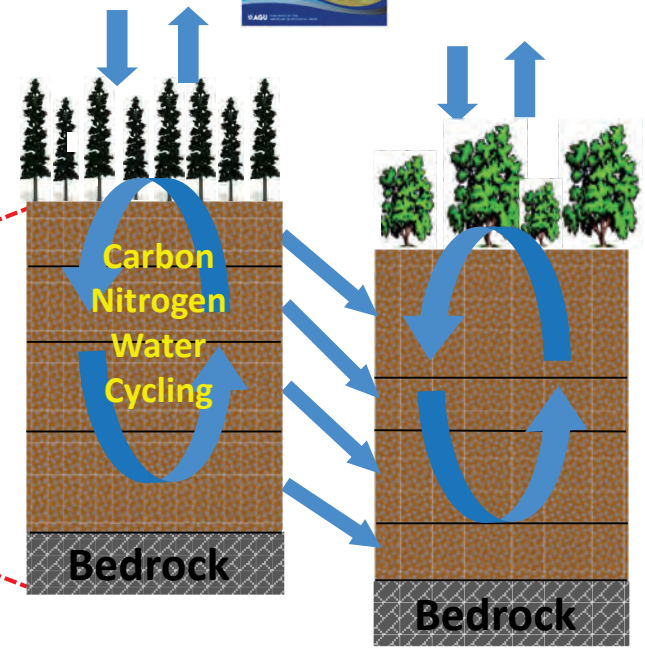


Changes in key ecosystem services:

- ***food & fiber production***
- ***water quality & quantity regulation***
- ***greenhouse gas regulation (CO_2, N_2O, NO_x)***
- ***carbon sequestration***
- ***regulation of nitrogen sources & sinks***
- ***(linkage to fish & wildlife models)***

