


Modeling Ecosystem Services and Tradeoffs for Multi-Objective Decision Making

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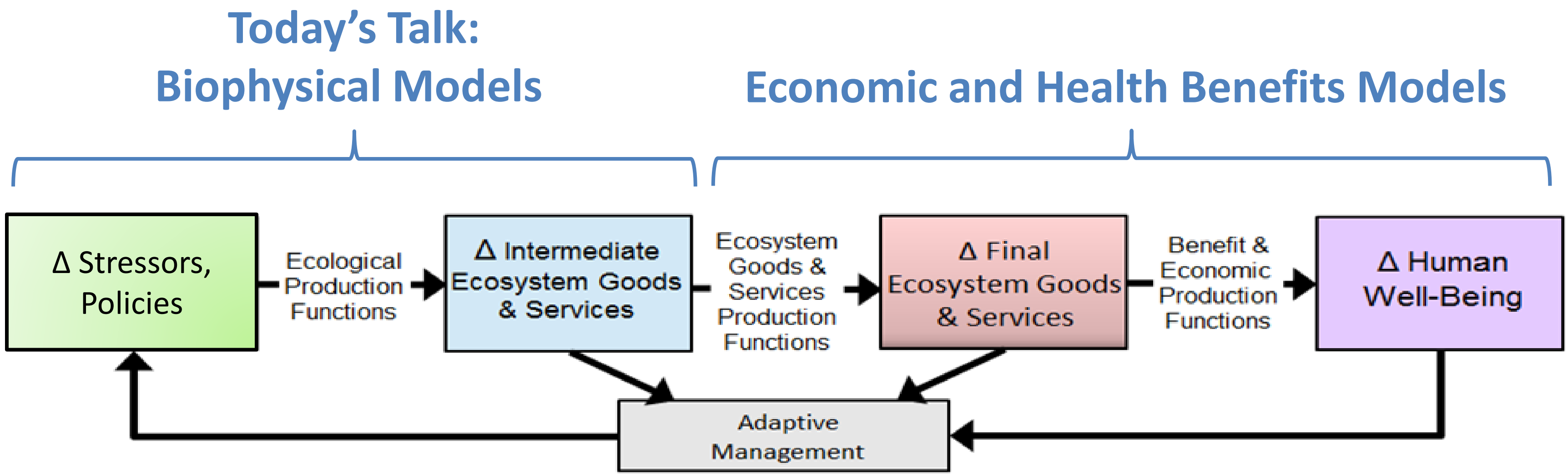
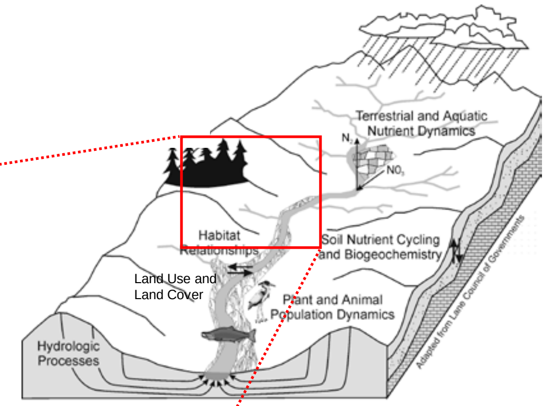
Conceptual Model and Talk Outline



Forest Ecosystem Services Case Study

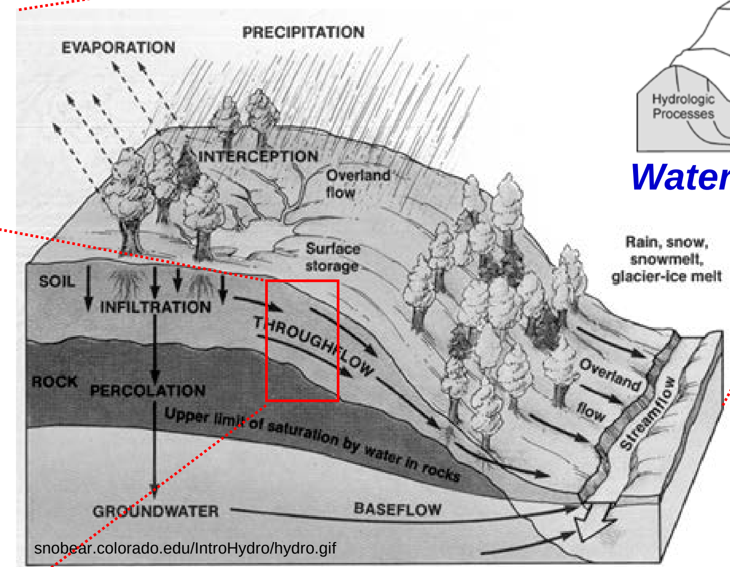
- **How will alternative forest management and climate scenarios affect multiple ecosystem services?**
  - ✓ Timber production
  - ✓ Water quantity (peak & low flows)
  - ✓ Water quality (nutrients, temperature, sediments…)
  - ✓ Climate regulation (carbon sequestration, GHGs)
  - ✓ Habitat for fish & wildlife populations
  - ✓ Recreational opportunities
- **Can all of these services be managed sustainably?**
- **To what extent does emphasizing a particular service result in tradeoffs with others?**
- **Can models reliably address these questions at the spatial and temporal scales required by resource managers & communities?**

Premise: intermediate ecosystem services are strongly regulated by hydrological and biogeochemical processes that interact across multiple scales

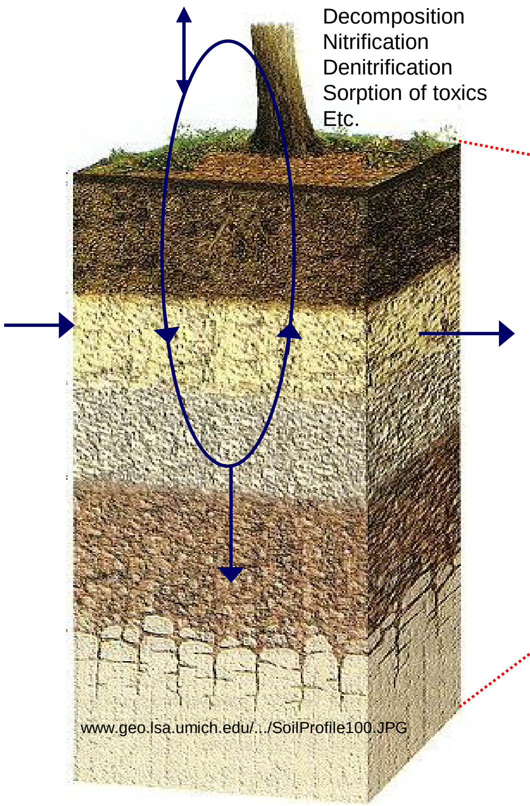


Watershed-scale processes

Nitrogen uptake
Litterfall
Soil formation
Decomposition
Nitrification
Denitrification
Sorption of toxics
Etc.



