Bringing Sustainability into the Assessment of our Nation's Bioenergy Future

CBES

Dec 17th, 2014

Managed by UT-Battelle
for the Department of Energy

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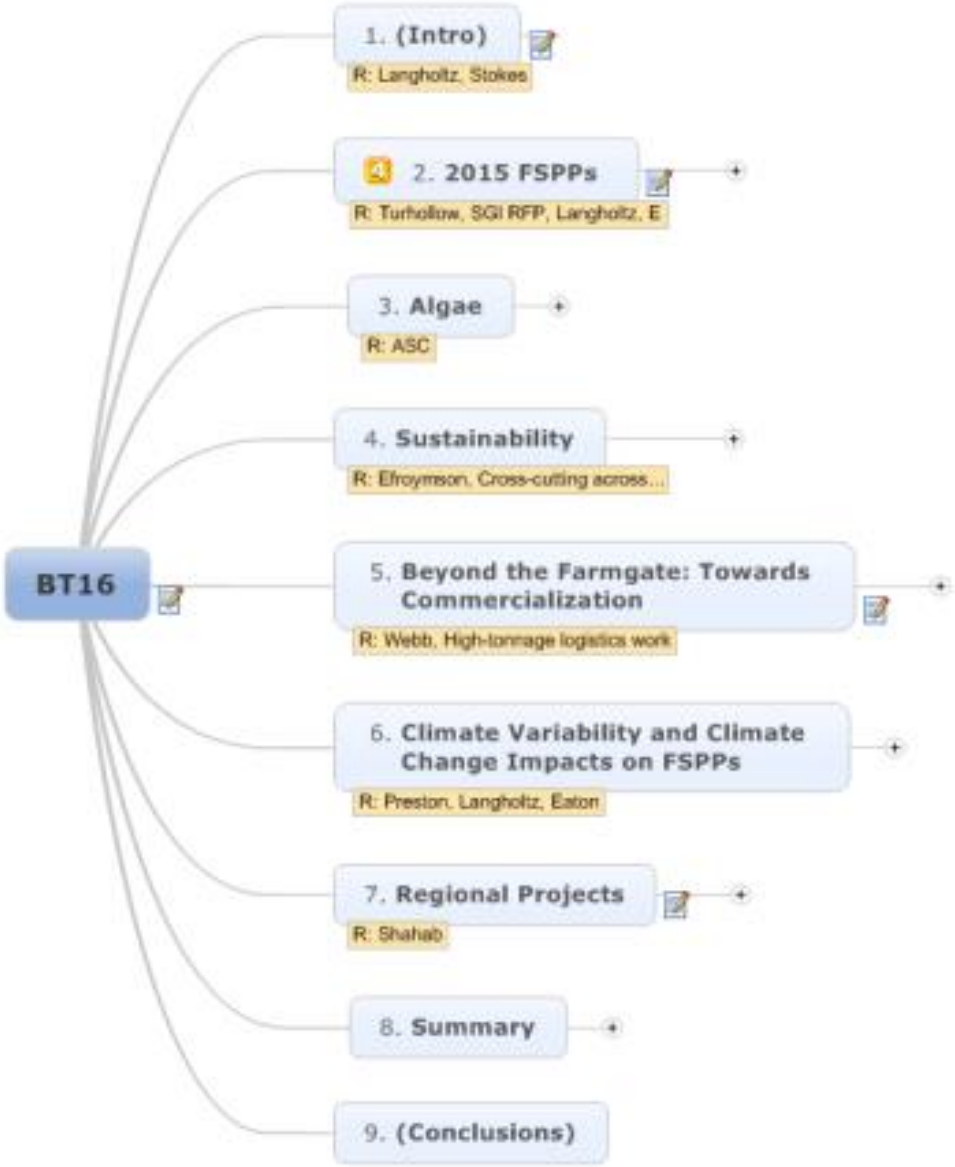
Outline

