DOE Bioenergy Technologies Office (BETO) 2019 Project Peer Review WBS#4.2.1.40 Visualizing Ecosystem Service Portfolios for Agricultural and Forested Biomass Production

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Technology Session Area Review

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Goal Statement

Illuminate paths leading toward co-production of biomass, clean water, and utility derived from biodiversity

What: Discover how we can manage production of advanced feedstocks to generate added value through ancillary (non-energy) ecosystem services.

Why: Society needs renewable energy <u>and</u> clean water <u>and</u> ecosystem goods & services[1] derived from wildlife.

How: Develop spatial eco-economic models and visualizations that link management of biomass feedstocks to the value provided by changes in fish, wildlife and downstream water quality.

[1]Ecosystem services are benefits or economic utility provided to society, some of which can be assigned monetary value through markets

Project Outcome

Determine how biomass production can increase resilience in ecosystem services by reducing the risk and intensity of wildfire and threats to water quality from hypoxia.

Biofuels are demonstrating potential to increase resilience to both disturbance regimes (Dale et al. 2018; Jager et al. 2018). By the end of the project, our research will have monetized ecosystem services provided by biomass production, illustrated by agricultural and forest case studies and previous regional-scale modeling of water quality. **Themes of biomass-assisted resilience, mediated by hypoxia and wildfire disturbance, will be addressed.**

Jager, HI and R Efroymson. 2018. Biomass production mediates the flow of ecosystem goods and services downstream to the Gulf of Mexico. Special Issue. Biomass and Bioenergy 114: 125-131

Dale, VD, HI Jager, AK Wolfe, and RA Efroymson. 2018. Risk and resilience in an uncertain world. Frontiers in Ecology and the Environment (Guest editorial). 16(1): 3-3.

Quad Chart Overview – 4.2.1.40

Timeline

- Original start date: 10/1/2010
- Project start date: 10/1/2017
- Project end date: 9/30/2020
- 50% complete

	FY16 New funds ($K)	FY 17 New funds ($K)	FY 18 New funds ($K)	FY19 New funds ($K)	FY20 New funds ($K)
DOE	410	400	375	350	

Collaborations

- Task 1. Langholtz (ORNL) – Env. Supply curves
- Task 2. ANTARES project, Roni (INL), Parish (ORNL), Lenhart (UTK)
- Task 3. PNNL, Forest service

Barriers addressed

- At-E. Quantification of Economic, Environmental, and Other Benefits and Costs.
- At-F. Science-Based Methods for Improving Sustainability

Objective

Design spatial eco-economic models and visualizations to discover how we can manage production of advanced feedstocks to generate significant ancillary environmental value (water quality and biodiversity).

End of Project Goal

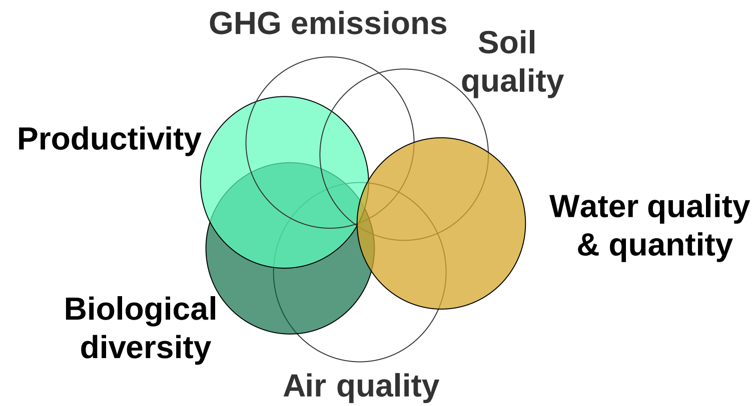
Demonstrate ways that biomass production can generate significant biodiversity benefits by showing how forest thinning and use of perennial feedstocks reduce the incidence of high-intensity wildfires and algal blooms.

1 - Project Overview

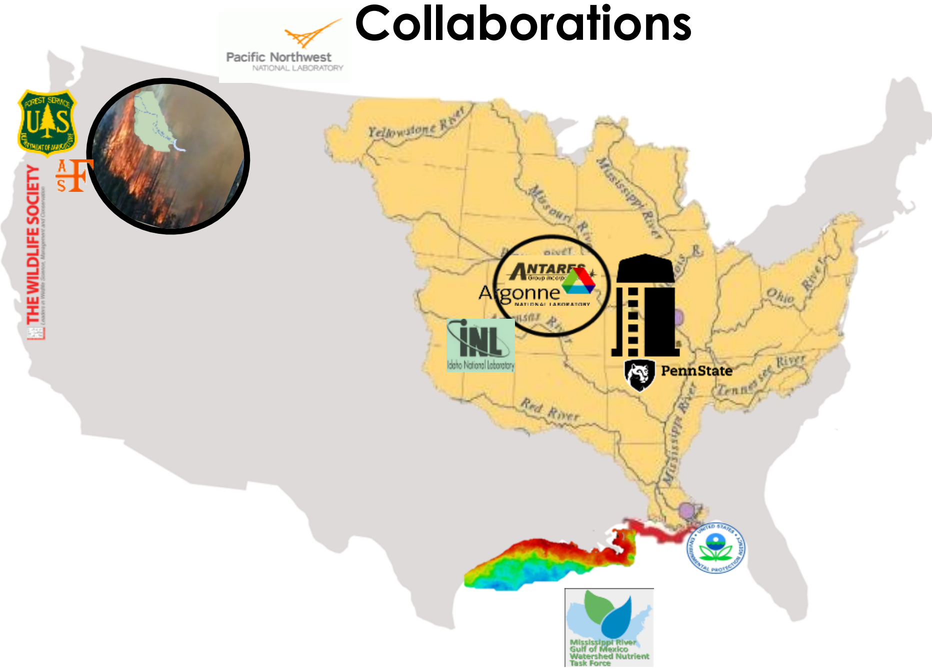
History

FY17	• Completed simulation of future BT16 and scenarios for tributary basins (ORNL-ANL) and the overall collaborative Mississippi River Basin modeling effort with ANL.
FY18	• Shift from **modeling water quality** to **valuation of water quality improvements** and **modeling biodiversity responses.**
FY19	• Developed ecological models to simulate population status and biodiversity in response to changes in land management associated with biomass production.

Dimensions of sustainability



Collaborations



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1 – Project Overview – Two case studies

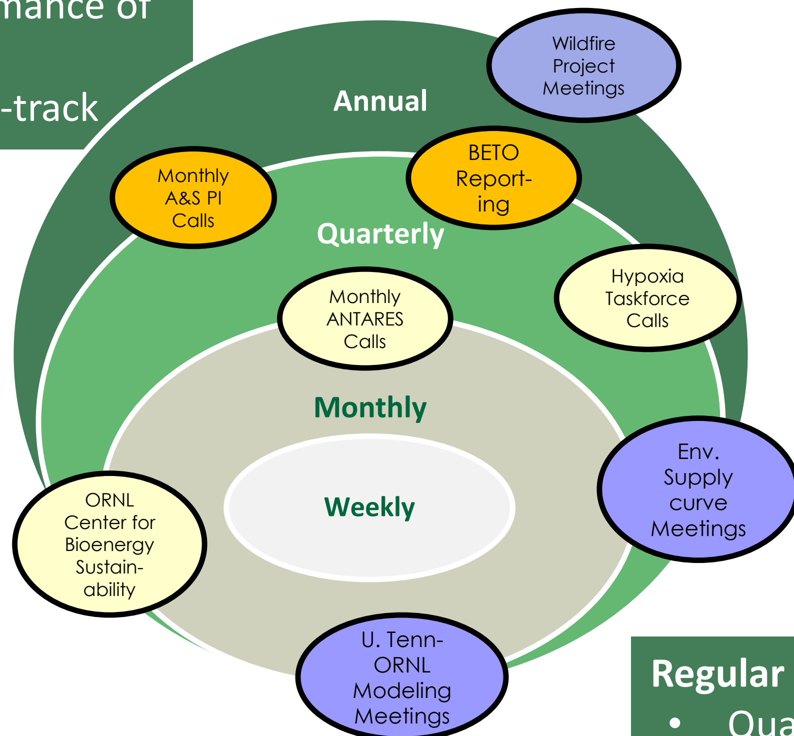
Visualizing ecosystem service portfolios

Agriculture (Landscape design for wildlife)

Forestry (Thinning-wildfire-listed salmonids)