Broad Applicability

Arctic Tundra

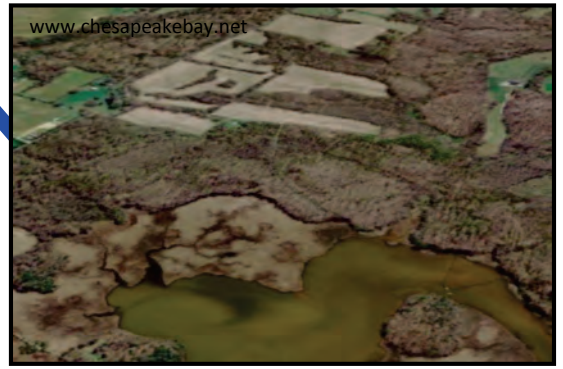
Urban Watersheds

PNW Salt Marsh

Northeastern Hardwoods

PNW Forests

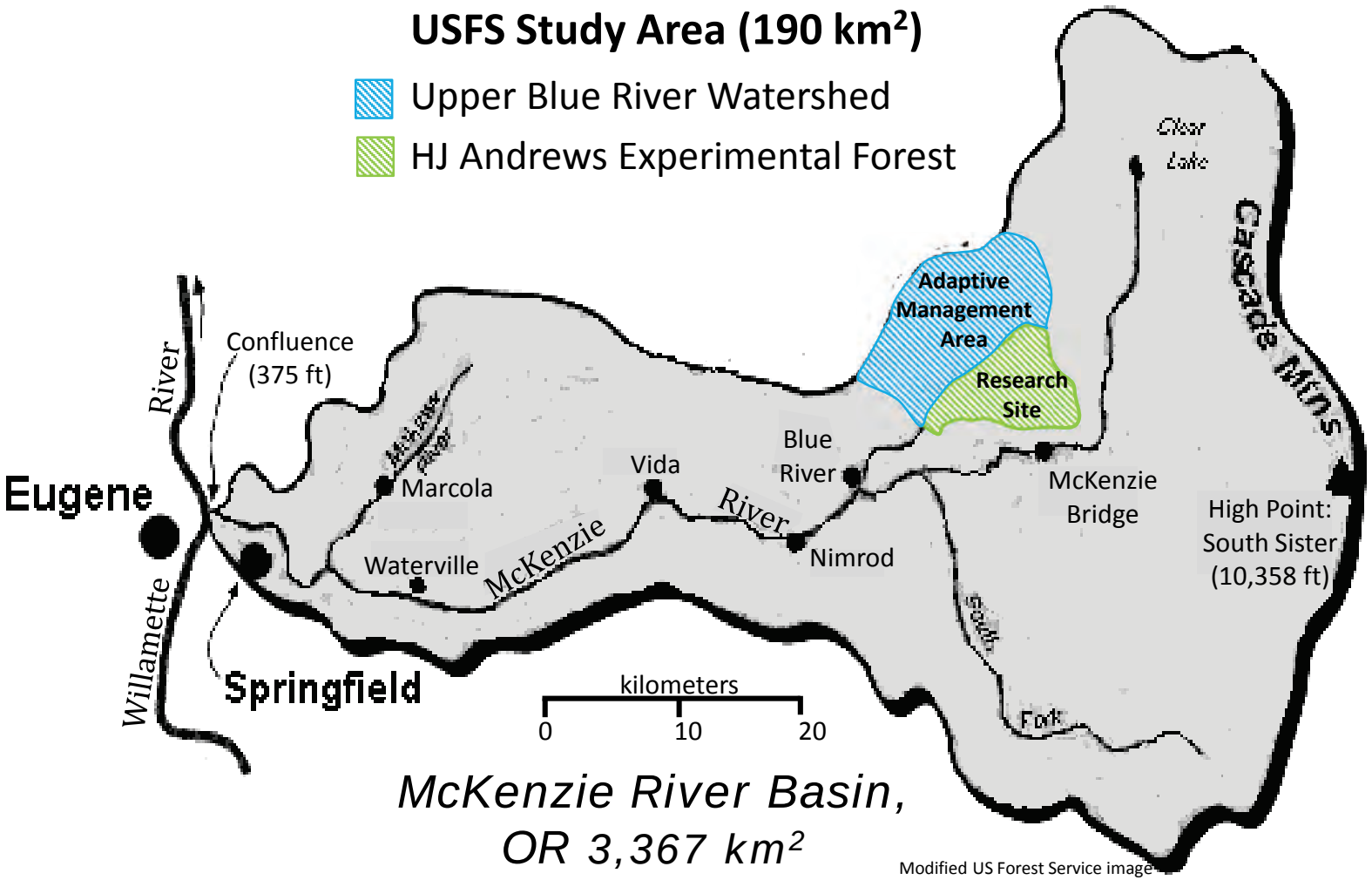
Central Plains Prairie



Chesapeake Bay

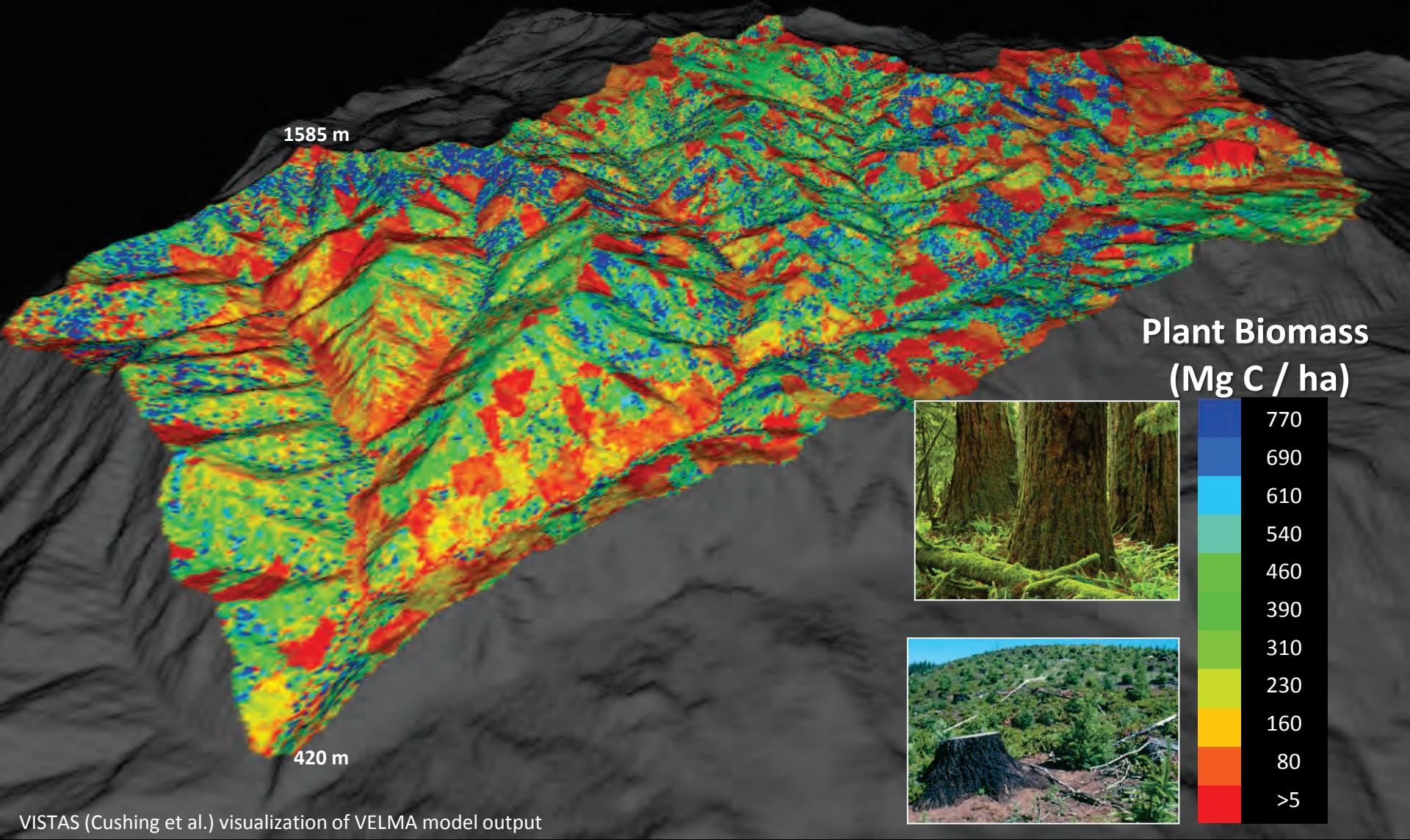
VELMA demo: Blue River Watershed, Oregon

How will alternative forest management practices affect tradeoffs among key ecosystem services?