- BT16, background, themes, schedule, collaborations.- Matt
  - Feedstock production
  - Economic scenarios – Laurence
- Sustainability Chapter outline- Rebecca
  - Water quality and Biodiversity – Yetta
  - Air quality, SOC, GHG – Matt and Craig
  - Downscaling – Craig or Matt
- Links to other chapters – Commercialization, Climate, MSW
- Discussion

Outline


BT16
1. (Intro)
R: Langholtz, Stokes
2. 2015 FSPPs
R: Turhollow, SGI RFP, Langholtz, E
3. Algae
R: ASC
4. Sustainability
R: Efroymson, Cross-cutting across...
5. Beyond the Farmgate: Towards Commercialization
R: Webb, High-tonnage logistics work
6. Climate Variability and Climate Change Impacts on FSPPs
R: Preston, Langholtz, Eaton
7. Regional Projects
R: Shahab
8. Summary
9. (Conclusions)

BT16

- **Draft: September 2015**
- **Additions to BT2: delivered supplies; algae; climate change and variability; *sustainability*.**
- **Sustainability background: focus shifted from quantifying sustainable supplies to quantifying environmental effects; shifted from BAU comparison to present vs projected.**
- **Interagency stakes: EPA, DOE, USDA FS.**
- **CRP: Pending BETO decision.**
- **Focus on delivered or farmgate: Pending decision.**

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Main scenarios

- Comparable to BT2 scenarios, $30-$100 in $5 increments (county-level):
  - USDA Baseline, no energy crops/residues (10-year)
  - Basecase (BC1): 1% per year yield improvements, 2014 USDA Baseline projection,
  - High-yield: energy crop yield improvements, high traditional crops and high no-till
    - HH2: 2% per year yield improvements
    - HH3: 3% per year yield improvements
    - HH4:, 4% per year yield improvements

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Supporting scenarios (national-level):

- Low Yield (LC1), 0.5% per year growth improvements
- High Case (HC1,HC2, HC4), 2%, 3% and 4% yield improvements, respectively, traditional crop as forecasted
- Feedstock-specific scenarios: BC2. All dedicated feedstocks run independently in base-case scenario. I.e., gross potential of each feedstock without competing feedstocks.
- Tillage scenarios: BC3, tillage scenarios 0-3
- Target (aka demand-run) scenarios:
  - DC1, 250 million dry tons in 2022, 2025, 2030, 2035, 2040
  - DC2, 325 million dry tons in 2022, 2025, 2030, 2035, 2040
  - DC3, 500 million dry tons in 2025, 2030, 2035, 2040
  - DC4, 750 million dry tons in 2030, 2035, 2040

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Goals and Objectives of Sustainability Chapter

- **Overarching goal: Quantify environmental effects of biomass production scenarios (previously: sustainable biomass supply in the BT16).**
- **Objectives**
  - **Assess effects of biomass projections on environmental indicators**
  - **Minimize environmental effects and maximize productivity through smart allocation of crops, employment of good management practices, and excluding or adding lands in simulations**
  - **Reveal tradeoffs among environmental effects and productivity**

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Scope of Analysis

- Agriculture and forestry
- 2 biomass demand scenarios (subset of those considered in other chapters)
  - Base case, BC1, 1% per year yield improvements, 2014 USDA baseline projection
  - High yield: energy crop yield improvements, high traditional crops and high no-till
    - HH2: 2% per year yield improvements
- Maps
  - Soil types
  - Current land use and land management (not clear if CRP lands will be in POLYSYS)
  - Assumptions about land use and management for 2040
  - Included/excluded areas
- Feedstocks: stover and straws, switchgrass, sorghum, Miscanthus, energy cane, willow, pine, poplar, forest thinnings, forest residues
- Crop production assumptions
- Forest biomass harvesting assumptions
- End of analysis at farmgate or reactor throat or gate

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Scale of Analysis

- **Extent**
  - Most analyses are national in extent
  - Water quality includes Missouri River Basin and Arkansas-White-Red Basin
- **Resolution**
  - County-level for most analyses
  - Sub-county level for organic C, biodiversity (using maps of soil type, land use)
  - HUC8 for water quality
- **Reporting**
  - County-level for most analyses
  - Possibly regional for GHG emissions