Hillslope-scale processes



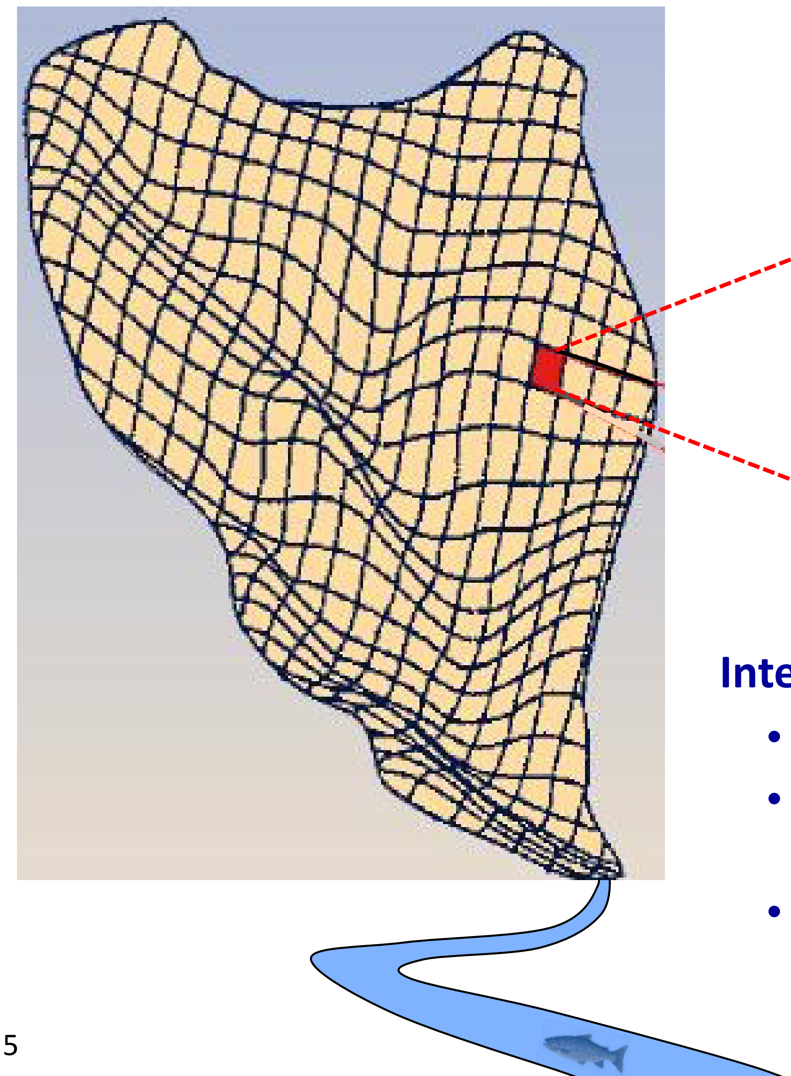
Plot-scale processes

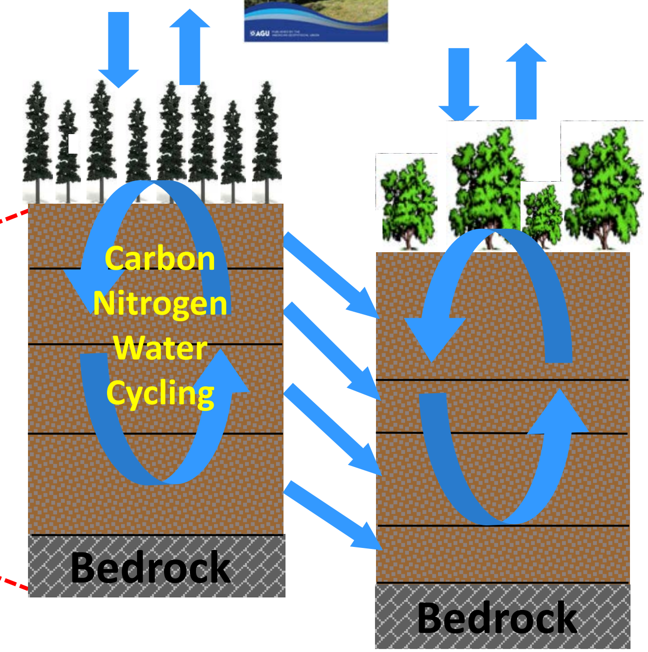
VELMA Ecohydrological Model

“**V**isualizing **E**cosystem **L**and **M**anagement **A**ssessments“

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*
- ***Data requirements:*** *daily temperature and precipitation, DEM, soil, LULC including location & timing of disturbances (fire, harvest, grazing, nutrient & contaminant inputs…)*