Upper Blue River Watershed (123 km^2)

Current Forest Biomass



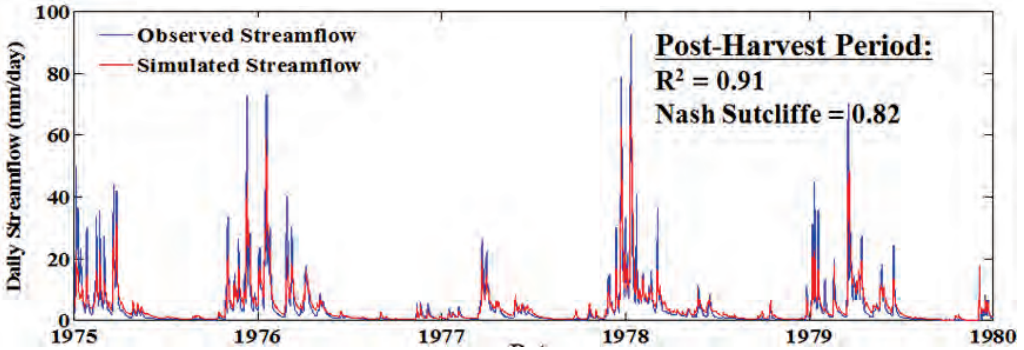
VISTAS (Cushing et al.) visualization of VELMA model output