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Environmental Sustainability Indicators

	Indicator
Soil quality	1. Total organic carbon (TOC)
	2. Total nitrogen (N)
	3. Extractable phosphorus (P)
	4. Bulk density
Water quality and quantity	5. Nitrate loadings to streams (and export)
	6. Total phosphorus (P) loadings to streams
	7. Suspended sediment loadings to streams
	8. Herbicide concentration in streams (and export)
	9. Storm flow
	10. Minimum base flow
	11. Consumptive water use (incorporates base flow)
	Addition: Water yield

	Indicator
Greenhouse gases	12. CO_2 equivalent emissions (CO_2 and N_2O)
Biodiversity	13. Presence of taxa of special concern
	14. Habitat area of taxa of special concern
Air quality	15. Tropospheric ozone
	16. Carbon monoxide
	17. Total particulate matter less than 2.5 µm diameter ($PM_{2.5}$)
	18. Total particulate matter less than 10 µm diameter (PM_{10})
	Possible additions: VOCs, SO_x, NO_x, NH_3
Productivity	19. Aboveground net primary productivity or Yield

McBride et al. (2011) *Ecological Indicators* 11:1277-1289

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Importance of Scale of Analysis

- **The majority of bioenergy feedstocks for BT16 will be estimated at the county level**
- **Can we design sub-county allocation of crops to improve environmental sustainability?**
  - **Soil organic carbon – soil type, current land use**
  - **Erosion – slope, proximity to receiving waters**
  - **Biodiversity – location of species of concern and critical habitat**
- **Supply that decreases in response to sustainability targets or best management practices may be mitigated with spatial reallocation**

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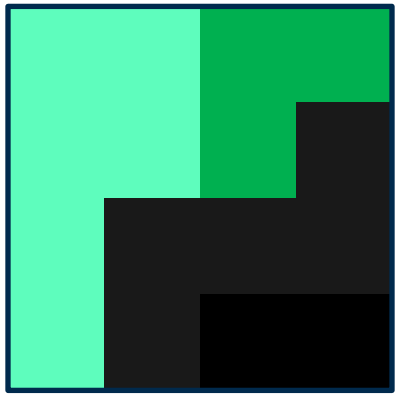
Scale of Analysis

POLYSYS Projections – County A

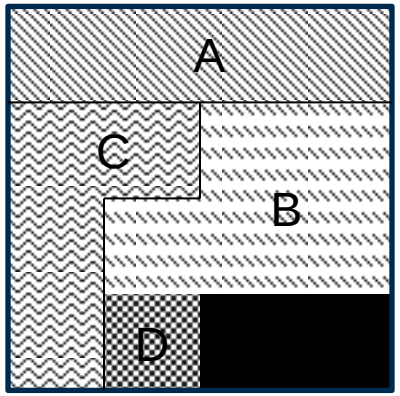
Crop	Production
Corn	120
Switchgrass	50
Soybeans	15

Intersecting Land Use with Soils

Geospatial Land Use Data



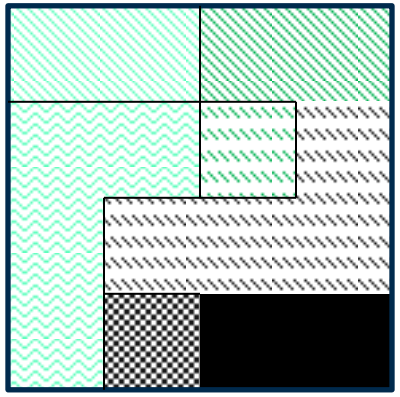
Geospatial Soils Data



Land Use	Area
Corn	6
Soybeans	3
Idle	5
Developed	2

Map Unit	Area
A	4
B	5
C	4
D	1

Intersecting Land Use with Soils



Crop	Map Unit	Production
Corn	A	40
	C	80
Switchgrass	B	40
	D	10
Soybeans	A	10
	B	5
Developed		0