VELMA Ecohydrological Model

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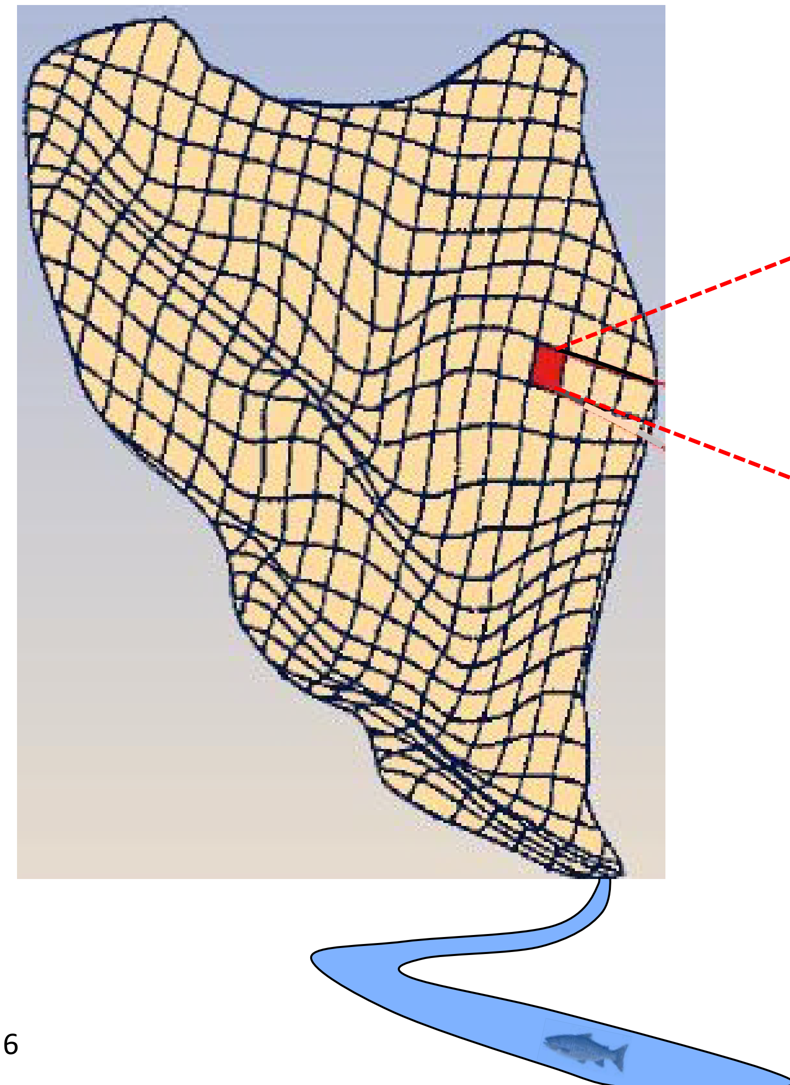
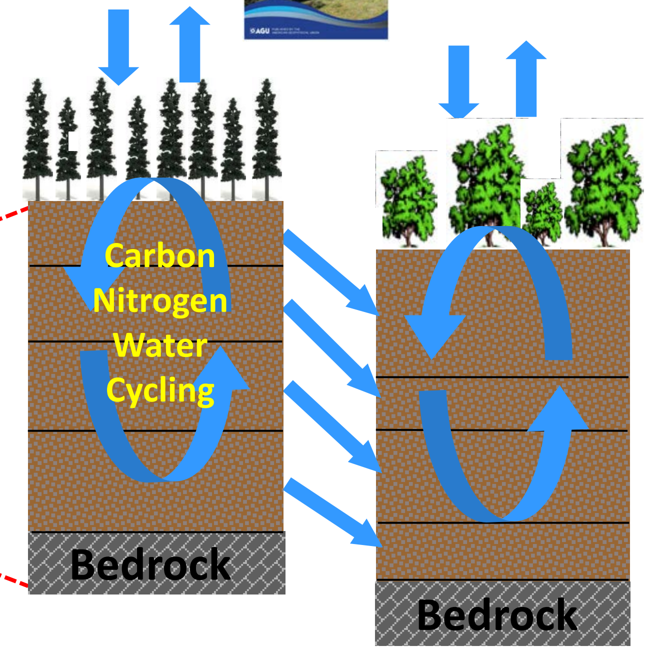
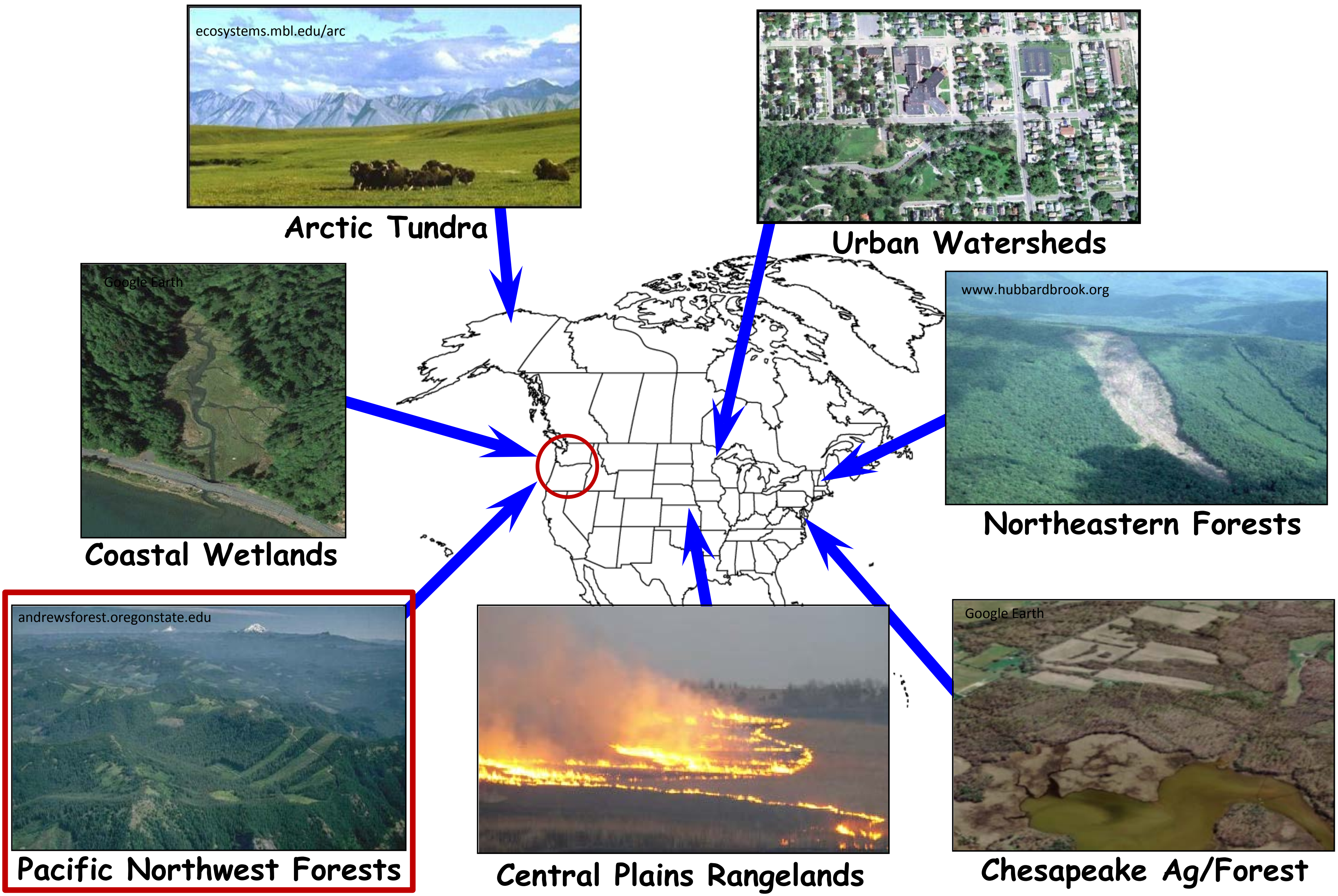




Intermediate Ecosystem Services regulating

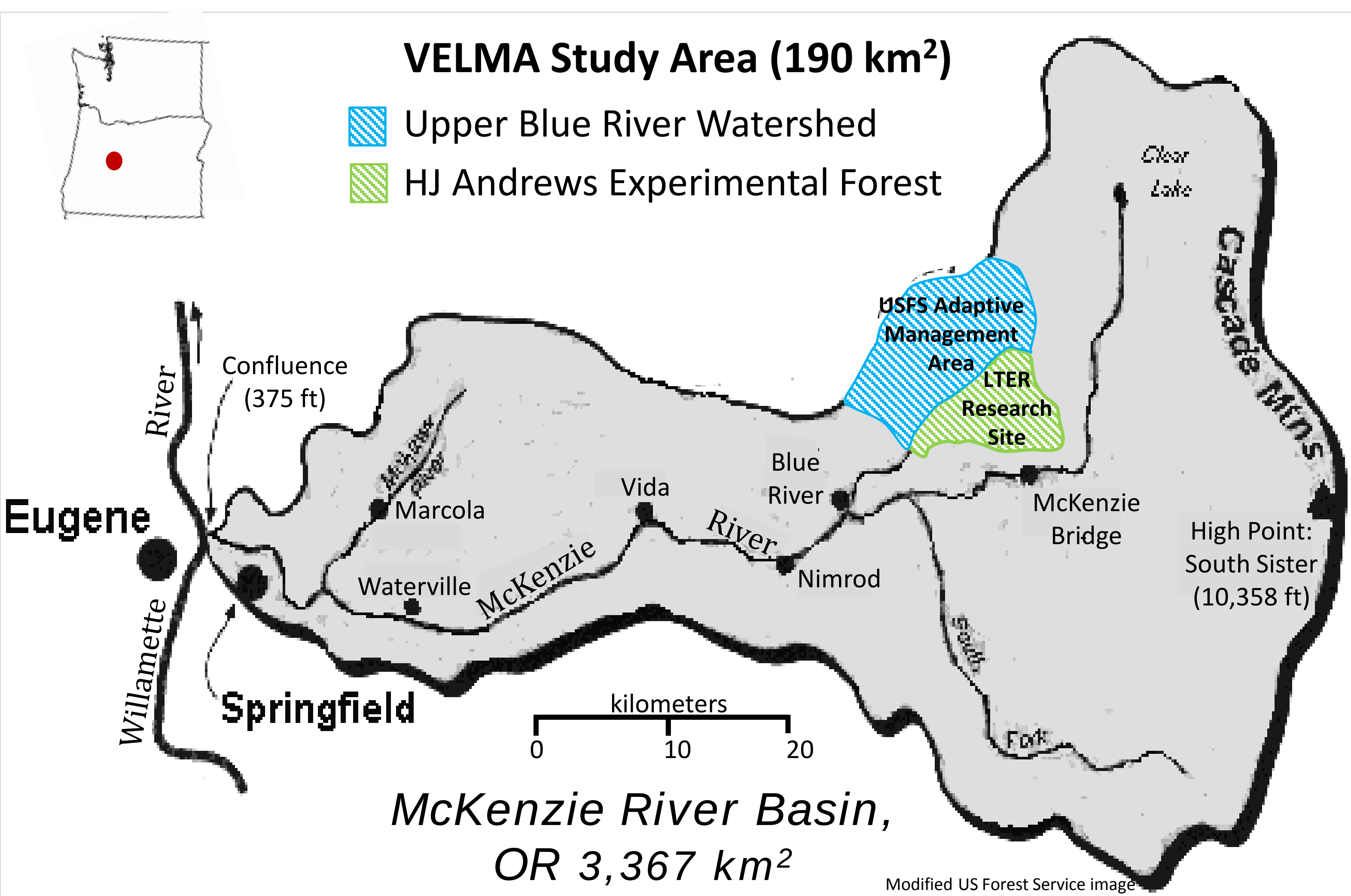
- ***Food & fiber production***
- ***Water quality & quantity***
- ***Greenhouse gases (CO_2, N_2O, NO_x)***
- ***Carbon sequestration (NEP)***
- ***Nitrogen sources & sinks (hot spots & hot moments)***
- ***Fish & wildlife habitat → Biodiversity models***