VELMA Validation Results

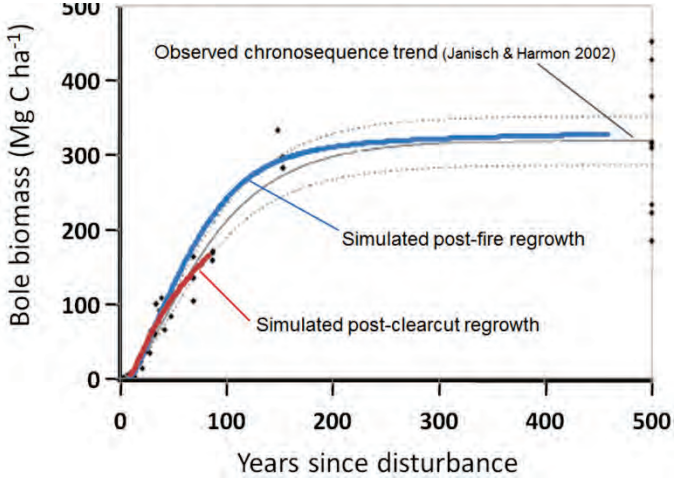
HJ Andrews Experimental Forest

Abdelnour et al. 2011 & 2013 in Water Resources Research

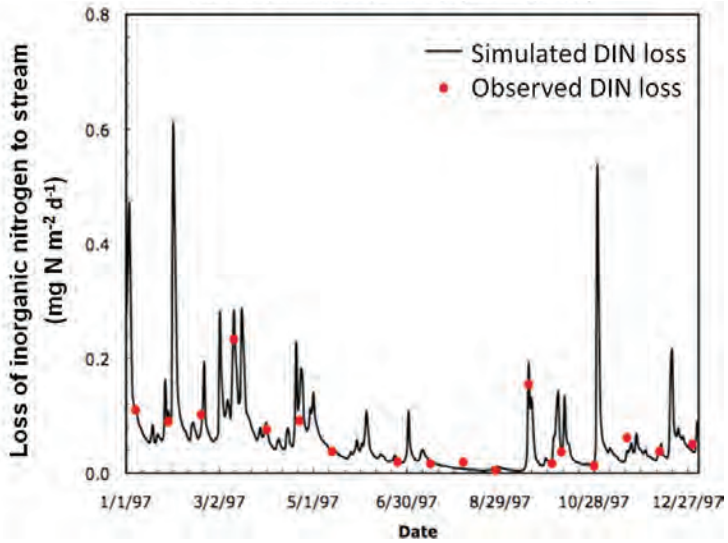
Validation of simulated streamflow



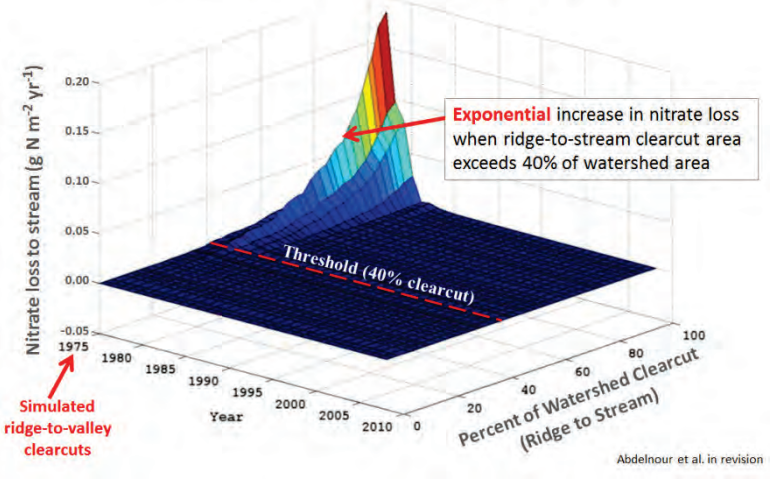
Validation of forest biomass dynamics



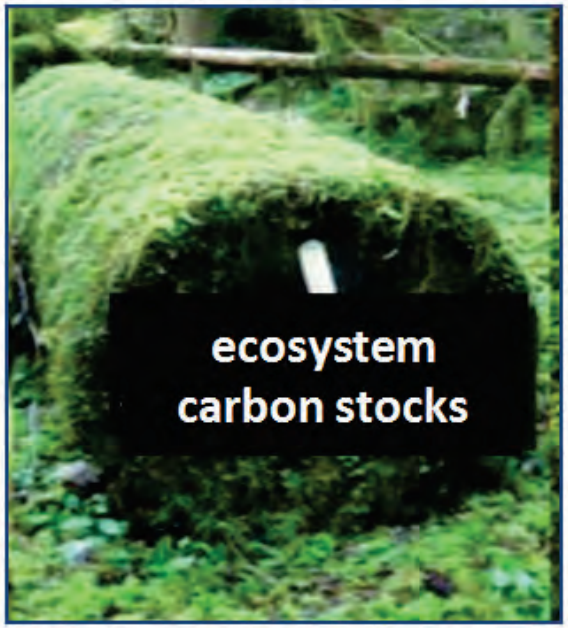
Validation of simulated stream nitrogen loads



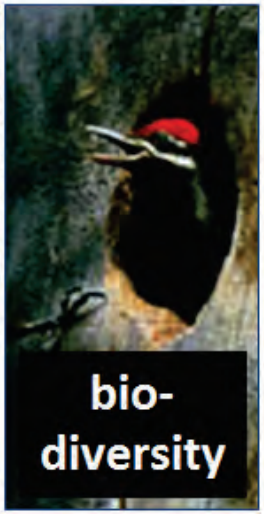
Simulated reduction in stream nitrate loads by uncut riparian buffers



Modeling Goal: analyze ecosystem service tradeoffs for alternative land use & climate scenarios



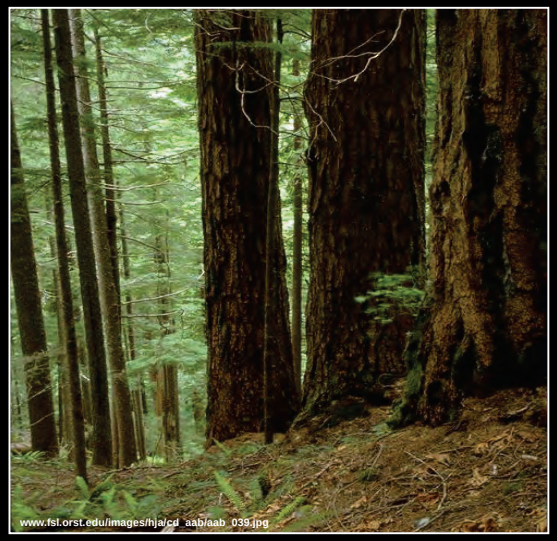
Trade-offs?



Trade-offs?