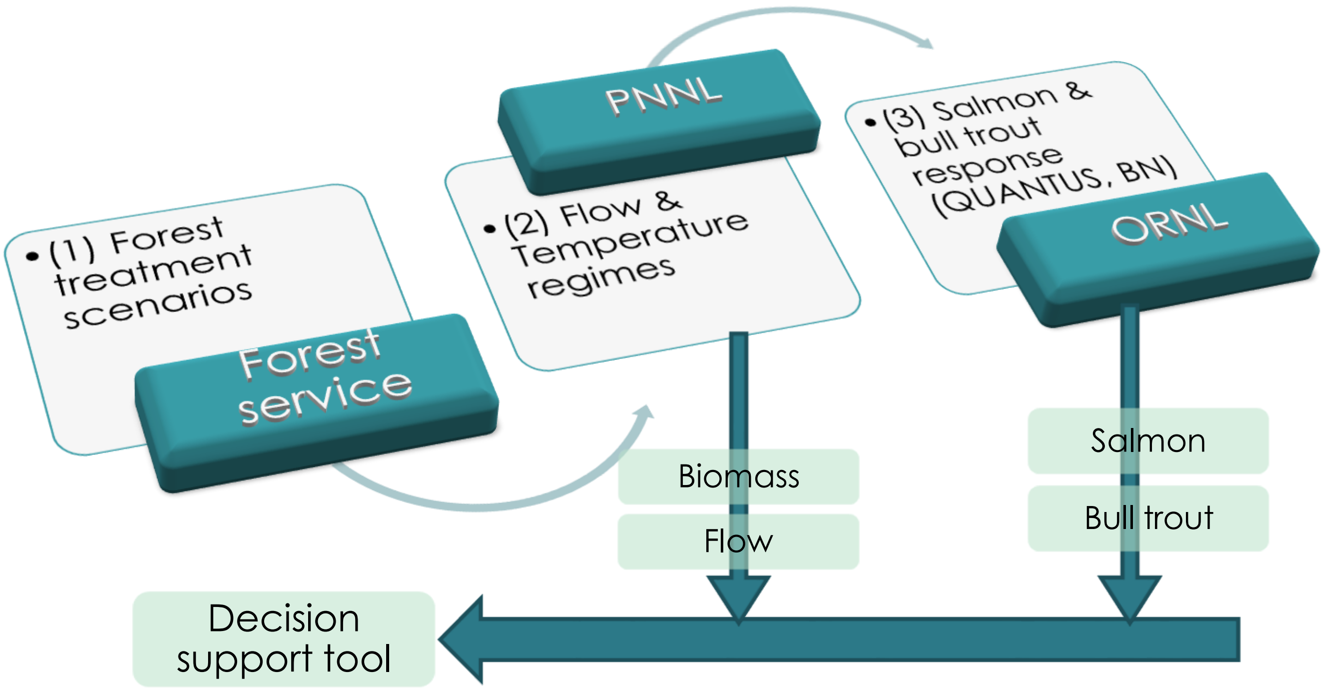
2 – Approach (Management)

Milestones Delivered
- Annual update of project plan
- Go/No-Go due in June will demonstrate the performance of our salmonid model
- Quarterly milestones on-track



Regular Communication
- Quarterly check-in
- Quarterly milestones, reports
- Monthly A&S PIs
- Monthly meetings for each task
- Weekly project meetings

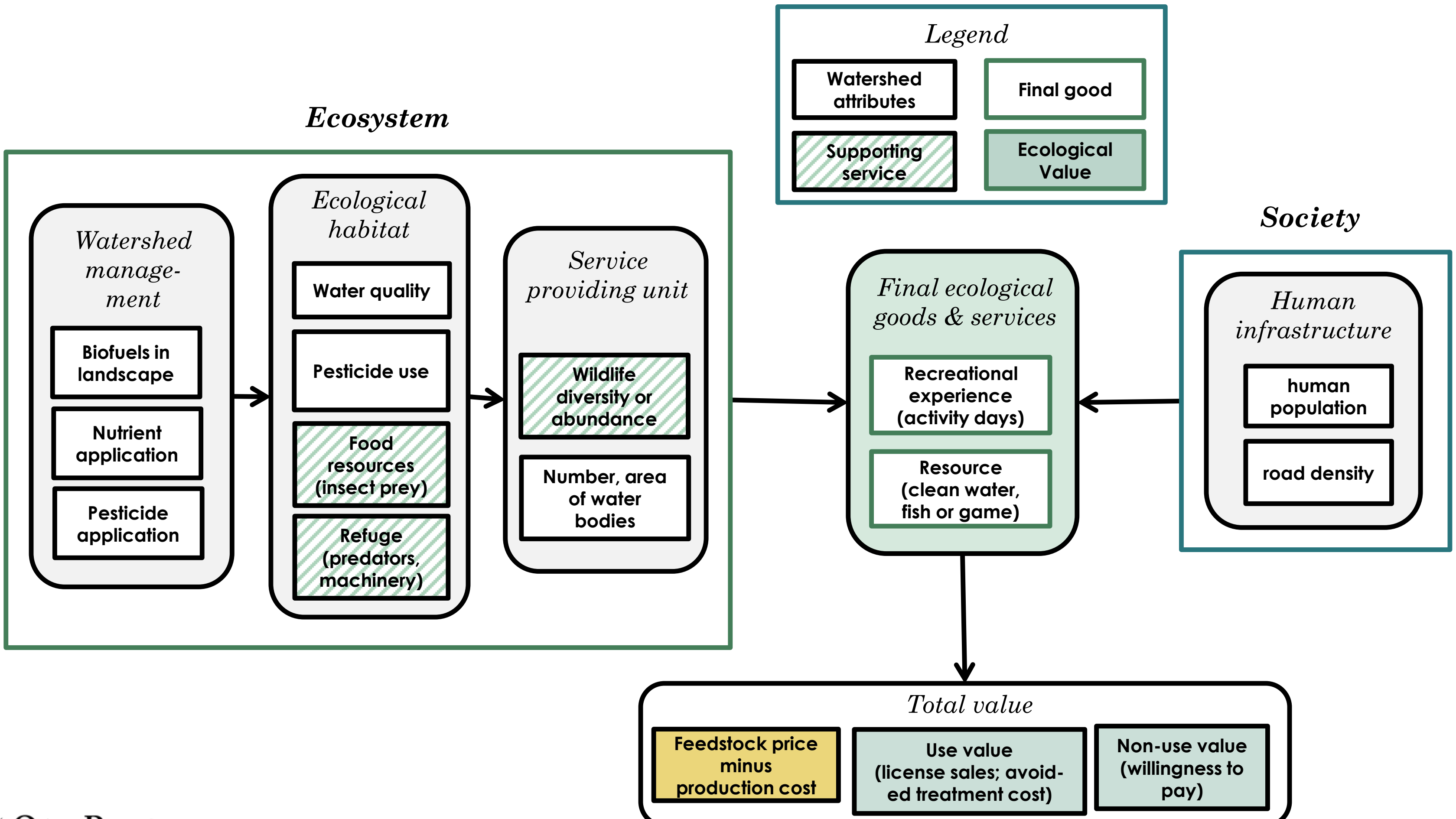
3- Approach (Management) Forest restoration



Information flow returning simulated ecosystem services to decision support tool

2 – Approach (technical)

Our research develops and uses bioeconomic models (BioVEST) to communicate the costs and benefits of alternative biomass production scenarios.

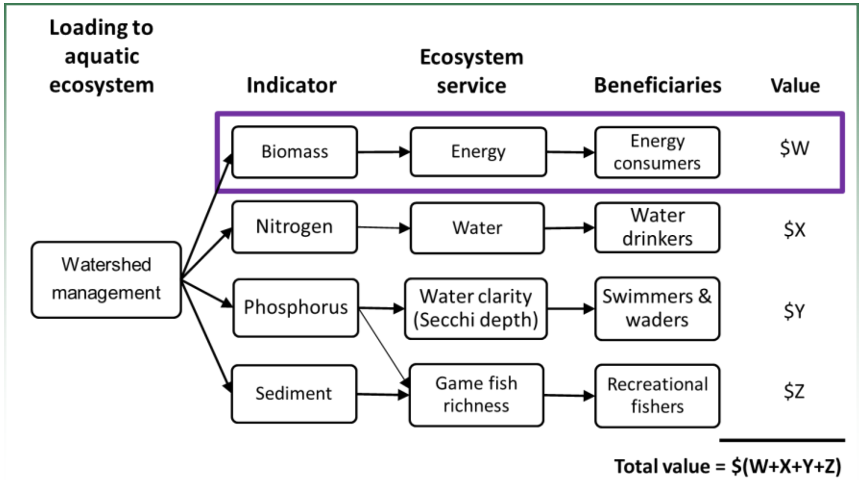


2 – Approach (Technical)

Major challenges	Critical success factors
Ecological modeling needs versus budget, timeline	• Availability of ecological models, tailoring tools to fit project needs
Challenges of cross-disciplinary research	• Successful collaboration with experts *(foresters, wildfire experts, hydrologists, logistics, agriculture)*
Challenges in visualizing multi-dimensional data	• Identified solutions including *1) valuation to a common currency* *2) quantile-based supply curves*

2 – Approach: Visualizing Ecosystem Services Portfolios

Quantify benefits of water quality improvements



Approach

- Drinking water
  - Avoided treatment cost
  - Nitrate standard
  - EPA cost data
- Swimming, wading
  - Contingent valuation (transfer of marginal value per household, lake)
  - Geographic extrapolation to study region

Total value, subbasin x — *Farmgate price minus production costs by crop, y* — *Avoided water treatment cost* — *Recreational value*