Broad Applicability



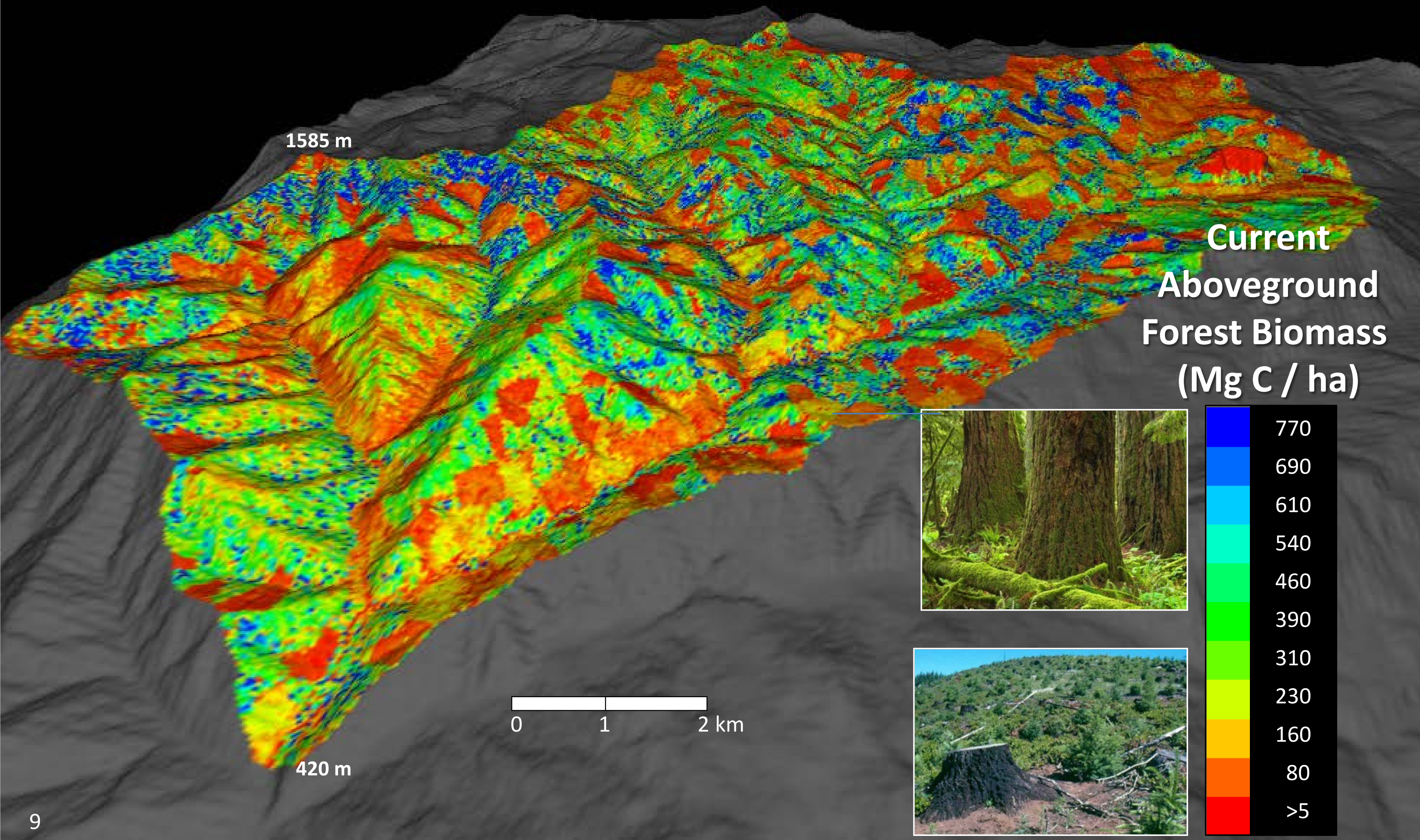
Forest Application: Blue River Watershed, Oregon

How will alternative forest management & climate scenarios affect tradeoffs among key ecosystem services?



Upper Blue River Watershed (123 km^2)

Visualization of VELMA Model Output

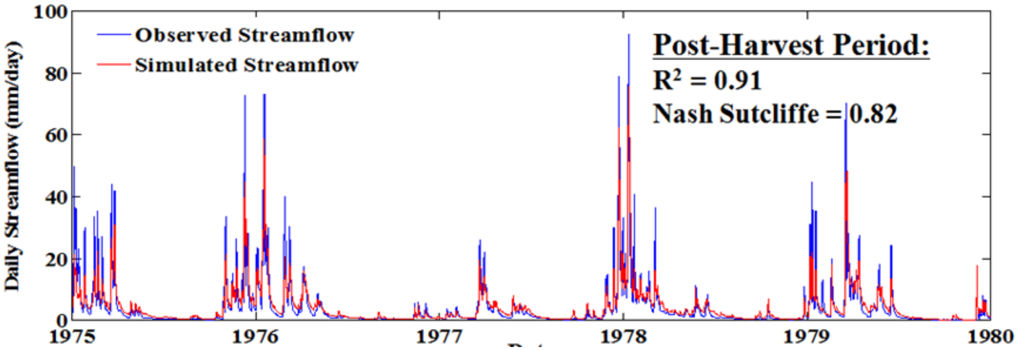


VELMA Validation Results

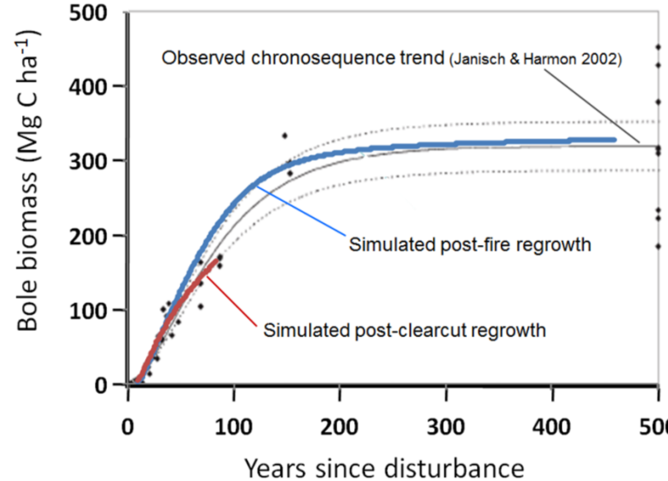
HJ Andrews Experimental Forest & LTER Site

