Oak Ridge National Laboratory

Bringing ecosystem services into the equation

Presenters: Yetta Jager & Natalie Griffith

Contributors: Esther Parish, Matt Langholtz, Terry Matthews

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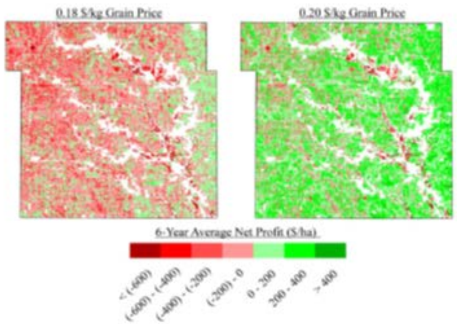
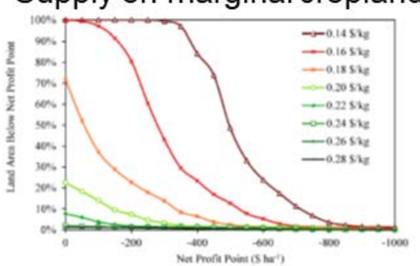
Supply



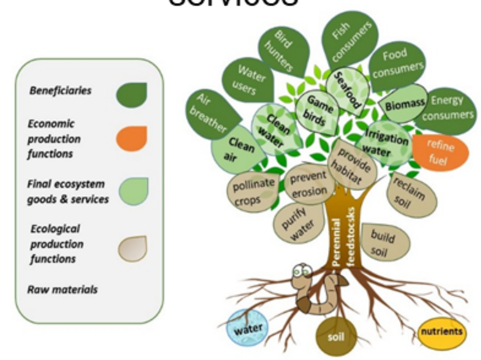
Supply on marginal cropland



Bonner et al. 2014

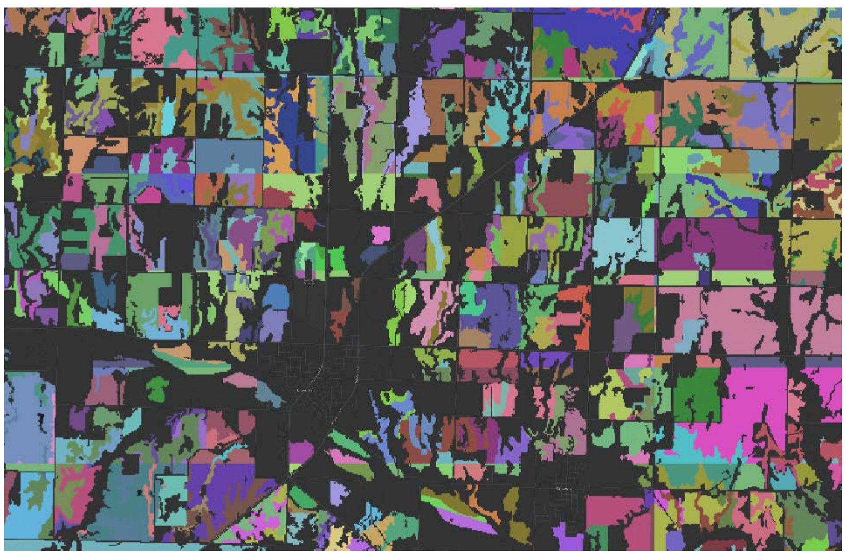
Demand

Other ecosystem services

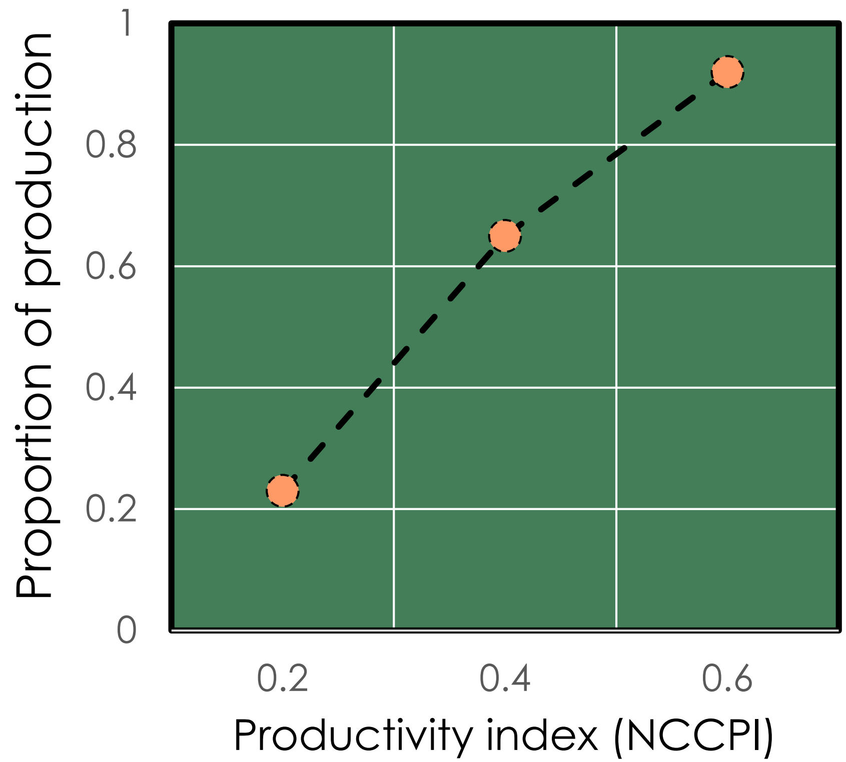