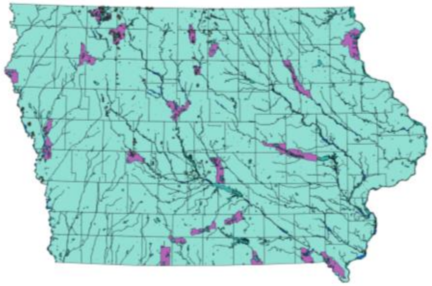
$$TV_x(\$) = \sum_y A_{x,y}\left[\left(I - P_{x,y}\right) + WWCn_{x,y} + CVp_{x,y}\right]$$

2 – Approach: Landscape design for biomass production & wildlife

Two modeling approaches

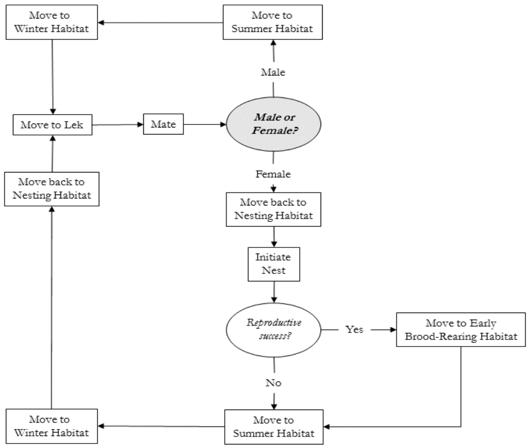
- BioEST modeling of multiple native species of concern in Iowa
  - Occupancy data for Iowa
  - Climatic data, soils, crop, pesticide use, proximity to water, forest, edge
- Agent-based modeling to guide management (tractor, hunter, pheasant agents) at the scale of multiple fields.
  - Questions about timing and spatial pattern of farm operations.

Two scales



A. State of Iowa (fuelsheds); BioEST applied to multiple taxa

B. Field-scale; ring-necked pheasant



2. Approach - Candidate species

Value spectrum

Game species

High 'use' value

High 'non-use' value

Rare / listed species

Taxa

Birds

Reptiles

Mammals

Amphibians

Insects

Inverts (mussels)

Fish

Exposure

Terrestrial

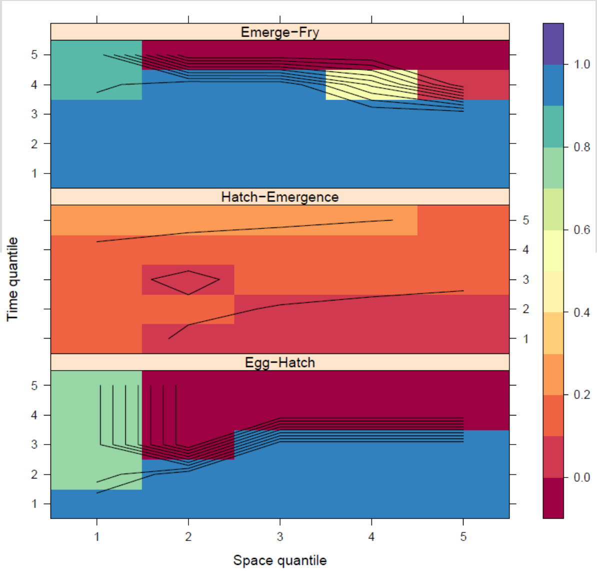
Aquatic

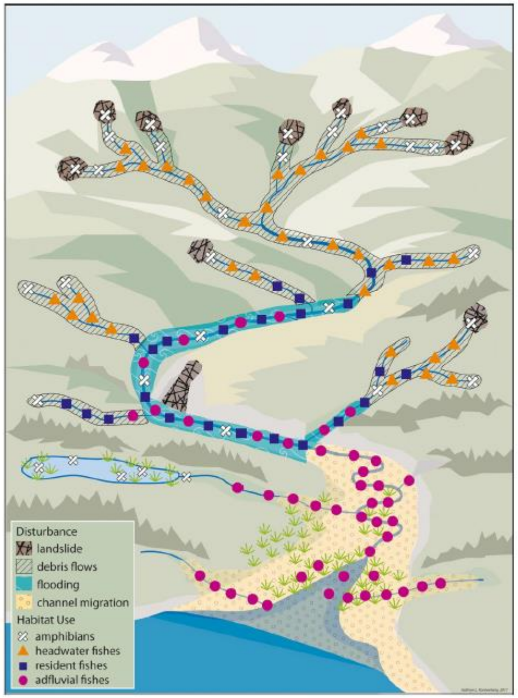
Questions

- How does the risk signature of perennial biofuel production compare to that of row crops?
  - Crop operation timing
  - Pesticide use or not
- How do taxa differ in risks or benefits

2 – Approach: Can forest thinning reduce wildfire, shift timing of flow, & restore habitat for listed salmonids?

- Quantile model linking water quality to survival
  - Watershed models thinning scenarios => Flow and water temperature, daily drivers of QUANTUS fish model.
  - QUANTUS simulates incubation and rearing survival for spring Chinook salmon and bull trout as a function of temperature and floodplain inundation. Results are integrated over spawning time quantiles and reaches.
  - We also calculate frequency and duration statistics for use in the Bayesian network model.





Jager, HI. 2014. Thinking outside the channel: Timing pulse flows to benefit salmon via indirect pathways. Ecological Modelling 273: 117-127.

Decision support: Bayesian network modeling

Bayesian network model will use duration statistics and plugs into the decision support tool for forest management.

3-Technical Accomplishments, summary

Task	Publications / Reports since FY17	Tools / Models	Symposia organized, Presentations	Outreach / Impact
Water quality in the Mississippi River Basin	• Wang et al. 2018 (**FY18 Q2 milestone**, Tenn. River basin) • Gulf Hypoxia workshop report	• SWAT-MARB	• Presented Joint ORNL-ANL-DOE Webinar Dec 2018 on Mississippi River Basin, available on KDF • Produced DOE Webinars on two Billion Ton 2016 Chapters • Invited AFS presentation in hypoxia symposium organized by USFWS Big Rivers/Midwest LLC	• Participation in Gulf Hypoxia Modeling Working Group. • Presentations to State and Federal agencies on EPA Gulf Hypoxia taskforce • Mississippi River basin modeling webinar attended by representatives from >90 organizations
Visualizing ecosystem services portfolios	• Jager & Efroymson 2018 (**FY18 Q1 milestone**) • Draft manuscript showing ESC for water quality submitted to BETO • Contributing to other papers based on BT16 V2, Efroymson, Langholtz (PI)	• New approaches to visualizing environ-mental supply curves • BioVEST spatial mapping of ecosystem services and values		• High-impact publication in progress, focused on water quality benefits in Arkansas-White-Red river basin

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3-Technical Accomplishments, summary

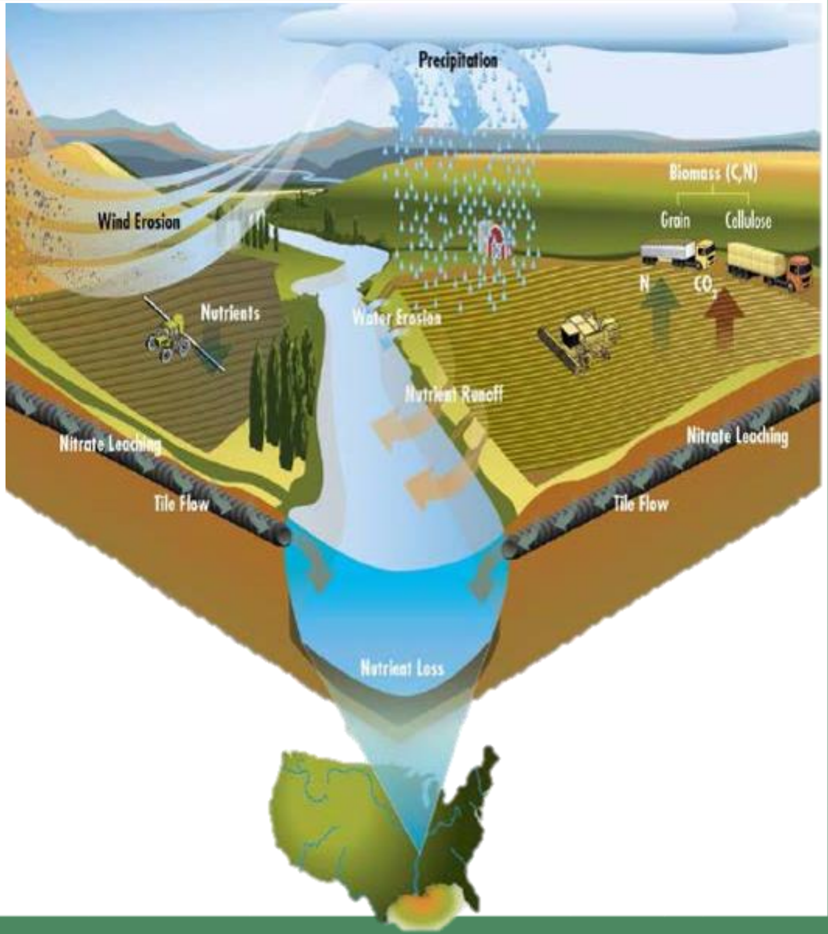
Task	Publications / Reports since FY17	Tools / Models	Symposia organized, Presentations	Outreach / Impact
Landscape design for biomass & wildlife	• Jager & Kreig (2018) (Designing landscapes for biomass & biodiversity) • In progress: 2-3 papers, MS PhD theses	• Agent-based model • Bio-EST • Econometric models	• Organized 2nd symposium on Biomass & Biodiversity, Int. Association of Landscape Ecologists • Co-organizing Symposium 'Natural Resource Conservation in Agricultural Landscapes' AFS-2019	• Publication with global scope
Forest thinning-wildfire-salmonids	• Paper in progress	• Models linking fish response to habitat (ORNL) • Watershed treatment effects on streams (DHSVM, PNNL)	• Invited presentation, 2018 American Fisheries Society symposium: 'Watershed influences on aquatic habitat' • Organizing 2-day wildfire and wildlife symposium at joint meeting of AFS-The Wildlife Society in Reno, NV	• Wildfire-wildlife symposium involves 3 TWS working groups, EPRI, and 2 AFS Sections