Abdelnour et al. 2011 and 2013, *Water Resources Research*

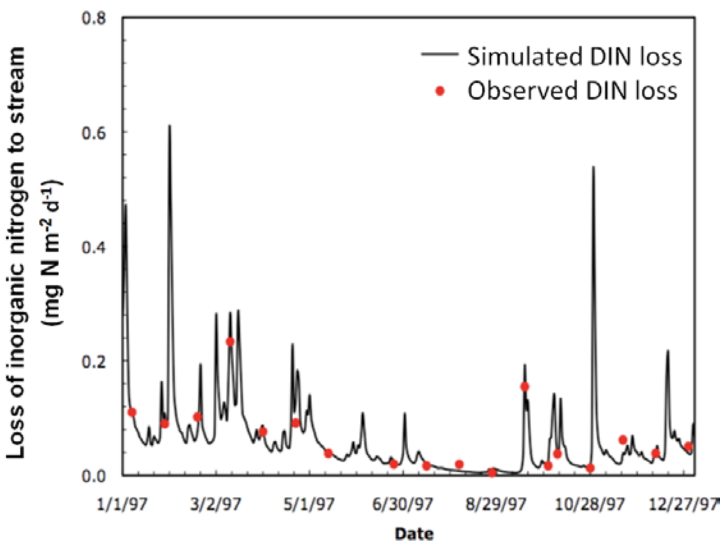
Streamflow Validation



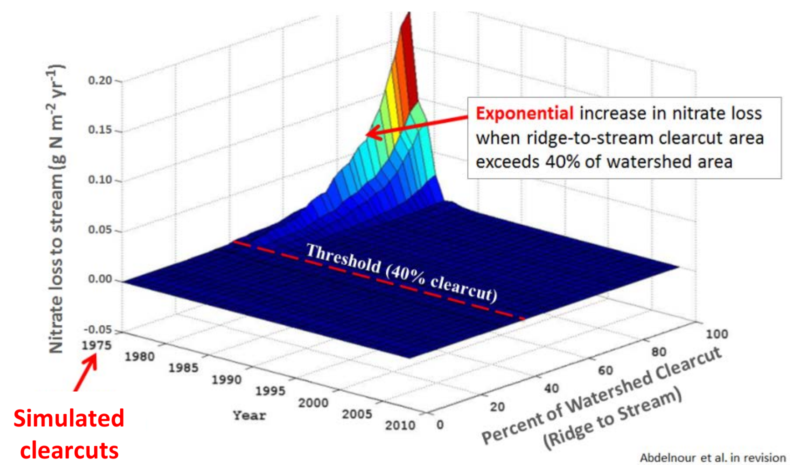
Forest Growth Validation



Stream Chemistry Validation



Simulated stream nitrogen loads vs. riparian buffer cover & time since harvest



Simulation of alternative management scenarios

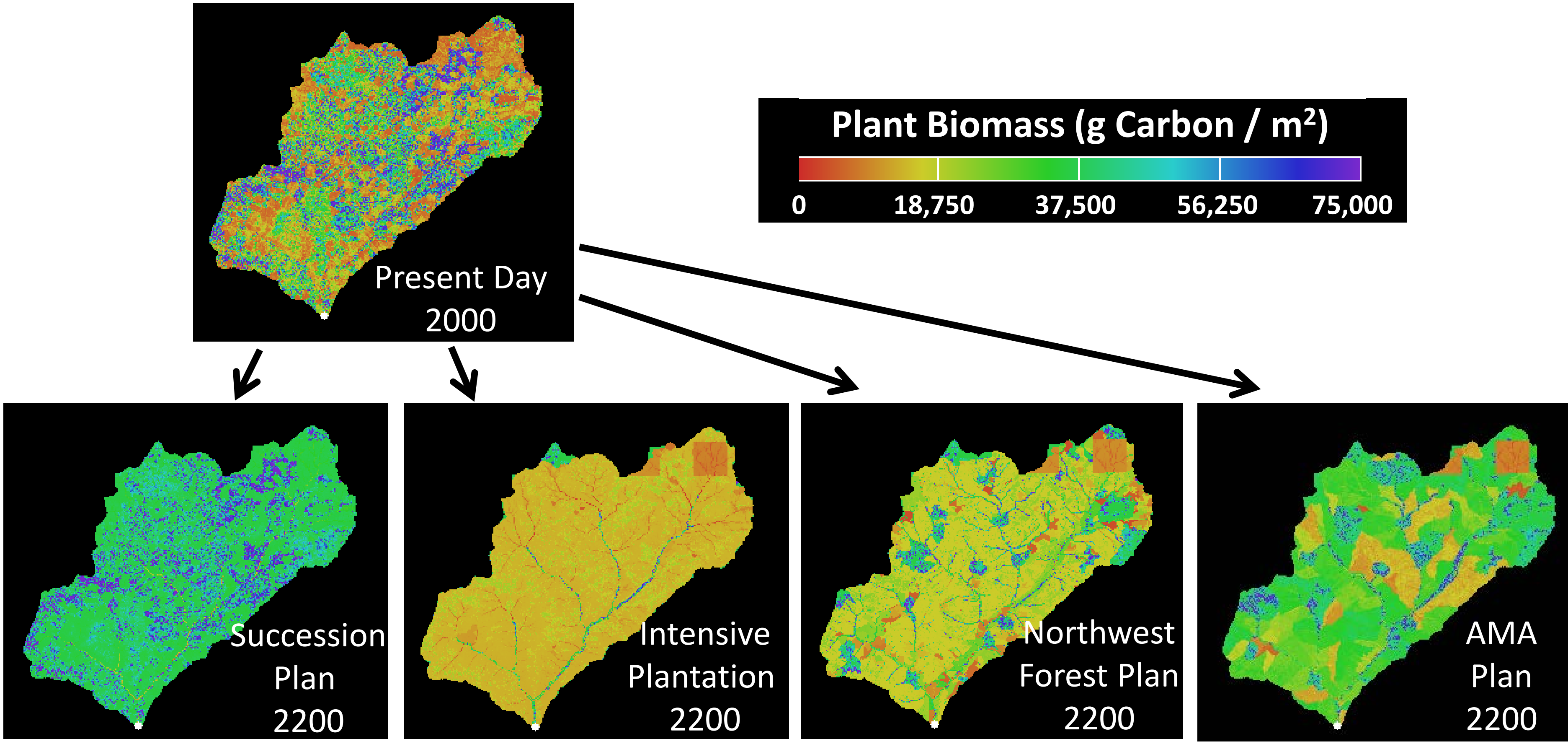
Upper Blue River Watershed

Succession Plan
(no harvest)

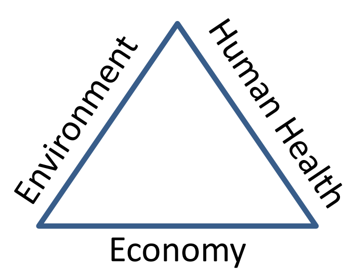
Intensive Plantation
(40-year harvest interval)