VELMA simulation of alternative forest management scenarios

Upper Blue River Watershed

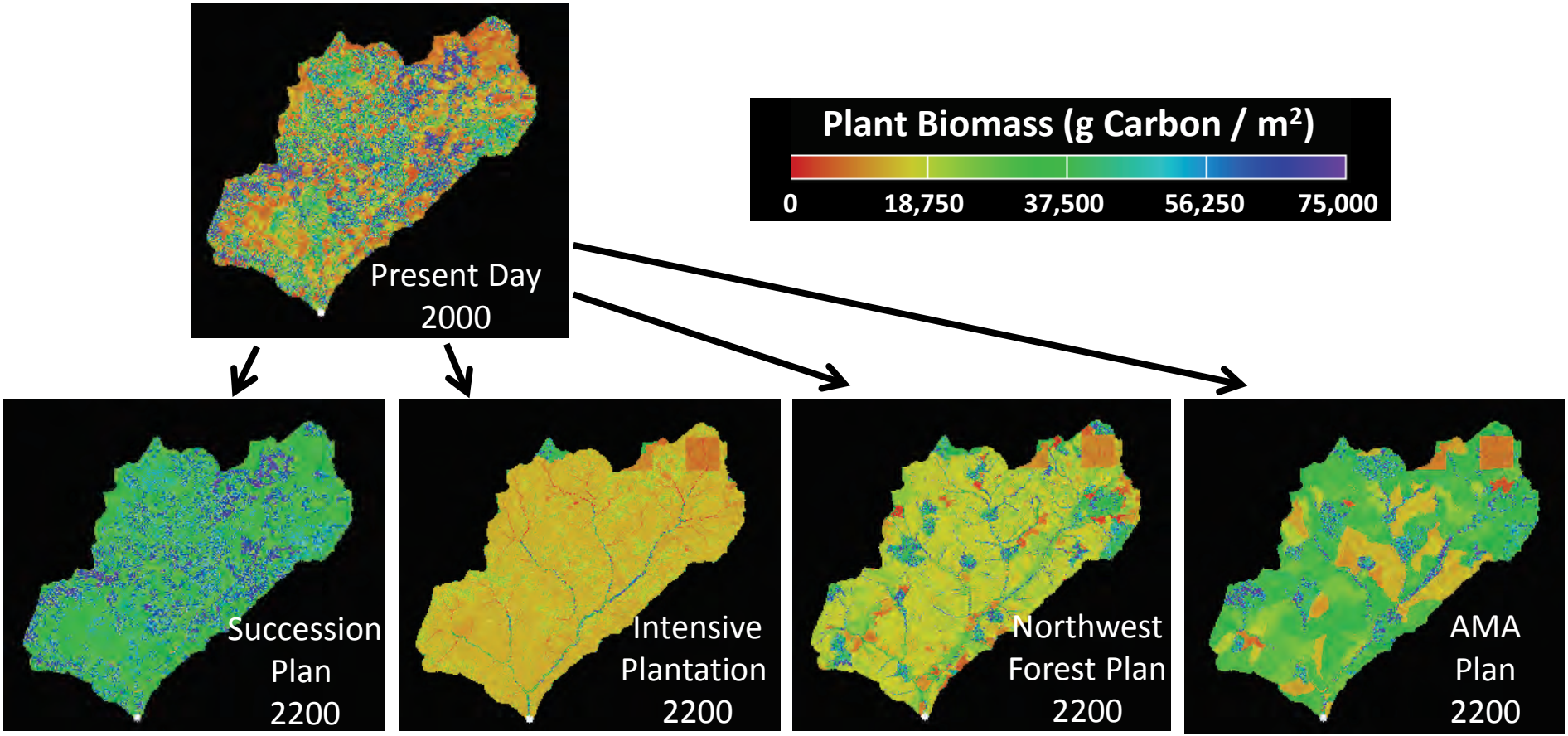


Succession Plan
(no harvest)

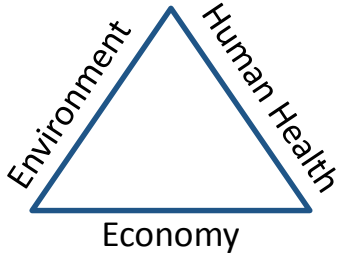
Intensive Plantation
(40-year harvest interval)

Northwest Forest Plan
(80-year harvest interval, with some old-growth protected)