3 – Technical accomplishments and progress

- Completed joint SWAT-MARB assessment with Argonne to quantify bioenergy influences on nutrient exports. Published results for the Tennessee River Basin (Wang et al. 2018), conducted Webinar, and posted SWAT data and metadata to the KDF.
- Developed valuation methods and produced spatial visualizations and curves depicting supply of total value. Prepared a draft manuscript on total-value supply curves and maps.
- Developed and published landscape design guidelines for biodiversity (Jager and Kreig 2018).
- Developed first version of an agent-based model of pheasants to identify optimal strategies to recover pheasants in Iowa farms and lands growing perennial biofuel crops.
- Demonstrated use of salmon model to quantify survival in response to water temperature and flow as part of a decision support for thinning of Western forest to promote biofuel and salmon production with PNNL, Forest Service.

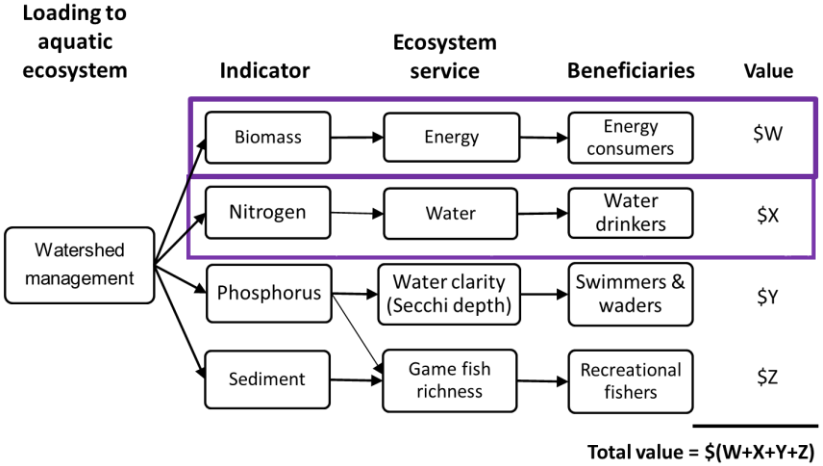
3 –Results: Water Quality Modeling of Mississippi River Tributary Basins

- Published results for each river basin.
- Future BT16 landscapes showed net reductions in nutrients and sediment loadings caused by perennial crops, but considerable geographic variation.
- Engaged with broader scientific community to highlight bioenergy as a potential part of the solution to Gulf Hypoxia
  - **Participated in Hypoxia Taskforce Watershed Modeling Group**
  - **Co-organized Gulf Hypoxia Workshop; produced workshop report**
  - **Joint webinar summarizing results presented to 117 attendees from >90 organizations.**

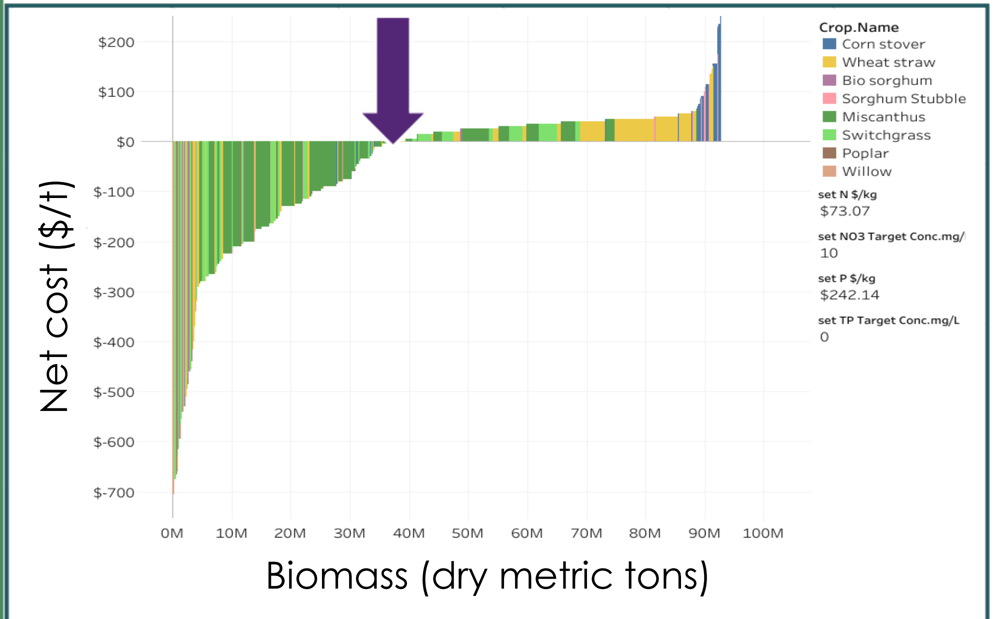


Wang G, Jager HI, Baskaran LM, Brandt CC. 2018. Hydrologic and water quality responses to biomass production in the Tennessee river basin. GCB Bioenergy 10: 877–893. https://doi.org/10.1111/gcbb.12537

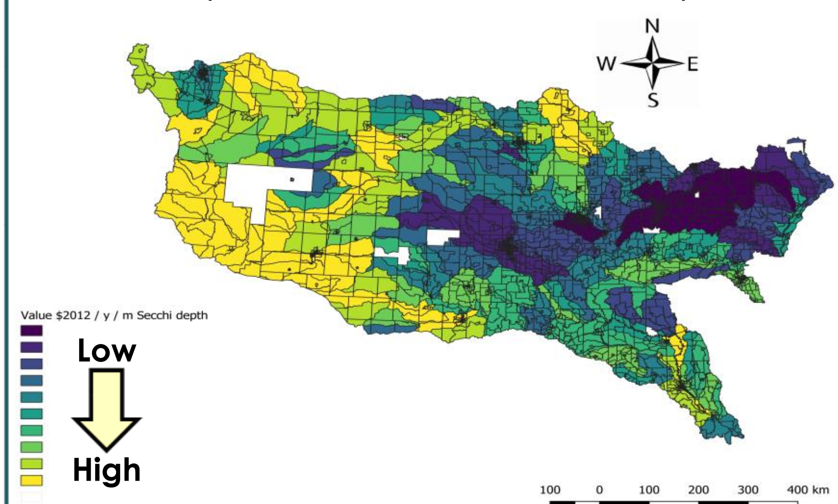
3 – Results: Environmental supply curves illustrate value of water quality improvements from perennial crops



- Implemented ecological valuation for two types of beneficiaries of high-quality water.
- 40MT of feedstock could be produced with water purification benefits exceeding production cost of biofuel crops.



Draft geographic distribution of value (water drinkers & feedstock)