ORNL-INL partnership demonstrated that supply can be produced on less-productive croplands at a National scale

23%, 65%, and 92%, of the 205 million tons of switchgrass produced on 37 million acres can come from marginal lands with NCCPI values less than 0.2, 0.4, and 0.6, respectively. Opportunities for producing feedstocks on marginal lands may be focused in the South Central and Southeast US, particularly for pastureland.



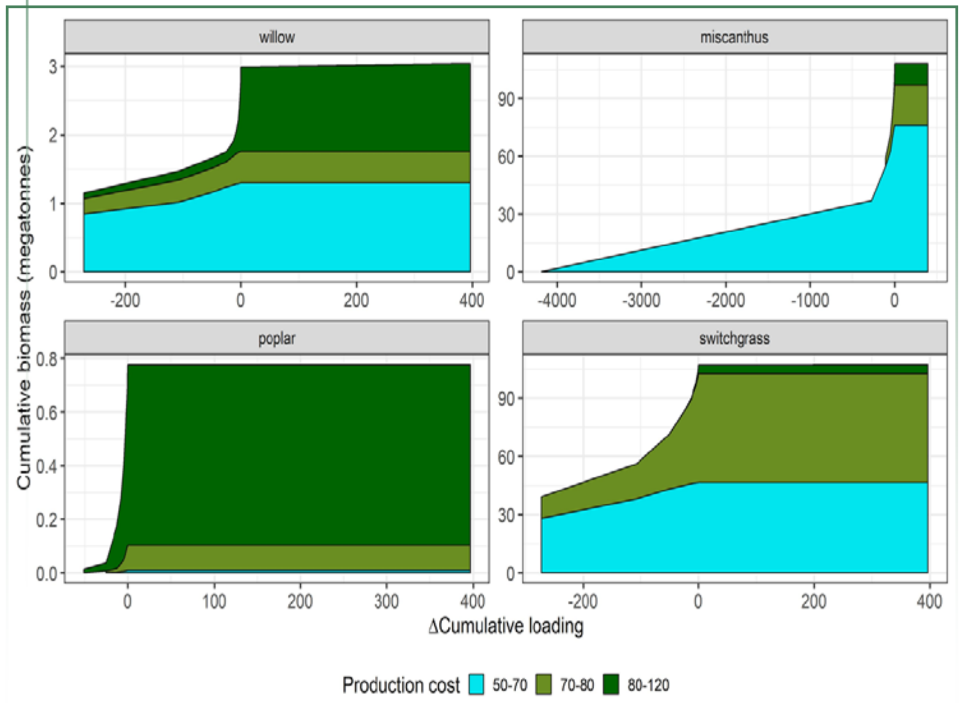
Intersection of seven crop types and ten NCCPI values with randomized color scheme in a subarea of Kansas