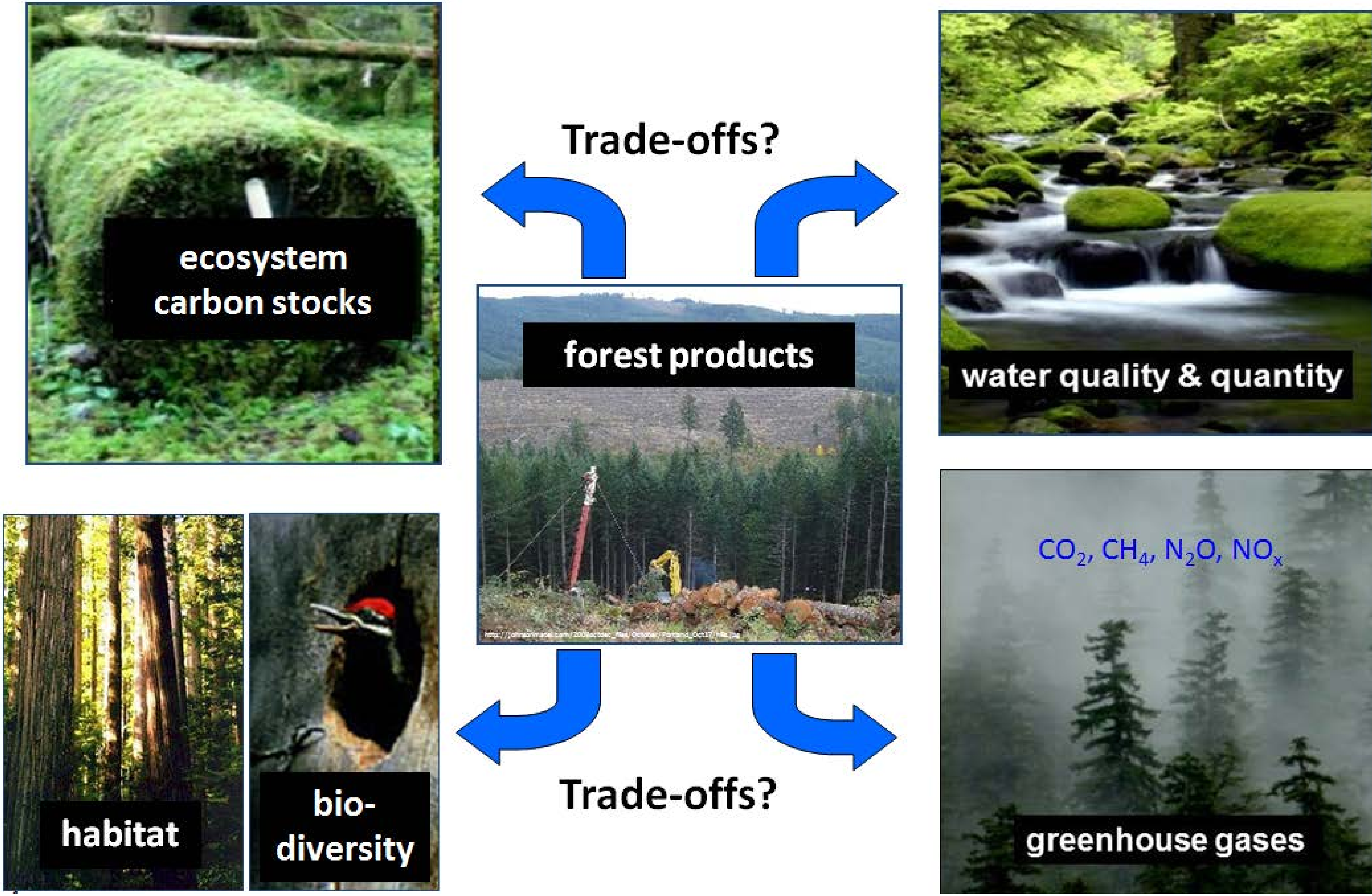
Northwest Forest Plan
(80-year harvest interval, with some old-growth protected)

Future Blue River landscapes for 4 alternative scenarios



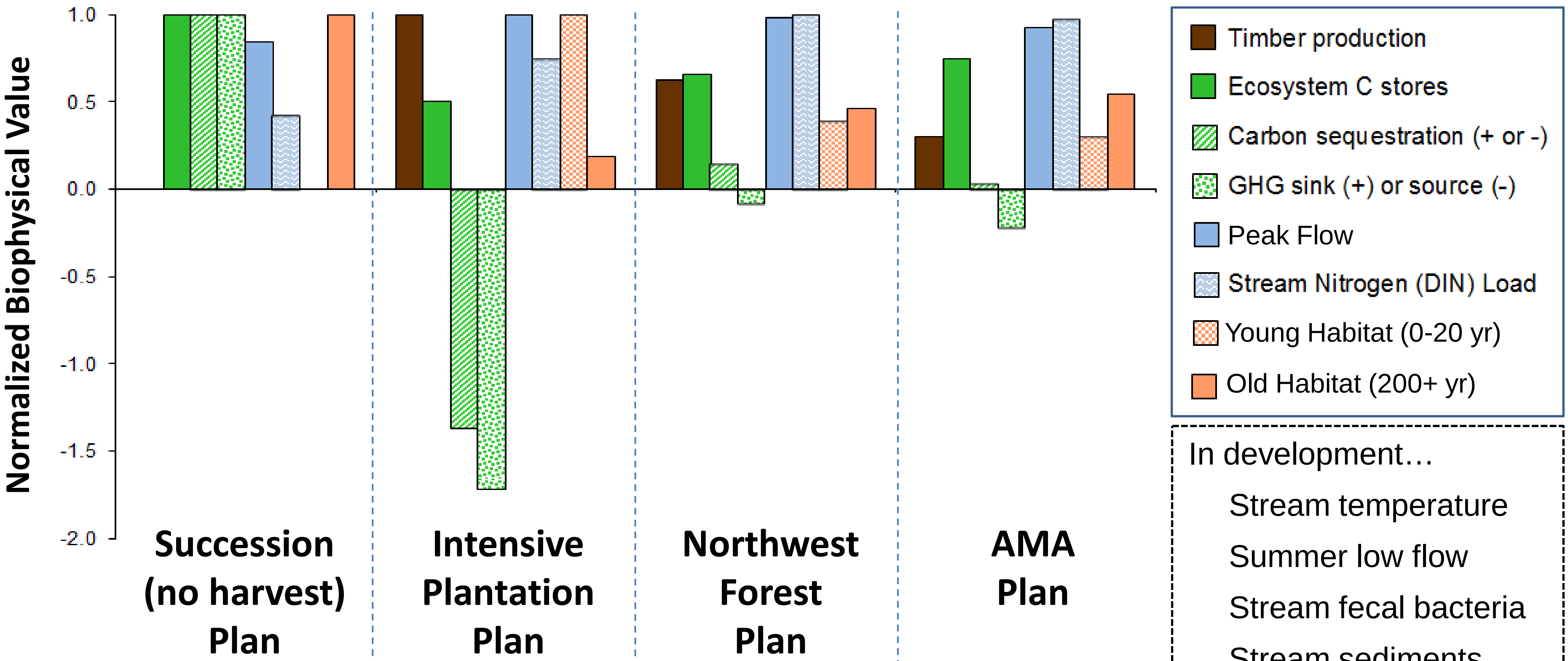
Which is better?




ecosystem carbon stocks
Trade-offs?
forest products
water quality & quantity
habitat
bio-diversity
Trade-offs?
CO_2, CH_4, N_2O, NO_x
greenhouse gases

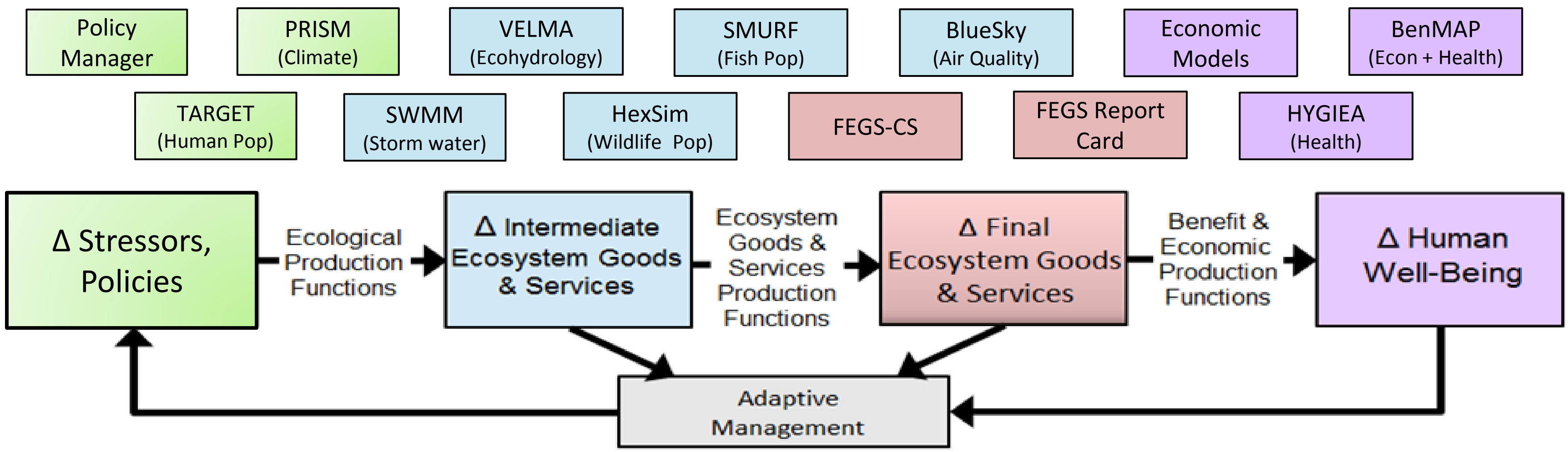
Ecosystem service tradeoffs for alternative forest management scenarios, 2000 → 2200