Future Blue River landscapes for 4 alternative scenarios

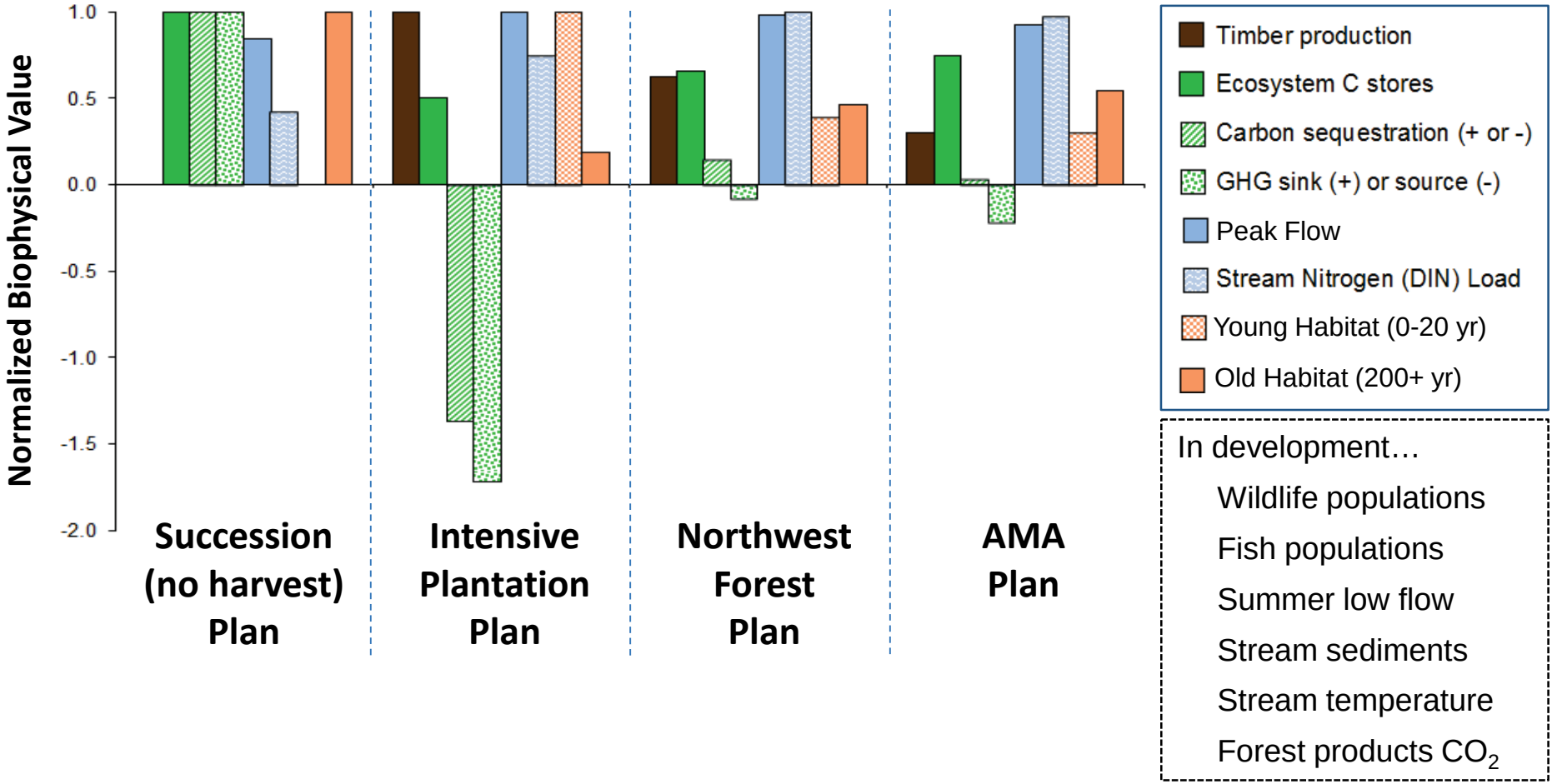


Which is better?



Ecosystem service tradeoffs for alternative forest management scenarios, 2000 - 2200

Upper Blue River Watershed

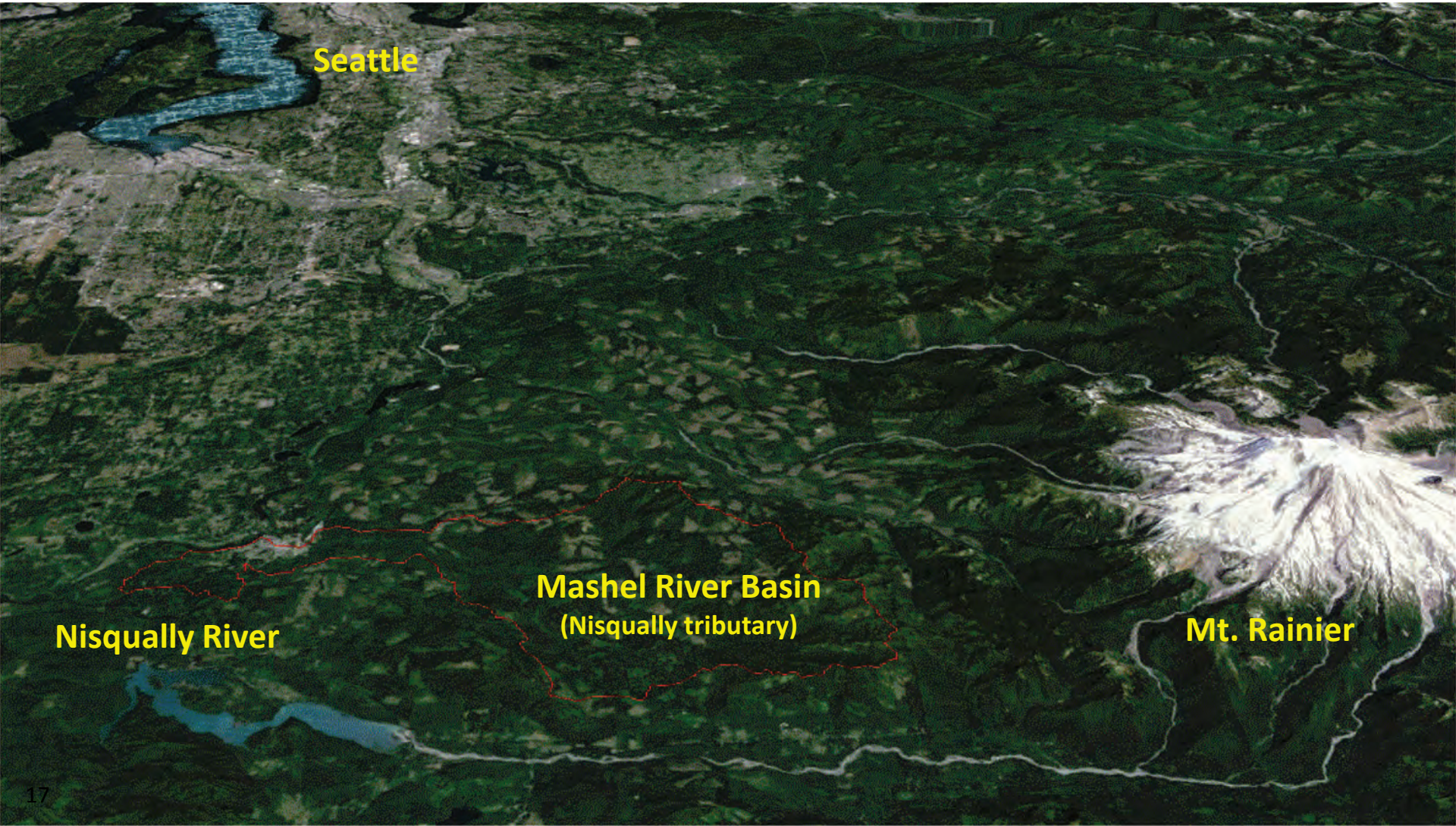


Salish Sea
VELMA Applications

Nisqually Watershed Project (in progress)

Can long-rotation forestry improve summer low flow conditions that limit salmon migration & spawning in the Nisqually watershed?