ORNL demonstrated that non-fuel ecosystem services (ES) have significant value (can match that of fuel feedstock)

Sustainable supply

- Supply curves can represent other values, above and beyond feedstock price.
- Here, supply with acceptable nutrient loadings are graphed for different levels of production cost (color).
- We conducted this integrated spatial analysis using BioVEST

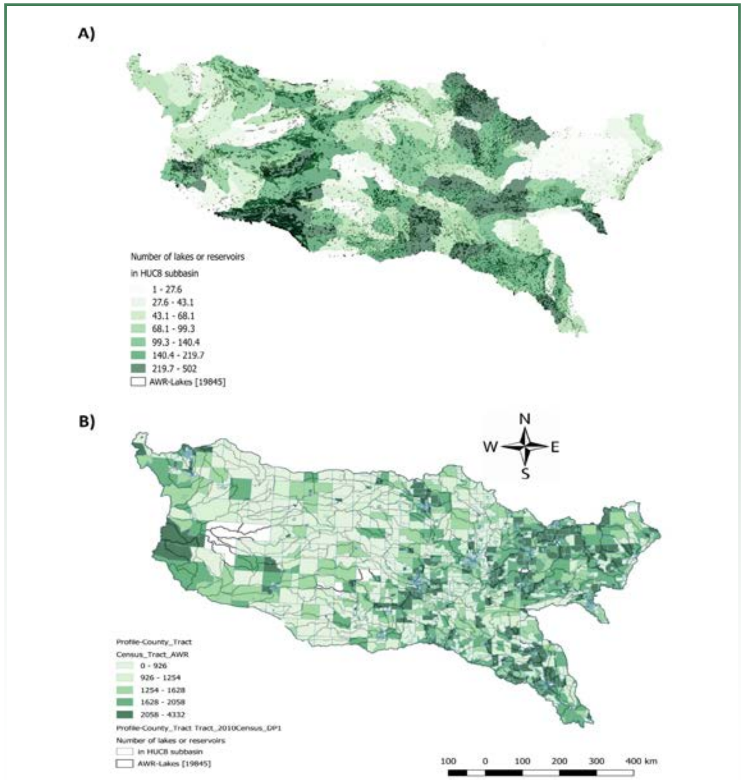


Implications for research

- Goal: Support decisions based on 'total value'
- Understand how economic and social incentives 'nudge' land managers to produce cellulosic feedstock (e.g., certification, payments for ecosystem services, environmental markets)
- Identify indicators to quantify ecosystem services, (these integrate socioeconomic and environmental dimensions of value).
- Develop sensors and AI tools to measure indicators of ecosystem services
- Tailor spatial biophysical models to quantify the effects of biomass management decisions on ecosystem services and their values
- Tailor valuation models for bioenergy, including appropriate baselines and thresholds (e.g., BioVEST)

Spatial management decisions require mapping of ecosystem services and values: I. water quality

Where does growing perennial crops measurably improve water quality for swimmers & waders?



Utility was greatest where:

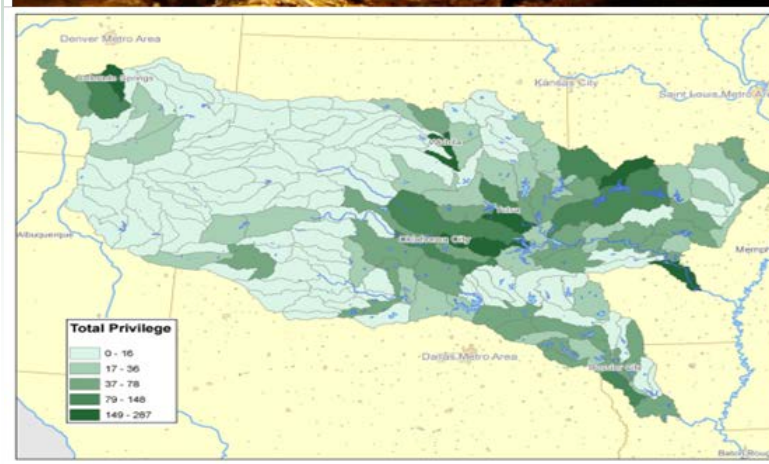
- beneficiaries and potential ecosystem services (clean water) co-occurred
- initial water quality was visibly poor (below threshold Secchi depth)
- improvement in water quality was significant