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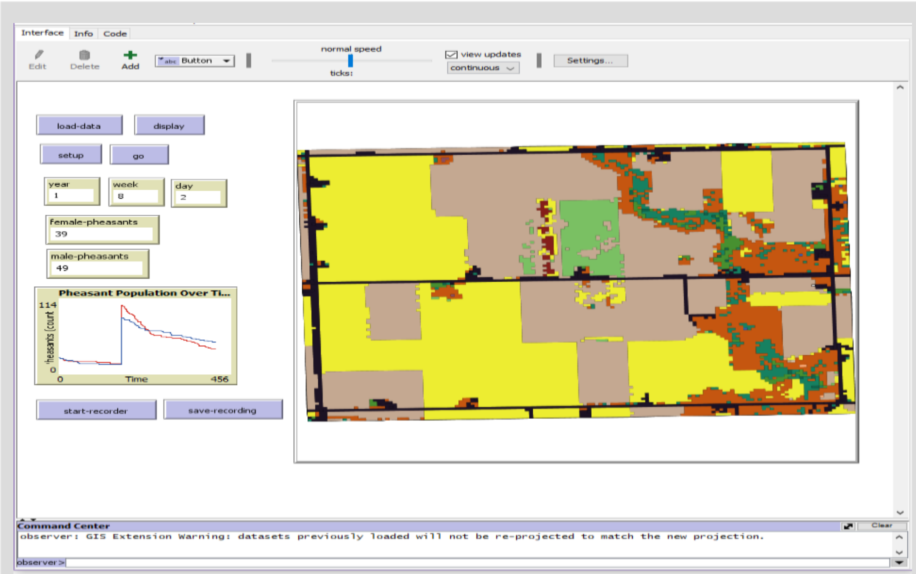
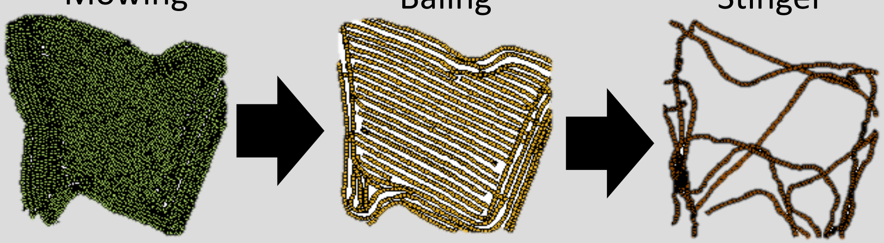
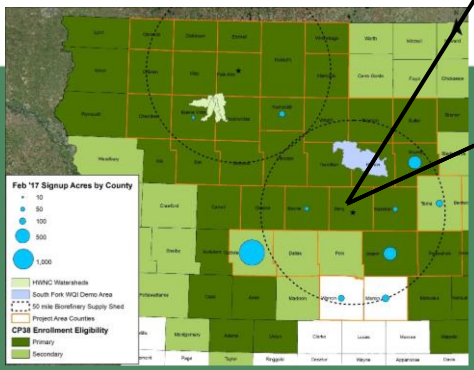
3-Results--Design of wildlife-friendly biomass-producing landscapes in Iowa





- Acres designated for pheasant habitat enhancement are located near two Iowa refinery supply-sheds (>3,000 acres and >34 growers).
- Obtained spatial landscape data from ANTARES and implemented habitat relationships for each life stage in pheasant model.
- Obtained operations tracks from INL for use in evaluating how they influence nesting mortality.
- Implemented 1st version of an agent-based pheasant model (screenshot left) with pheasants, tractors, hunters
- Agent-based model description and demonstration; MS thesis (April).



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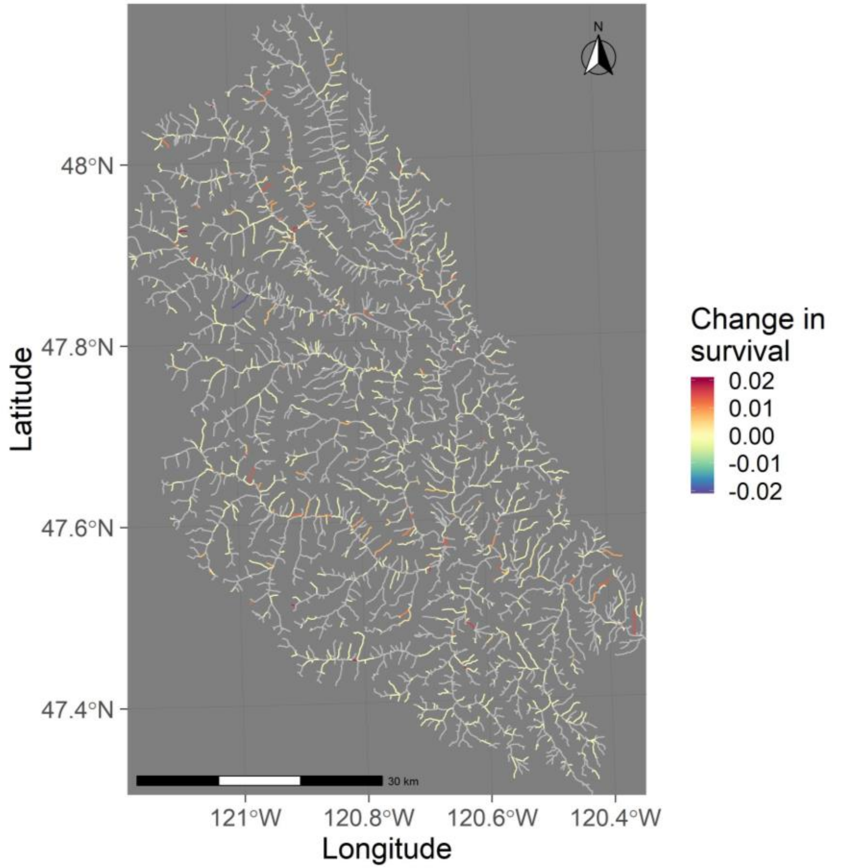
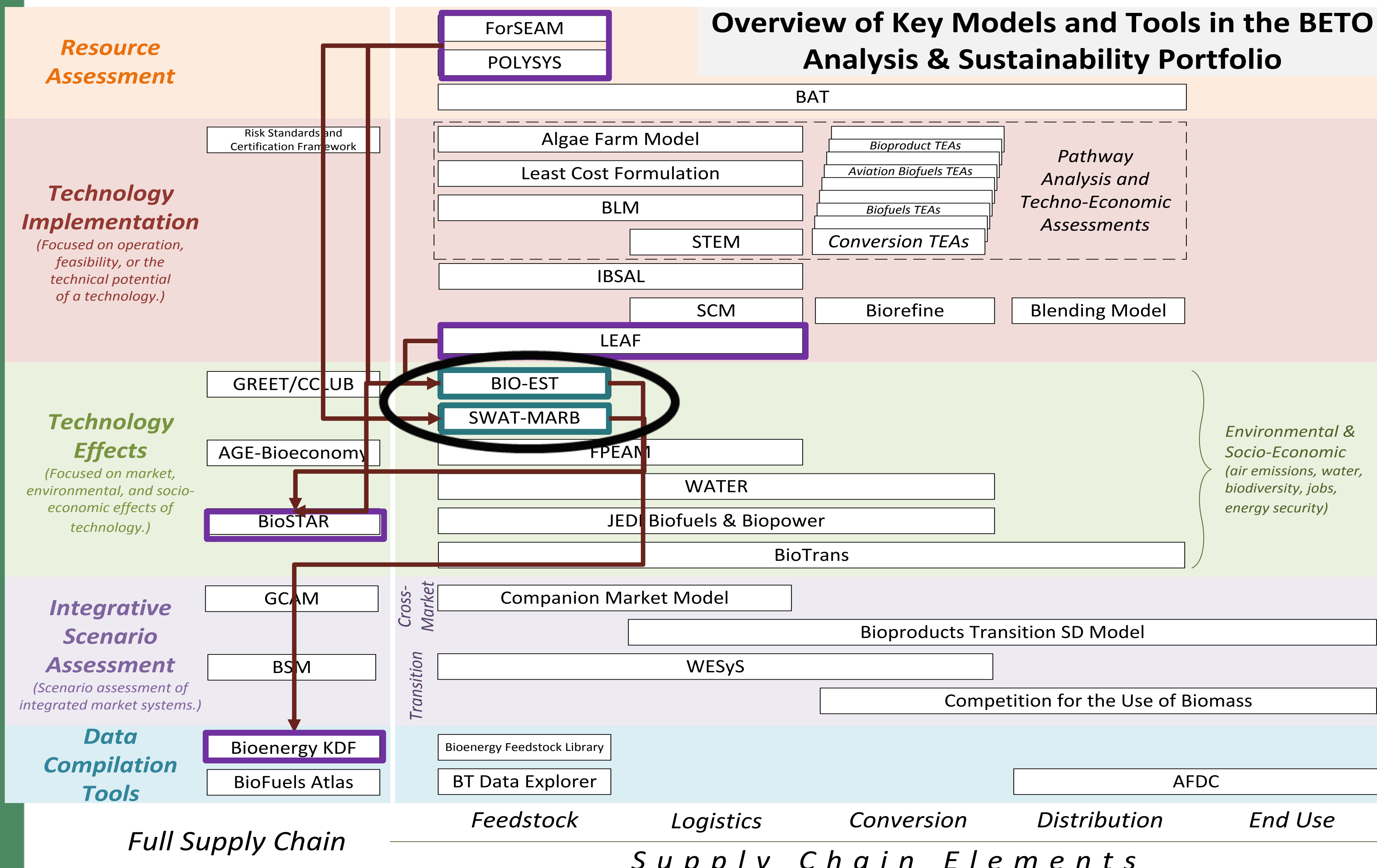
3 – Results: Forest thinning-Wildfire-Salmonids

- Adapted the QUANTUS salmon model and simulated the baseline flow and temperature inputs for ten years for streams in the Wenatchee basin.
- Implemented a BN model based on thresholds in Netica and Genie for use in the EMDS decision support tool.
- Treatments effects:
  - ↓ incubation survival
  - ↑ juvenile rearing survival
  - ↑ overall survival



Model and Tool Primary Analytical Purpose



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4 –Relevance – We address several MYPP goals; these are the two most-relevant.

At-E. Quantification of Economic, Environmental, and Other Benefits & Costs

- *Bioenergy technologies less likely to be adopted by the private sector when their benefits are uncertain or not quantified…*
- All of our research quantifies economic and environmental costs and benefits for alternative management scenarios.
  - Via eco-economic models to monetize changes in ecosystem services associated with biomass production.
  - Via new visualization methods for monetized ecosystem services (total value curves & mapping).