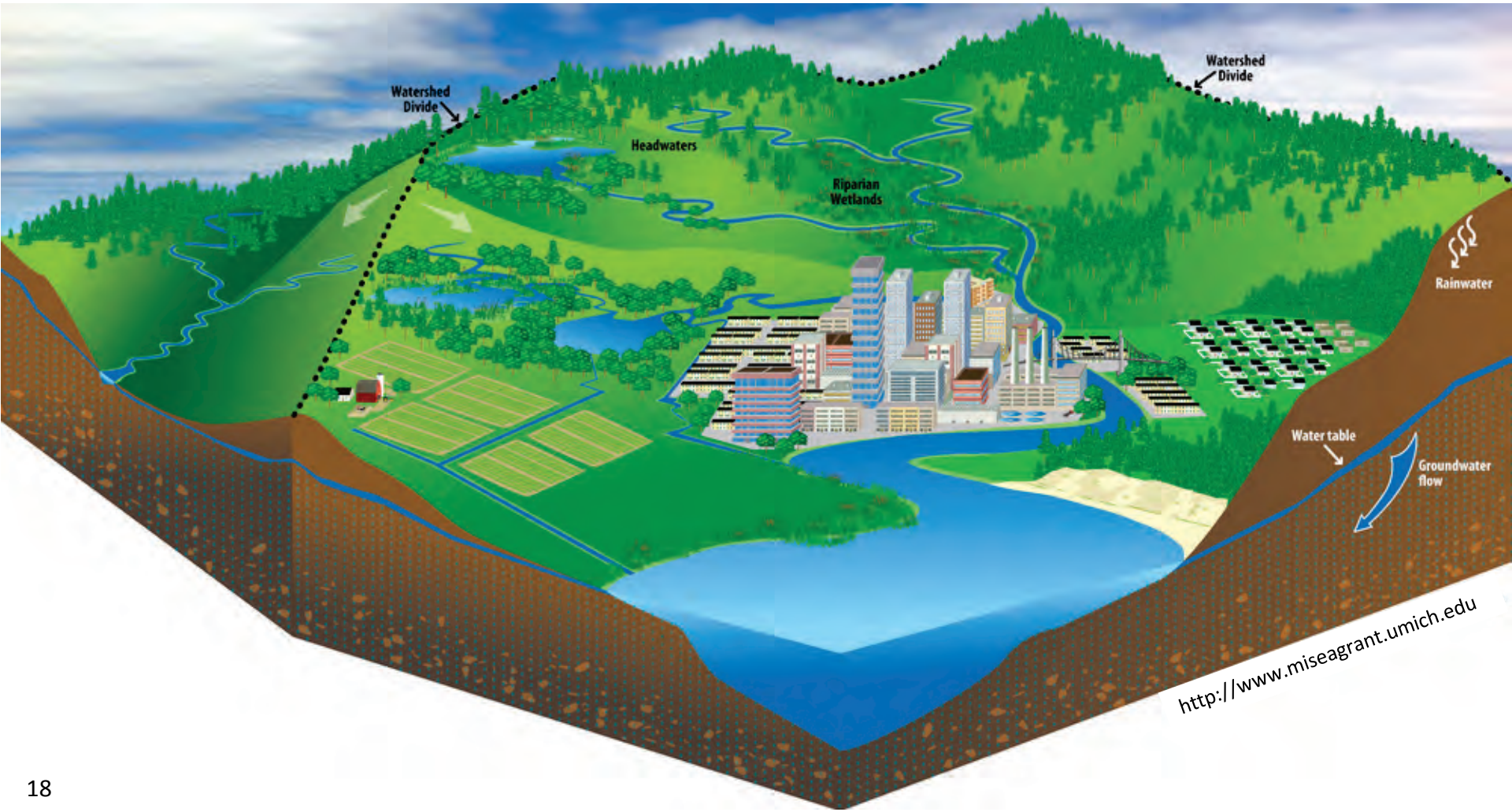
Partners: Washington DNR, Nisqually Tribe



Puget Sound Watershed-Estuary Linkages (proposed)

Identify green infrastructure best practices for reducing impacts of urban & rural contaminants on shellfish and salmon populations