Spatial management decisions require mapping of ecosystem services and values: II. biodiversity

When water quality improves, recreational fishers benefit

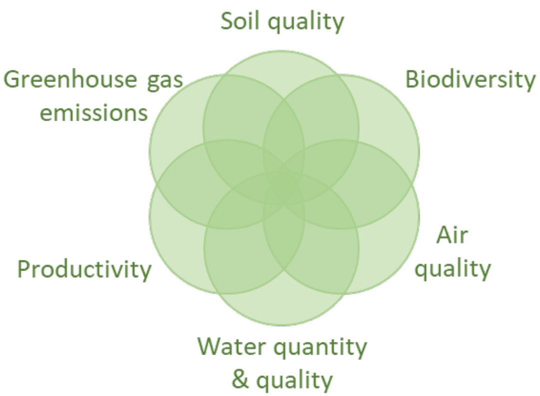
- Modeled geographic distribution of activity days based on:
  - Biophysical final goods *(lakes, rivers with high quality water/habitat)*
  - Ecological final goods *(total or game fish richness – correlated)*
  - Capital infrastructure or access *(roads, human population)*
- Valued activity days based on license sales for different beneficiaries
- Similar analysis of aquatic invertebrates and functional groups is contemplated.

Spatial valuation can inform crop-management decisions

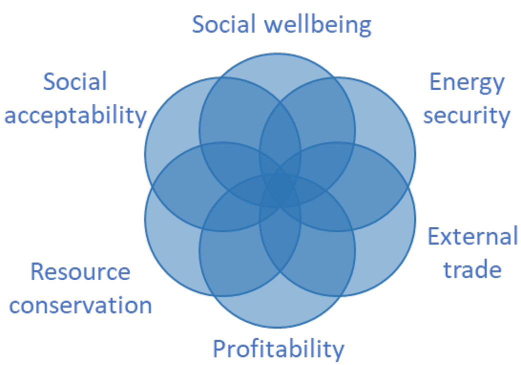


Indicators can help quantify ecosystem services

Environmental Indicators



Socioeconomic Indicators



Indicator Category	Ecosystem Services			
	Provisioning	Regulating	Supporting	Cultural
Soil quality	✓	✓		
Water quality & quantity	✓	✓		✓
Greenhouse gas emissions		✓		
Biodiversity	✓	✓	✓	✓
Productivity	✓		✓	
Air quality		✓		
Social wellbeing	✓			
Energy security	✓			
External trade	✓			
Profitability	✓			
Resource conservation	✓			
Social acceptability				

For more information:

- McBride et al. (2011) Indicators to support environmental sustainability of bioenergy systems. *Ecological Indicators* 11(5) 1277-1289.
- Dale et al. (2013) Indicators for assessing socioeconomic sustainability of bioenergy systems: a short list of practical measures. *Ecological Indicators* 26:87–102.
- Dale et al. (2018) Bridging biofuel sustainability indicators and ecosystem services through stakeholder engagement. *Biomass and Bioenergy* 114:143-156.

Sensors improve measurement of ES indicators

Measurement of environmental indicators for bioenergy can be labor intensive, time consuming, and costly.

Temporal & spatial resolution of manual measurements is often low.