At-F. Science-Based Methods for Improving Sustainability

- We have authored six different tools, some used by other A&S projects
- Producing guidelines for designing landscapes for wildlife
  - Effects of crop placement (Juxtaposition of habitats, Pesticide use)
  - Optimal harvest strategies for wildlife and cellulosic biofuel production.
  - Comparison of outcomes for listed salmonids for different forest thinning scenarios

4 –Relevance

At-A. Analysis to Inform Strategic Direction

Analysis is needed to better understand factors influencing the growth and development of the bioenergy and bioproducts industries, identify the most impactful R&D strategies, define BETO goals, and inform BETO strategic direction.

- Comparing pesticide use in biomass for energy and crops to assess the potential for significant improvements in water quality and biodiversity.
- Exploring the potential for biomass production and harvest to help recover ESA-listed species, game species, and other species of conservation concern.

At-H. Consensus, Data, and Proactive Strategies for Improving Land-Use Management

Science-based, multi-stakeholder strategies are needed to integrate bioenergy with agricultural and forestry systems in a way that reduces wastes, maintains crop yields, enhances resiliency, and supports multiple ecosystem services.

- Our final project milestone is to evaluate the potential for increased resilience to disturbance regimes, hypoxia and wildfire.

5 – Future Work

- A 2 day symposium on '**Wildfire and Wildlife**' has been proposed for a joint meeting of the American Fisheries and The Wildlife Society at the beginning of October, 2019 in Reno that will include thinning research, research, 27 confirmed speakers.
- ***Publication and dissemination of results:***
  - *Wenatchee basin salmonid modeling analysis; extension to future climate and valuation of salmonid costs/benefits based on Loomis contingent valuation.*
  - *Spatial valuation of water-quality improvements*
  - *Develop design recommendations from biodiversity modeling (Landscape Design project)*
  - *Kreig MS thesis defense on Agent-based modeling: April 2, 2019*
  - **Special issue proposal:** Renewable Energy and Species Conservation in a Changing World, Renewable & Sustainable Energy Reviews or Frontiers in Ecology & Evolution.

Project end goal: Determine how biomass production can reduce the risk and intensity of wildfire and threats to water quality from hypoxia. Biofuels are demonstrating potential to increase resilience to both disturbance regimes (Dale et al. 2018; Jager et al. 2018). By the end of the project, our research will have monetized ecosystem services provided by biomass production, illustrated by agricultural and forest case studies and previous regional-scale modeling of water quality. **Themes of biomass-assisted resilience, mediated by hypoxia and wildfire disturbance, will be addressed in FY20 publications.**

5-Future Plans

Publications in progress

- Jager, Efroymson, Langholtz, Hilliard, & Brandt. In progress. Environmental Supply Curves for biomass and water quality. Target journal: PNAS.
- Jager, HI, RA Novello. In progress. Resilient forests: Can thinning forests increase habitat for ESA-listed salmonids in the Wenatchee river basin, USA under current or future climate? Nature Climate Change or Special Issue in Sustainable and Renewable Energy Reviews
- Jager, HI, M. Wigmosta, R. Novello, P. Hessberg, K. Reynolds, R. Flitcroft. Model-based scaling from mechanistic models to Bayesian network and logic decision frameworks: managing forests for biomass and ESA-listed salmonids. Ecosphere: Methods, Tools, and Technologies.
- Jager, Bowen, …other organizers. Submit by Dec, 2019. Wildfire and wildlife: summary of a symposium focused on wildfire and its effects on fish and wildlife populations. Fisheries.
- Kreig, J. (proposed). Evaluating scenarios using a spatially-explicit agent-based model to recover pheasant populations and maximize biomass harvest. MS Thesis, Math Department. University of Tennessee.
- Kreig, J., HI Jager, S. Lenhart, others. In progress. Optimal control of switchgrass and stover harvest to promote ring-necked pheasant recovery and biomass quality. Ecosphere or Special Issue in Renewable and Sustainable Energy Reviews.
- Efroymson, Jager, Kreig. In progress. Can biofuels bring back beneficial insects? (pesticide comparison)
- Kreig, J., HI Jager, S. Lenhart, others. In progress. Predicting changes in biodiversity associated with biofuel production in an agricultural landscape. Ecosphere or Special Issue in Renewable and Sustainable Energy Reviews.

6 - Summary

Criterion	Project approach
Approach(es)	▪ Eco-economic models to visualize the value of ecosystem services provided by biomass production, including water quality, fish, and wildlife. ▪ Modeling biodiversity responses to bioenergy-related land management (forest thinning, landscape design of crops, timing of harvest, pesticide use).
Technical accomplishments	▪ Simulated water quality changes in two large river basins ▪ Spatial valuation of ecosystem services: water quality improvements. ▪ Progress in biodiversity modeling to support ANTARES landscape design ▪ Progress in salmon and bull trout modeling for forested case study.
Relevance	▪ Quantification of economic, environmental, and other benefits and costs (tools to quantify ecosystem services associated with biomass production, water purification, and biodiversity) ▪ Identify and promote spatial design and management strategies to benefit, or avoid harm to, fish and wildlife.
Critical success factors & challenges	▪ Challenge: Difficulty in visualizing diverse, multi-dimensional ecosystem services ▪ Success factor: Invention of valuation-based and quantile-based approaches; Portfolio of models and experience
Future work	▪ Completion of two case studies with species response models and guidance for managing biofuel systems to benefit wildlife. ▪ Valuation of benefits (salmon, pheasants, water quality)
Technology transfer	• Visualization tools hosted on KDF, BioSTAR, Forest Service decision tool (EMDS). • Publish management strategies to increase resilience of species of concern and associated portfolios of ecosystem services in systems that produce biomass for energy.

Additional Slides

Responses to Previous Reviewers' Comments

- **Comment**: The models of species biodiversity offer a perspective not provided by other projects in the portfolio we reviewed. …Moving forward, it would be beneficial to focus on improving the biodiversity models for the purpose of screening biofuel feedstocks for their effects on biodiversity.
- **Response:** We agree that this is important. As the strength of our project is eco-economic modeling, we are shifting to focus on biodiversity by 1) mechanistically modeling the effects of management operations on a specific taxa, and 2) examining broad-scale patterns (e.g., related to pesticide use and conversion to perennial crops in Iowa).
- We do not have the capacity to do this with current funding, but in future, we would be interested in designing a project that integrates field research with our modeling in coordination with an academic partner in the Midwest. We are exploring options, including a South Dakota study of mixed plantings , research at Iowa State (STRIPS), DOD plantings of Miscanthus in air fields.

Responses to Previous Reviewers' Comments

- **Comment**: It would be beneficial to ensure coordination between this project and the ORNL project to define sustainability metrics for the portfolio (#4.2.2.40). To ensure synergies and provide a potential test case. It would also be helpful to spell out connection to other projects (#4.2.2.60) which has a focus on conservation reserve programs and ORNL's project on forest restoration (#4.1.1.52).
- **Response:** We have increased the degree of coordination with #4.2.2.40 (Parish). In FY18, the Bio-EST model was used to assess the potential impacts of wood pellet production to biodiversity in the Savannah case study fuel shed. We are currently working together to define biodiversity and water quality indicators for visualization of the Iowa Landscape design project's sustainability tradeoffs within ORNL's Bio-STAR tool.
- #4.2.2.60 (ANTARES). One of our tasks is devoted to providing the biodiversity assessment for the ANTARES-led Landscape Design project. We participate in monthly calls and annual meetings in Des Moines.
- #4.1.1.52 (PNNL, Wigmosta). We are closely coordinated with this project. FS provides restoration scenarios to PNNL; PNNL simulates flow and temperature; ORNL simulates fish responses; Integrated in decision tool by FS.