Partners: EPA Region 10…

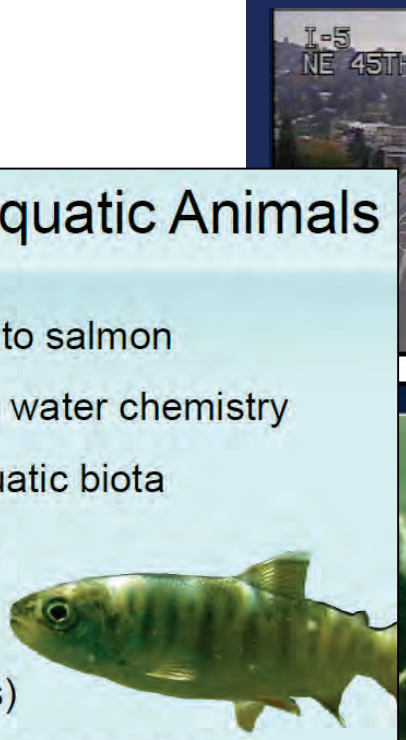


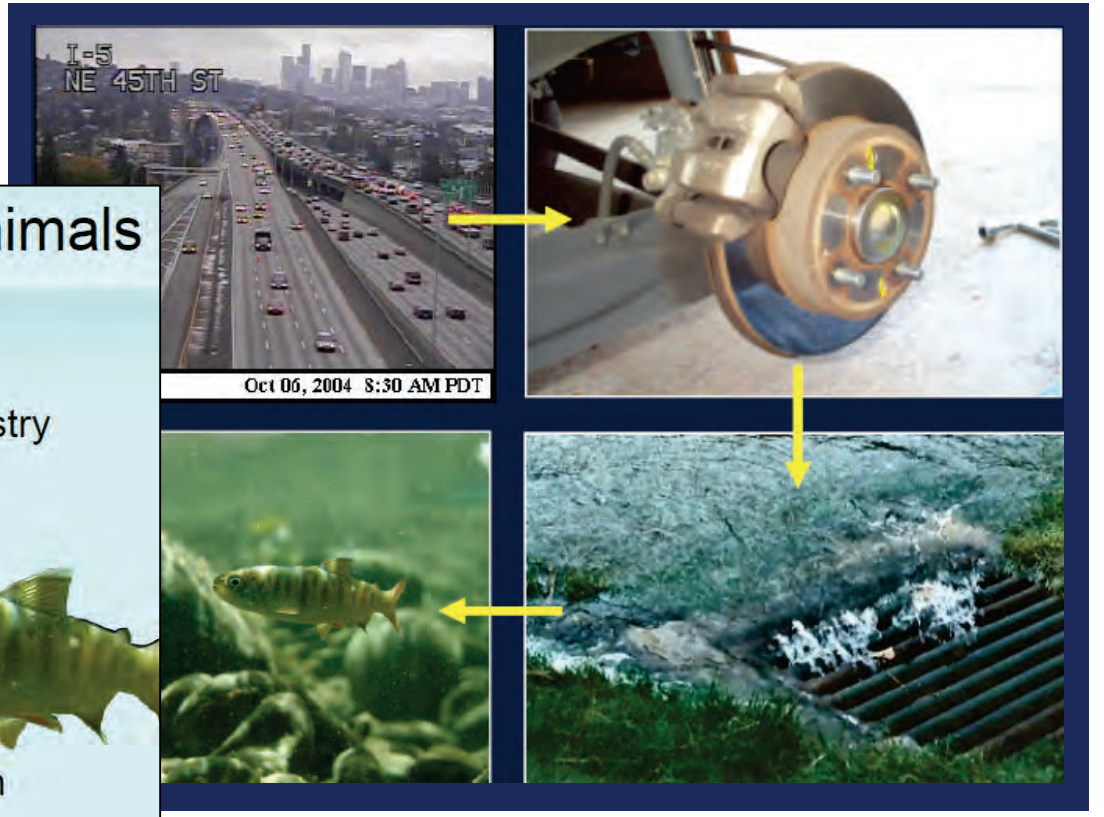
"Paved surfaces have created expressways for oil, grease, and toxic pollutants into coastal waters. Every eight months, nearly 11 million gallons of oil run off our streets and driveways into our waters – the equivalent of the Exxon Valdez oil spill"

- America's Living Oceans (Pew Oceans Commission 2003)

Copper Effects on Aquatic Animals

- Copper toxicity not specific to salmon
- Copper toxicity depends on water chemistry
- Copper can be lethal to aquatic biota
  (<100 ppb; hours to days)
- Copper is neurotoxic
  (<20 ppb; minutes to hours)
- Low ppb dissolved copper affects salmon behavior & survival





Slide credit: Nat Scholz and others, NOAA

Engineered & Natural Green Infrastructure for Protecting Water Quality

VELMA Team

EPA Western Ecology Division

- Bob McKane, team lead – biogeochemistry, systems ecology
- Allen Brookes – computer science
- Kevin Djang (CSC) – computer science
- Jonathan Halama – GIS
- Paul Pettus – GIS
- Mike Papenfus – environmental economics
- Don Phillips – climate simulation
- Brad Barnhart – mathematical optimization

Georgia Institute of Technology

- Marc Stieglitz – hydrology
- Alex Abdelnour (McKinsey & Co.) – hydrology, biogeochemistry
- Feifei Pan (Univ. of North Texas) – hydrology

Image credit: Jessica Jahre & Anne Neal, USEPA