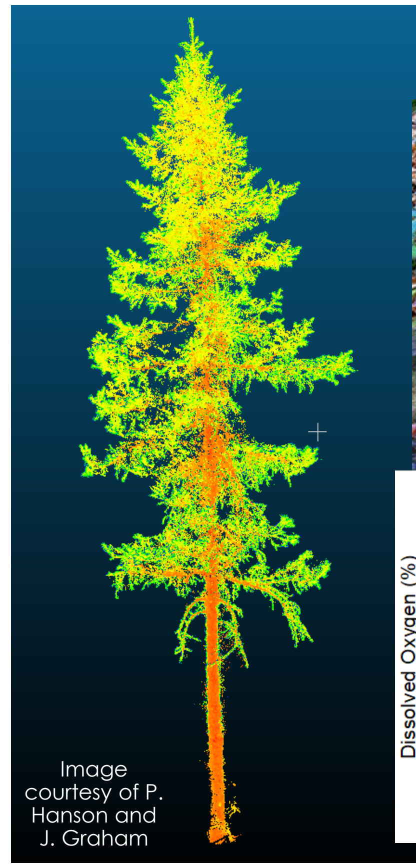
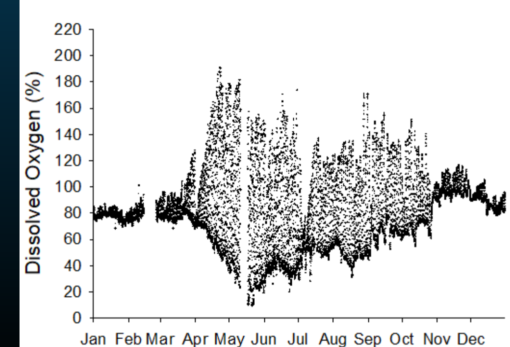


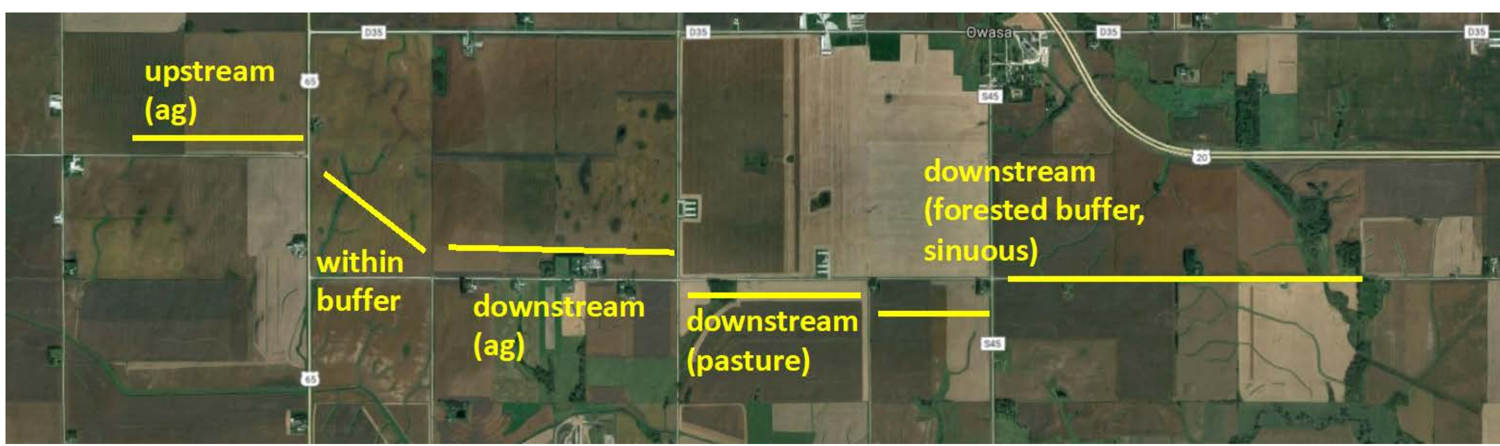
Image courtesy of P. Hanson and J. Graham



Sensors can alleviate issues with low temporal (and sometimes spatial) resolution.

Coupling sensors to remote platforms

- Rapid development in the use of drone-sensor systems.
- Great potential to develop and apply these technologies to evaluate environmental sustainability of bioenergy.
- ORNL BETO project is using a drone-water quality sensor system to map water quality within a bioenergy landscape.