Publications

- Jager, HI and RA Efroymson 2018. Can upstream biomass production increase the flow of downstream ecosystem goods and services? Special issue on Ecosystem Services in Biomass & Bioenergy 114: 125-131.
- Jager, HI and JF Kreig. 2018. Designing landscapes for biomass production and wildlife. Global Ecology and Conservation 16 doi.org/10.1016/j.gecco.2018.e00490
- Wang G, Jager HI, Baskaran LM, Brandt CC.2018. Hydrologic and water quality responses to biomass production in the Tennessee river basin. GCB Bioenergy 10: 877–893. https://doi.org/10.1111/gcbb.12537

Publications in review

- Kreig, J., HI Jager, C. Negri, H. Ssesane, I. Chaubey, and others. In review. Designing bioenergy landscapes to improve water quality. Global Change Biology: Bioenergy
- Chen, H., D. Zhongmin, H. Jager, S. Wullschleger, J. Xu, and C. Schadt. In review. Meta-analysis shows how N fertilization and climate regime influence the above-ground biomass yields of bioenergy crops across the globe. Renewable & Sustainable Energy Reviews.
- Schweizer, Jager, Eaton, Efroymson, and Baskaran. Hot spots for recreational fishing: mapping the value of ecosystem services at the confluence of fish diversity, water quality, and people with access to freshwater. Fish and Fisheries.
- Gorelick & Jager. In review. Siting bioenergy feedstock introductions through multi-objective spatial optimization, Land Use Policy
- Jager, Efroymson, Baskaran. Avoiding conflicts between future freshwater algae production and water scarcity in the United States at the energy-water nexus. Special Issue Energy-Water Nexus, Water. (not A&S funded)

Related publications, non-BETO

- Jager, HI, RA Novello, VH Dale, A Villnas, and KA Rose. 2018. Unnatural hypoxic regimes. Ecosphere 9(9) DOI 10.1002/ecs2.2408
- Dale, VD, HI Jager, AK Wolfe, and RA Efroymson. 2018. Risk and resilience in an uncertain world. Frontiers in Ecology and the Environment (Guest editorial). 16(1): 3-3.
- Jager, HI, AW King, S. Gangrade, A Haines, C DeRolph, BS Naz, M Ashfaq. 2018. Will future climate change increase the risk of violating minimum flow and maximum temperature thresholds below dams in the Pacific Northwest? Climate Risk Management 21: 69-84.
- Forbes, V, ..H. Jager,... 2019. Predicting impacts of chemicals from organisms to ecosystem service delivery. Science and the Total Environment 649: 949-959. doi.org/10.1016/j.scitotenv.2018.08.344
- Galic, ..Jager… In review. Predicting impacts of chemicals from organisms to ecosystem service delivery: A case study of insecticide impacts on a freshwater lake. Science and the Total Environment.

Progress FY17 – FY19

Received: 1 May 2018 | Accepted: 25 June 2018
DOI: 10.1111/gcbb.12537
ORIGINAL RESEARCH
WILEY BIOENERGY

Hydrologic and water quality responses to biomass production in the Tennessee river basin

Gangsheng Wang[1,2,3] | Henriette I. Jager[1,2] | Latha M. Baskaran[1] | Craig C. Brandt[4]

Abstract
Reducing dependence on fossil-based energy has raised interest in biofuels as a potential energy source, but concerns have been raised about potential implications for water quality. These effects may vary regionally depending on the biomass feedstocks and changes in land management. Here, we focused on the Tennessee River Basin (TRB), USA. According to the recent 2016 Billion-Ton Report (BT16) by the US Department of Energy, under two future scenarios (base-case and high-yield), three perennial feedstocks show high potential for growing profitably in the TRB: switchgrass (*Panicum virgatum*), miscanthus (*Miscanthus × giganteus*), ...

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Review Paper

Designing landscapes for biomass production and wildlife

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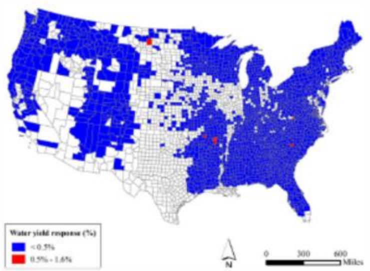
ARTICLE INFO / ABSTRACT
Replacing fossil with biomass-based sources of energy may help to reduce climate threats ...

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
2016 BILLION-TON REPORT
Effects on Water Quality, Quantity, and Consumption under *BT16* Scenarios

Effects on Water Quality, Quantity, and Consumption under *BT16* Scenarios

The *2016 Billion-Ton Report (BT16) Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1* is a pioneering effort to analyze a range of potential environmental effects associated with illustrative near-term and long-term biomass-production scenarios. Key environmental indicators studied include water-quality and water-quantity indicators for agricultural and forestry biomass.[1] Results summarized here pertain to the 2017 and 2040 scenarios analyzed in volume 2.[2]



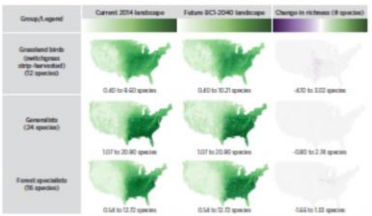
Modeled response of county-level mean annual water yield under baseline (ML) 2040 harvesting scenario showing percentage change from reference conditions. A majority of the counties have annual water yield increases of less than 0.5% of background ...

Summary
Water Quality (Agricultural)
An analysis of two tributary basins of the Mississippi River found that suitable ...

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
2016 BILLION-TON REPORT
Effects on Biodiversity under *BT16* Scenarios

Effects on Biodiversity under *BT16* Scenarios

The *2016 Billion-Ton Report (BT16) Volume 2: Environmental Sustainability Effects of Select Scenarios from Volume 1* is a pioneering effort to analyze a range of potential environmental effects associated with illustrative near-term and long-term biomass production scenarios. Key environmental effects studied include effects on avian biodiversity as a result of biomass crop production, as well as effects on biodiversity in forest ecosystems as a result of woody biomass harvesting.[1] Results summarized here pertain to the 2017 and 2040 scenarios analyzed in volume 2.[2]



Projected richness under the 2014 landscape (left column) and under a landscape consistent with the 2040 base-case yield (BC1) future agricultural scenario (middle column), as well as differences in richness (right column) for three groups of species. Rows display distributions for grassland, generalist, and forest specialist species. The range for differences in richness displayed by the legend row (below headers) is indicated below each map.

Summary
One of the objectives of this study was to quantify projected changes in suitable ...

Woody-biomass harvest in the examined scenarios would primarily affect biodiversity through changes ...

esa ECOSPHERE
INNOVATIVE VIEWPOINT

Unnatural hypoxic regimes

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Citation: Jager, H. I., R. C. Novello, V. H. Dale, A. Villnäs, and K. A. Rose. 2018. Unnatural hypoxic regimes. Ecosphere 9(9):e02408. 10.1002/ecs2.2408

Abstract. Coastal hypoxia is increasing worldwide in response to human-caused changes in global climate and biogeochemical cycles. In this paper, we view anthropogenic trends in coastal hypoxia through the lens of disturbance ecology and complexity theory. Complexity theory provides a framework for describing how estuaries and other coastal aquatic ecosystems respond to hypoxia by understanding feedback loops. Can it also be valuable in understanding how these ecosystems behave under (unnatural) disturbance regimes? When viewed as a disturbance regime, ... and fragmentation) and temporal (frequency and duration of events) ... be used to track changes into a non-stationary future. ...

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Research paper

Can upstream biofuel production increase the flow of downstream ecosystem goods and services?

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Gulf of Mexico
Hypoxia
Payment for Ecosystem Services (PES)

ABSTRACT
Advanced biomass feedstocks tend to provide more non-fuel ecosystem goods and services (ES) than 1st-generation alternatives. We explore the idea that payment for non-fuel ES could facilitate market penetration of advanced biofuels by closing the profitability gap. As a specific example, we discuss the Mississippi-Atchafalaya River Basin (MARB), where 1st-generation bioenergy feedstocks (e.g., corn-grain) have been integrated into the agricultural landscape. Downstream, the MARB drains to the Gulf of Mexico, where the most-valuable fishery in the US is impacted by annual formation of a large hypoxic "Dead zone." We suggest that advanced biomass production systems in the MARB can increase and stabilize the provision of ES derived from the coastal and marine ecosystems of the Gulf-of-Mexico. Upstream, we suggest that choosing feedstocks based on their resistance or resilience to disturbance (e.g., perennials, diverse feedstocks) can increase reliability in ES provision ... incentivize producers of advanced feedstocks ... biofuels to perennial-based fuels and other advanced ... animal wastes) can be encouraged by ... for upstream producers. In future ... research is needed to ...

GUEST EDITORIAL

Risk and resilience in an uncertain world

Ecological disturbances are occurring with greater frequency and intensity than in the past. Under projected shifts in disturbance regimes and patterns of recovery, societal and environmental impacts are expected to be more extreme and to span larger spatial extents. Moreover, preexisting conditions will require a longer time to re-establish, if they do so at all. The word "unprecedented" is appearing more often in news reporting on droughts, fires, hurricanes, tsunamis, ice storms, and insect outbreaks. The causes and effects of these events are often exacerbated by human modifications of natural environments and influenced by technological developments.

At the same time, multiple events or different types of disturbances can undermine the ability of environmental systems to recover, and interacting disturbances can cause these systems to transition to new and undesirable states. For example, the combination of an expansion of impervious surface area, changes to hydrology and drainage systems, and wetland losses can interact to amplify the frequency and severity of flooding. In addition, actions that seek to manage individual rather than combined risks may induce unintentional consequences, increase the magnitude of impacts, or decrease resilience (the ability of an ecosystem to withstand or recover quickly from a disturbance). Furthermore, re-establishment may be to a new state or to what some call an "emerging ecosystem", whose properties then influence risks of and resilience to subsequent disturbances.

The need to proactively address risk and resilience is more pressing than ever. Managing complex ecosystems to maintain essential characteristics in the face of an uncertain future is challenging. Therefore, we offer a perspective on risk and resilience that encompasses interactions among ecosystems, social systems, infrastructure, and evolving technological capabilities. Management decisions need to concentrate on three topic areas: (1) risk assessment, monitoring, and mitigation; (2) natural resource use and ecosystem service management; and (3) linkages among humans, technologies, and emerging ecosystems.