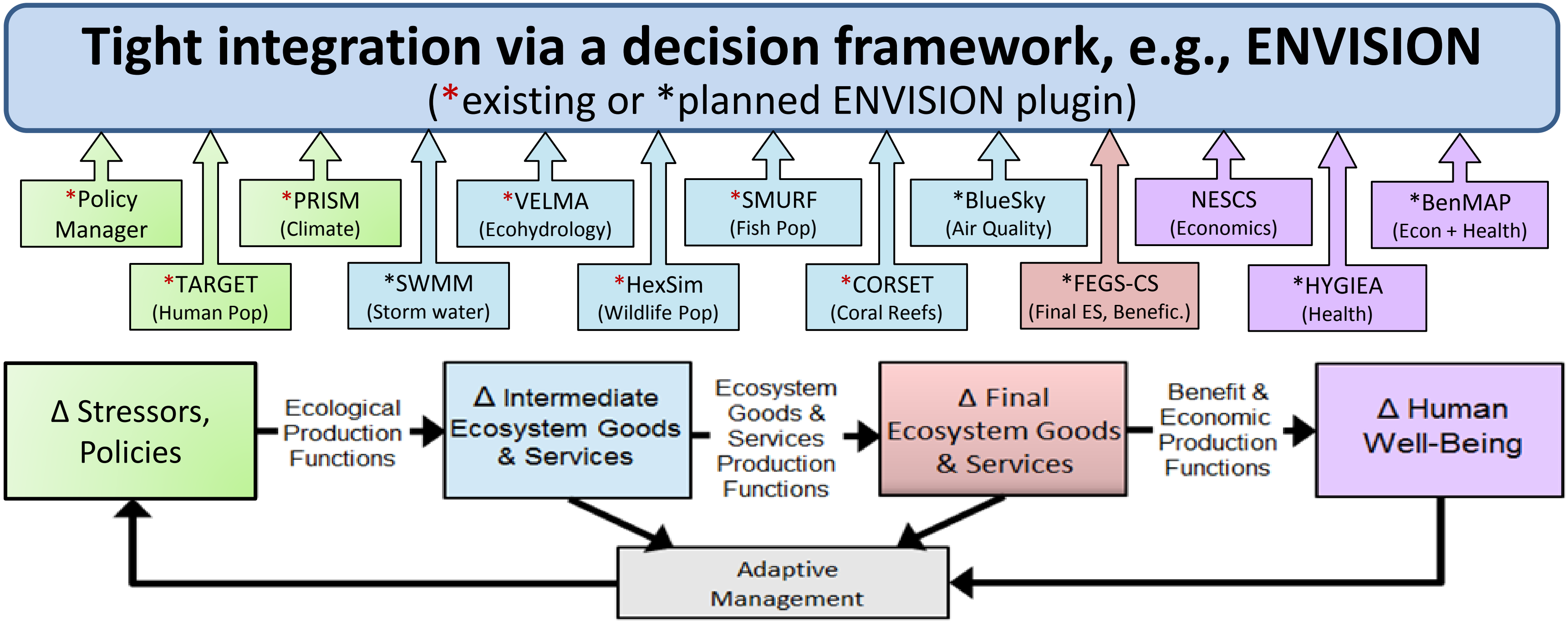
Upper Blue River Watershed



In development…

- Stream temperature
- Summer low flow
- Stream fecal bacteria
- Stream sediments
- Fish populations
- Wildlife populations


Policy Manager
PRISM (Climate)
VELMA (Ecohydrology)
SMURF (Fish Pop)
BlueSky (Air Quality)
Economic Models
BenMAP (Econ + Health)
TARGET (Human Pop)
SWMM (Storm water)
HexSim (Wildlife Pop)
FEGS-CS
FEGS Report Card
HYGIEA (Health)
Δ Stressors, Policies
Ecological Production Functions
Δ Intermediate Ecosystem Goods & Services
Ecosystem Goods & Services Production Functions
Δ Final Ecosystem Goods & Services
Benefit & Economic Production Functions
Δ Human Well-Being
Adaptive Management



Tight integration via a decision framework, e.g., ENVISION
(*existing or *planned ENVISION plugin)
*Policy Manager
*TARGET (Human Pop)
*PRISM (Climate)
*SWMM (Storm water)
*VELMA (Ecohydrology)
*HexSim (Wildlife Pop)
*SMURF (Fish Pop)
*CORSET (Coral Reefs)
*BlueSky (Air Quality)
*FEGS-CS (Final ES, Benefic.)
NESCS (Economics)
*HYGIEA (Health)
*BenMAP (Econ + Health)
Δ Stressors, Policies
Ecological Production Functions
Δ Intermediate Ecosystem Goods & Services
Ecosystem Goods & Services Production Functions
Δ Final Ecosystem Goods & Services
Benefit & Economic Production Functions
Δ Human Well-Being
Adaptive Management