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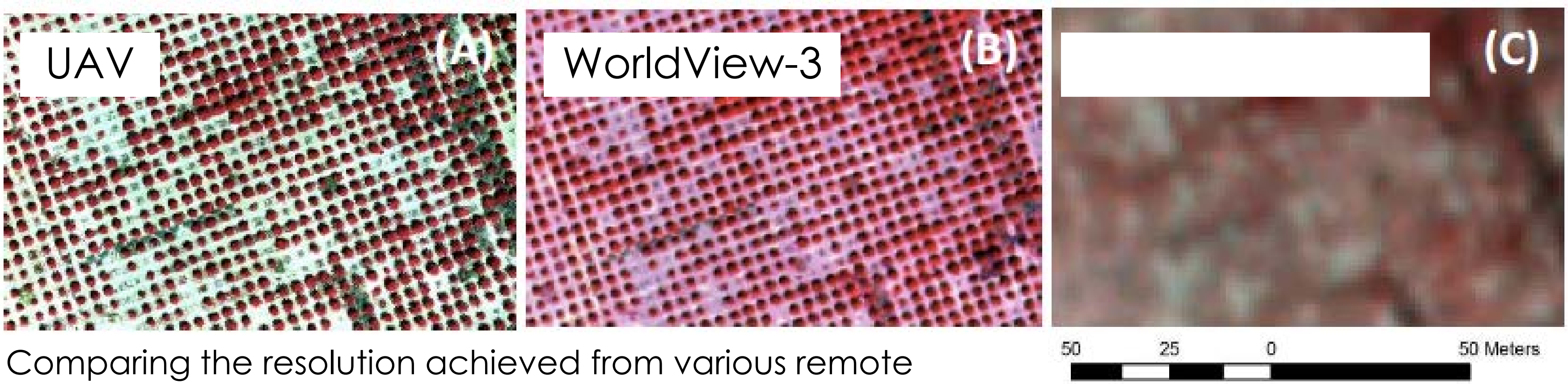
Sensors and artificial intelligence for measuring environmental sustainability indicators

- Drones have the potential to bridge the gap between on-the-ground measurements and remote sensing via satellite imagery.



Comparing the resolution achieved from various remote sensing platforms (from Manfreda et al. 2018).

- ORNL has expertise in coupling remote sensing with AI to for rapid identification of environmental conditions (e.g., vegetation classification, wildfire mapping) (Langford et al. 2019).

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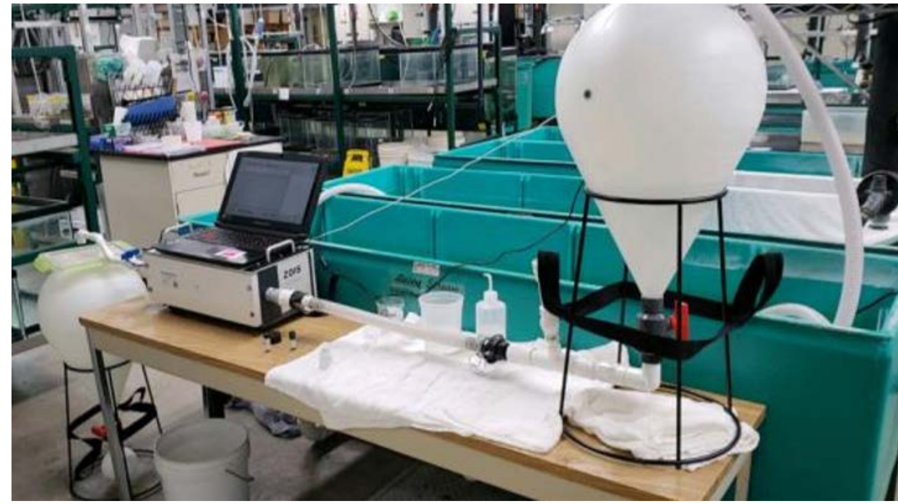
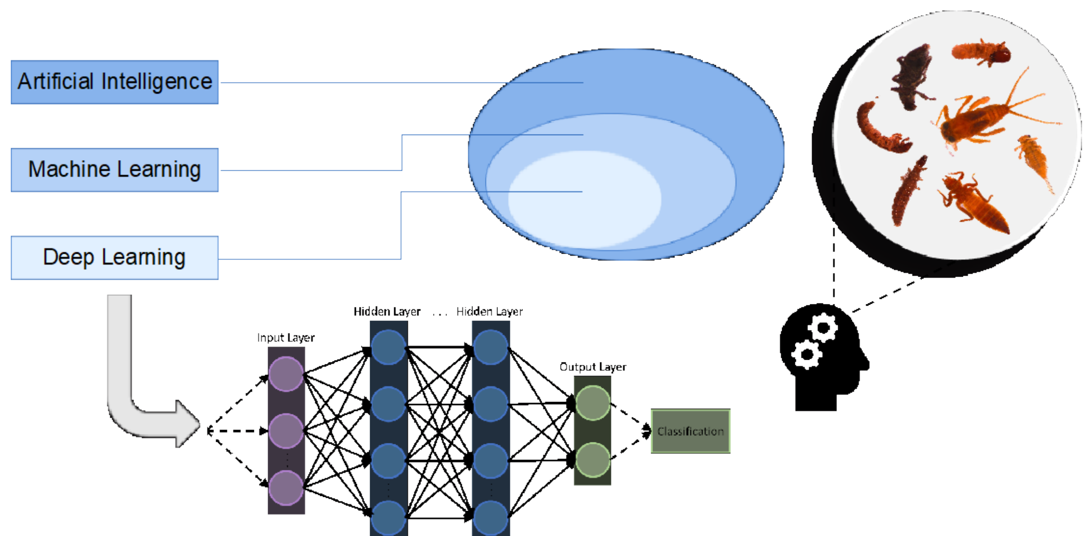
Sensors and artificial intelligence for measuring environmental sustainability indicators