More effectively managing natural resources and the ecosystem services they provide requires that scientists and managers anticipate shifts in disturbance regimes and analyze risk and resilience from broader perspectives. Whether and when risks and associated losses in ecosystem services ... or attenuated by future disturbances depends on how the environment, society ... nology respond. We cannot assume that practices that have worked ... Just as future disturbance regimes differ from those ... also changing.

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Oak Ridge National Laboratory

Progress FY17 – FY19

Webinars, presentations, and reports

- Johnson, K, HI Jager, and M Wu. Dec. 2018. Simulating water quality and hydrology responses to growing biomass feedstocks in the Mississippi River Basin. DOE Webinar. (FY19 Q1 milestone)
- Kreig, Jager, & Wang. 2018. A modeling framework for predicting species richness as a measure of biodiversity in changing bioenergy-landscapes. Ecological Society of America Annual Meeting, August 7, New Orleans.
- Jager, Novello, Wigmosta, Hessberg, Reynolds & Flitcroft. 2018. Bayesian network models explore how forest treatments can reduce wildfire risk and increase connected habitat for ESA-listed salmonids. Symposium: Advances in Understanding Landscape Influences...August 23, 2018 American Fisheries Society meeting, Atlantic City, NJ
- Jager et al… two presentations at the 'Bioenergy Solutions to Gulf Hypoxia' workshop
- Jager invited to present in a symposium on Renewable Energy and Wildlife at the Wildlife Society Meeting in Albuquerque, NM in 2018.
- Stage-gate review for ANTARES project, spring 2018, presentation on biodiversity research (Jager).
- Wang, Jager, Baskaran, Brandt. 2017. Water quality responses to biomass production in the Tennessee River Basin. ASA,-CSSA-SSSA 2017 International Annual Meeting, Tampa
- Negri, Jager, Nair, Ovard. Bioenergy Solutions to Gulf Hypoxia. 2018. Multi-lab Report on a Workshop. June, 2018

5 –FY19 milestones

Q2 Milestone

- Synthesize findings on the potential for reducing exposures to **pesticides** by growing perennial biomass crops through two pathways: 1) crops require minimal use of herbicides and insecticides, and 2) they intercept pesticide-laden runoff from agricultural fields. In addition, identify data sources to be used in BioEst to model wildlife responses to pesticide use in agricultural landscapes.

Q3 Milestone

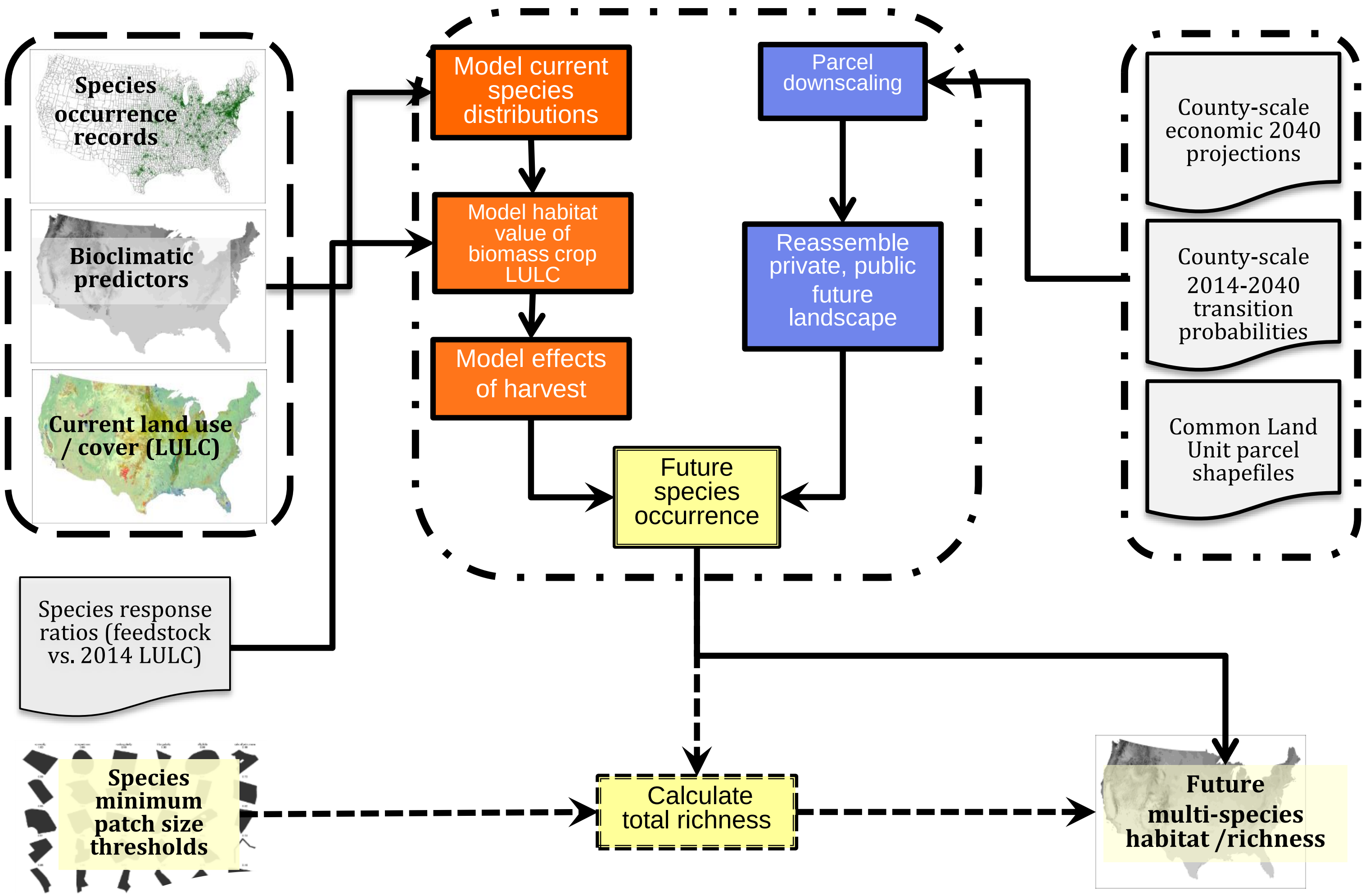
- **Go**: Demonstrate the ability to **predict salmonid distribution** from river flow and temperature. Success in classifying reaches as having the species present will be measured by true accuracy, defined as (the number of false negatives + true positives) / total reaches > 0.6. In addition, demonstrate that entropy reduction associated with flow and temperature each exceed 10%. Work will continue.

- **No Go**: If accuracy is less than 0.6 or demonstrates low entropy reduction for the two drivers, then the model is not particularly useful in demonstrating benefits of forest restoration for salmonids mediated by these two drivers. If this is the case, modeling salmonids for Task 3 will be discontinued and budget reduced accordingly.

Q4 Joint milestone (ORNL/PNNL)

- Complete the development of a forest restoration decision tool based on a suite of linked models to represent forest thinning treatments and responses in hydrology, wildfire, and listed salmonids in the basin. Complete a forest restoration plan by using the tool to evaluate multiple objectives including biomass production and salmonid recovery, in collaboration with PNNL and the Forest Service.

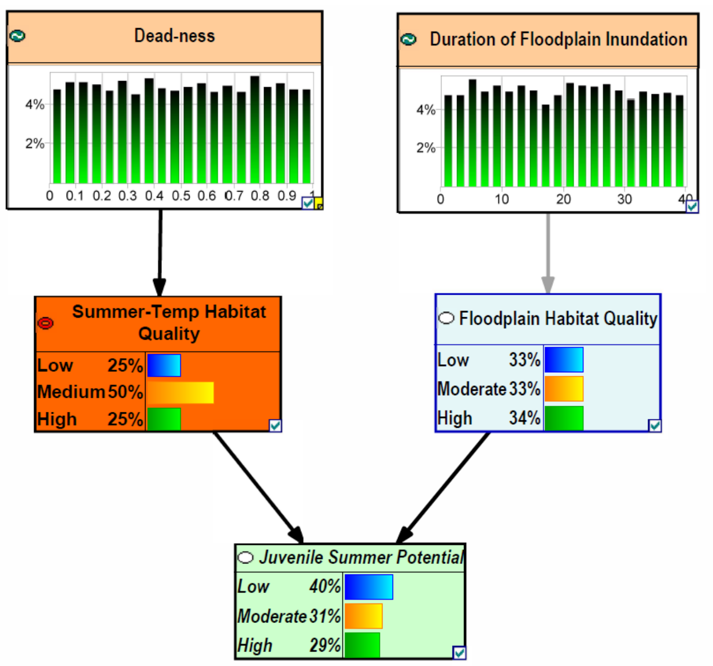
2 – Approach: Landscape design for biomass production & wildlife



3-Results - GeNie Bayesian network model

Milestones:
1) Evaluate model performance (Go-NoGo, Q3)
2) Provide GeNie BN to Forest Service for EMDS tool

Tributary (incubation / rearing)



Mainstem (juvenile growth)

(Flitcroft et al. 2016)