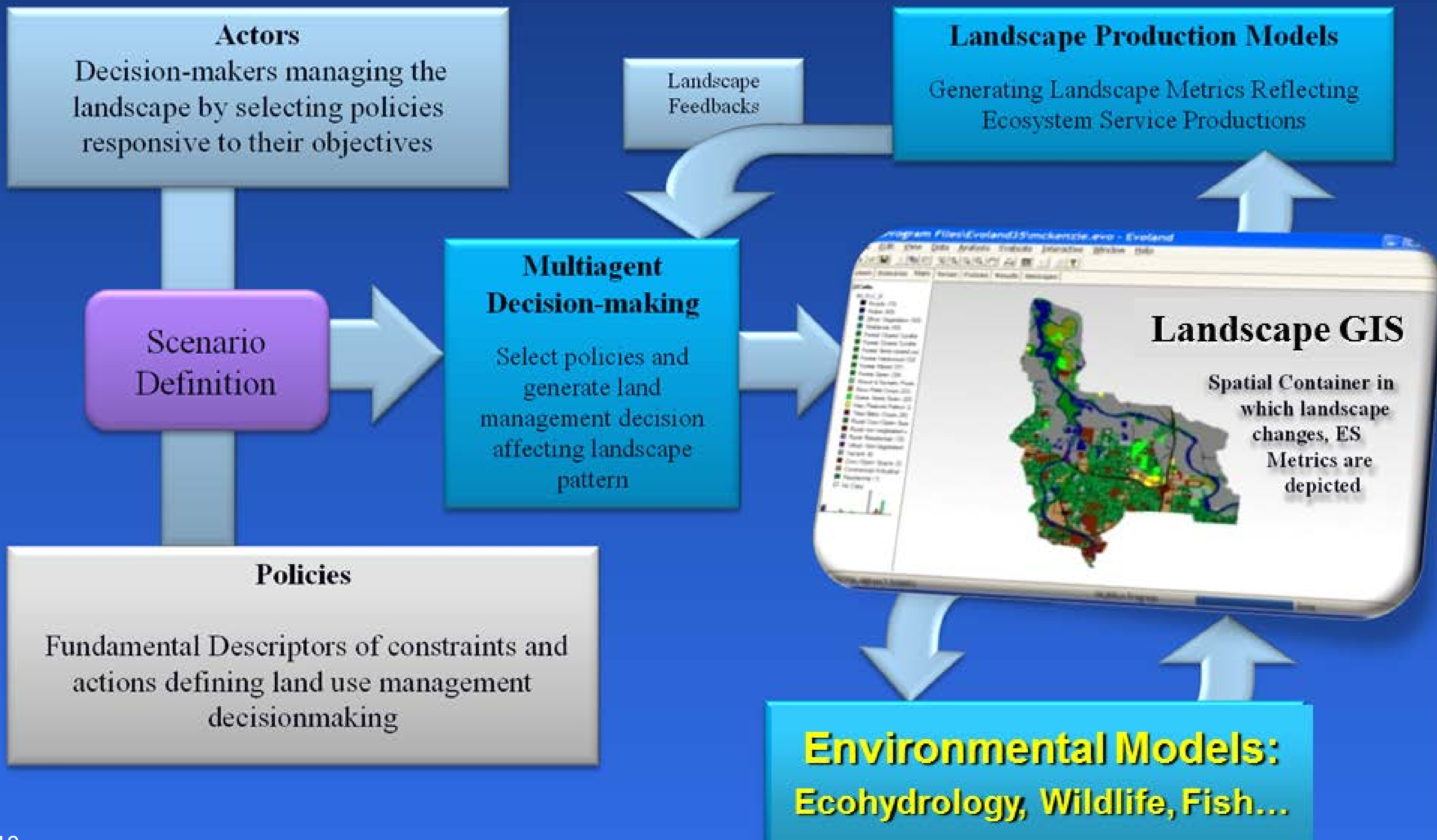
Closing thoughts about Biophysical Modeling and SEEA-EEA

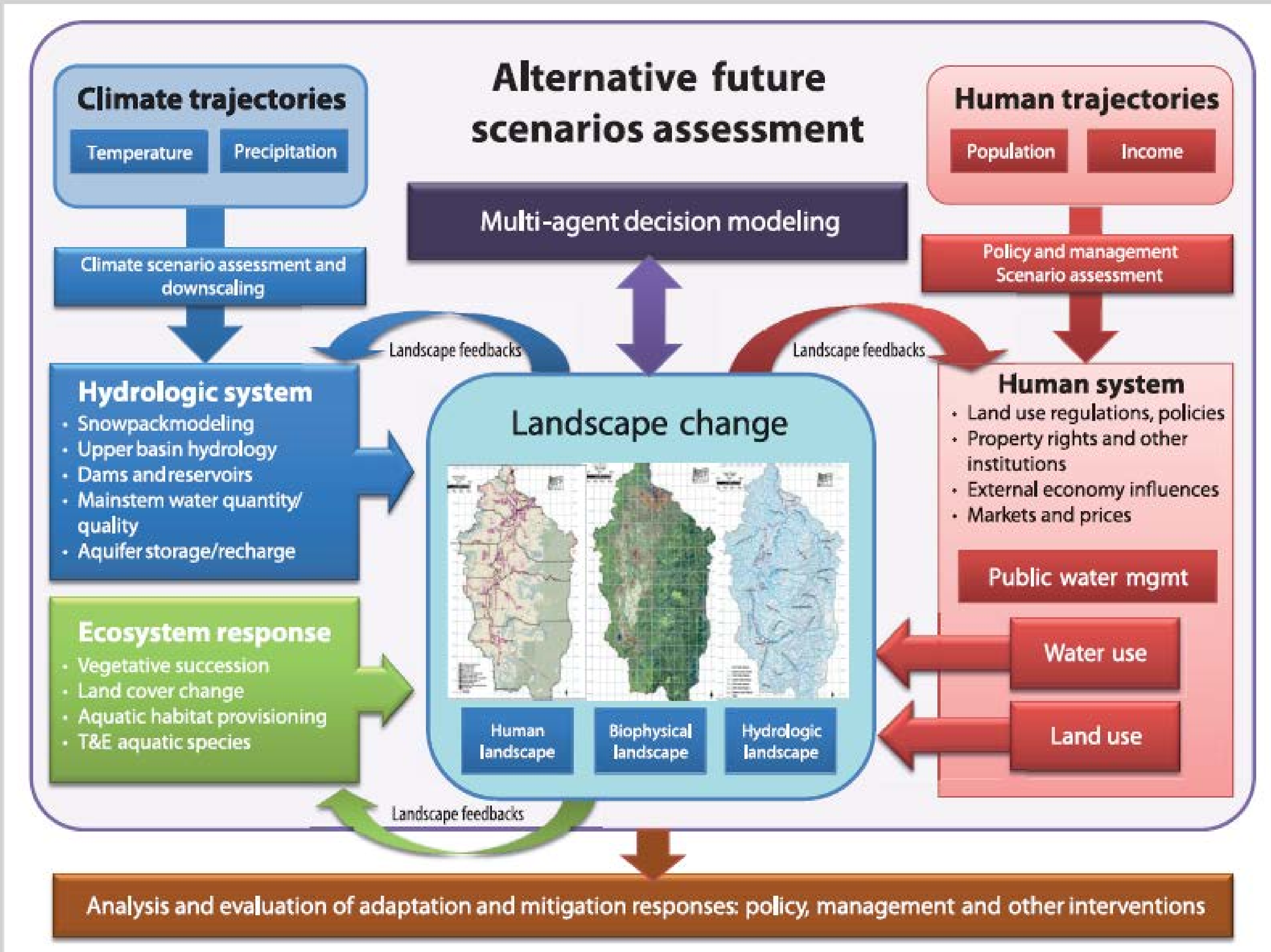
- Spatial scale of accounting units: 30m grids have generally proven to be most useful and readily obtainable for biophysical modeling in support of ecosystem service assessments:
  - ✓ This scale captures important hydro-biogeochemical interactions and is computationally efficient for basin-scale applications
  - ✓ Smaller (10m) and larger (250m) scales are useful for specific purposes
- Spatio-temporal grids needed for simulation of alternative future scenarios:
  - ✓ Climate change scenarios: build spatio-temporal grids based on current 30-yr mean climate grids (e.g., PRISM data) + IPCC climate scenario projections
  - ✓ Land use scenarios: build grids based on population & demographic trends, and alternative policies for urban growth boundaries, resource extraction, inputs of fertilizers and toxics, etc.
- Recruit & train next generation of modelers! Global coordination through SEEA-EEA?
- Land cover is a key variable for biophysical modeling, but it must be combined with other biophysical layers (topography, flow paths, soil properties, etc.) to be useful for modeling ecosystem structure & function and intermediate ecosystem services.

ENVISION Decision Support Tool

http://envision.bioe.orst.edu/

John Bolte, Oregon State University





John Bolte (http://oregonexplorer.info/willamette/Willamettehome)

VELMA Team

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Allen Brookes – software architecture & development
Kevin Djang (CSC) – software development
Brad Barnhart – multi-objective optimization
Mike Papenfus – environmental economics
Jonathan Halama – GIS
Paul Pettus – GIS
Don Phillips – climate simulation

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Marc Stieglitz – hydrology
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Feifei Pan (Univ. of North Texas) – hydrology