- Stream invertebrates are often used to assess stream condition and health, but classification is costly and time consuming.
- ORNL is working to improve an invertebrate imaging system and use AI to automate identification.





Images courtesy of M. Landon

National-scale assessment is a grand challenge

…but we're up to it!

Labs are poised to make progress

- Improved supply allocations across the US can start to consider valued 'e-coproducts'
- Improved technologies for measuring ES indicators facilitate research at larger scales
- Gridded water models with better nutrient dynamics are being developed
- National-scale datasets suitable for HP computation can support spatial decisions informed by the ES landscapes (e.g., BioSTAR)
- GPU-based computation is well-suited for spatial modeling and optimization
- These advances are adding up

Big data, spatial models, sensors, & computing resources are converging

SUMMIT - the biggest supercomputer in the world!

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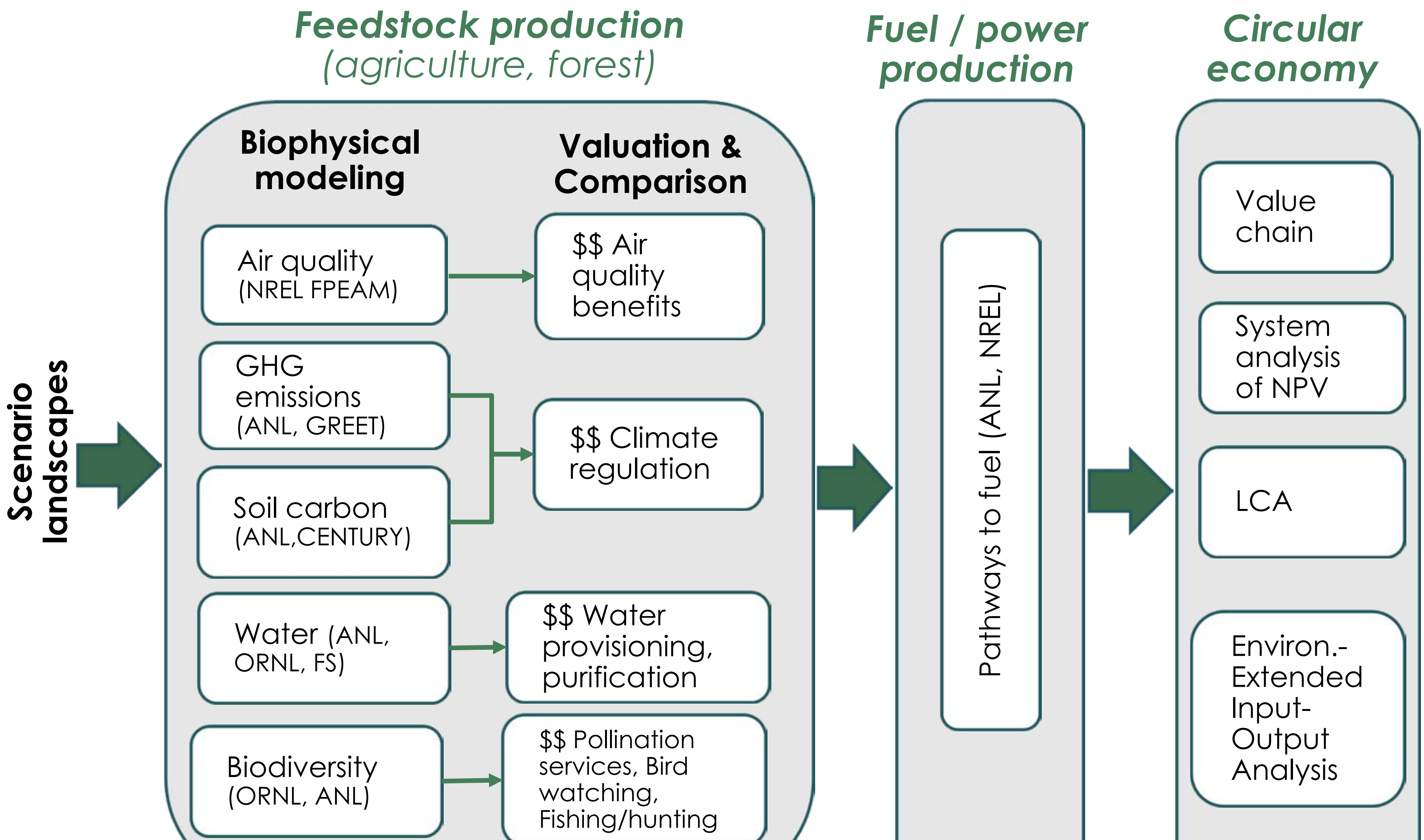
Labs have complementary expertise across ecosystem services and fuel pathways



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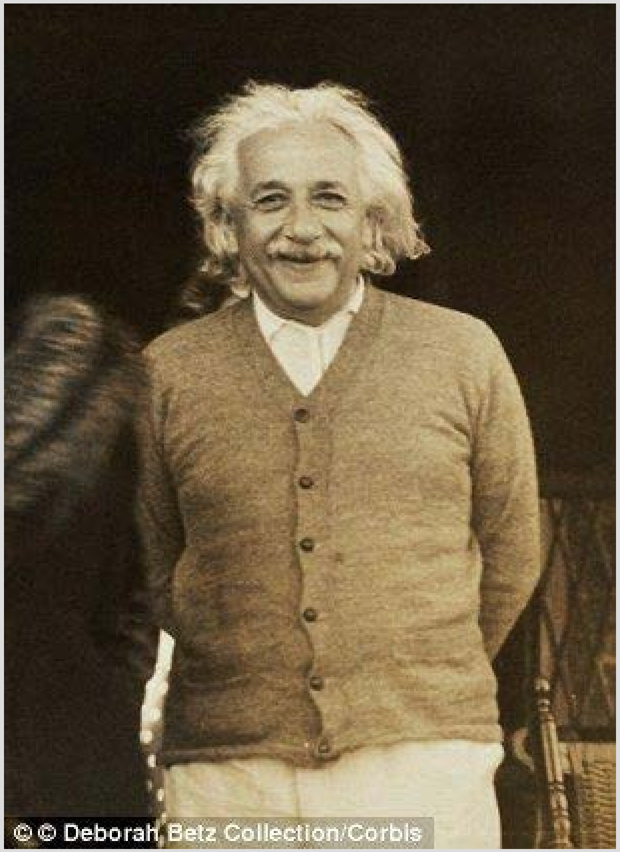

$E = mc^2$ + Profit for biofuels

+ Other ecosystem services