Sustainability indicators or indices based on crop and map unit attributes

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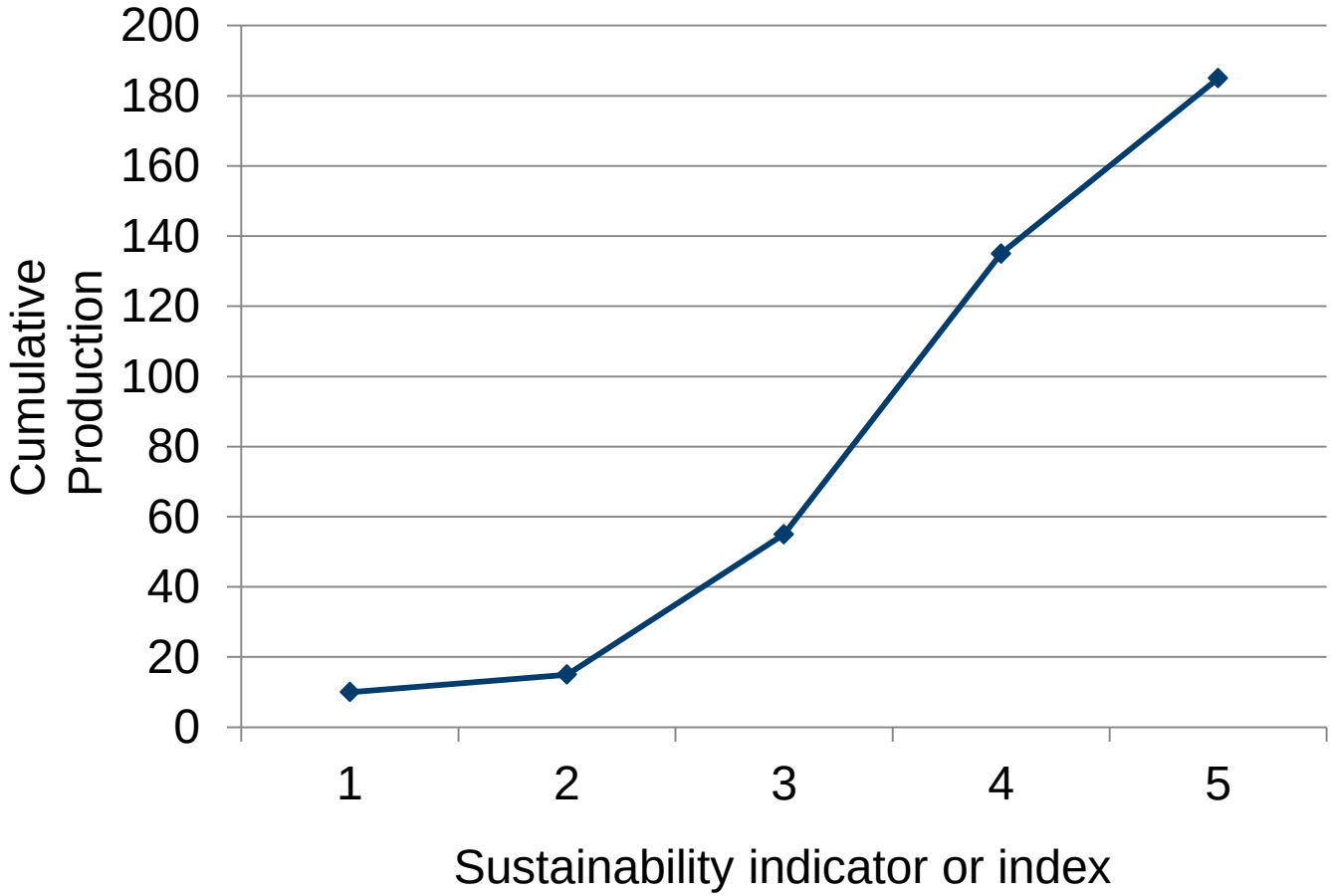
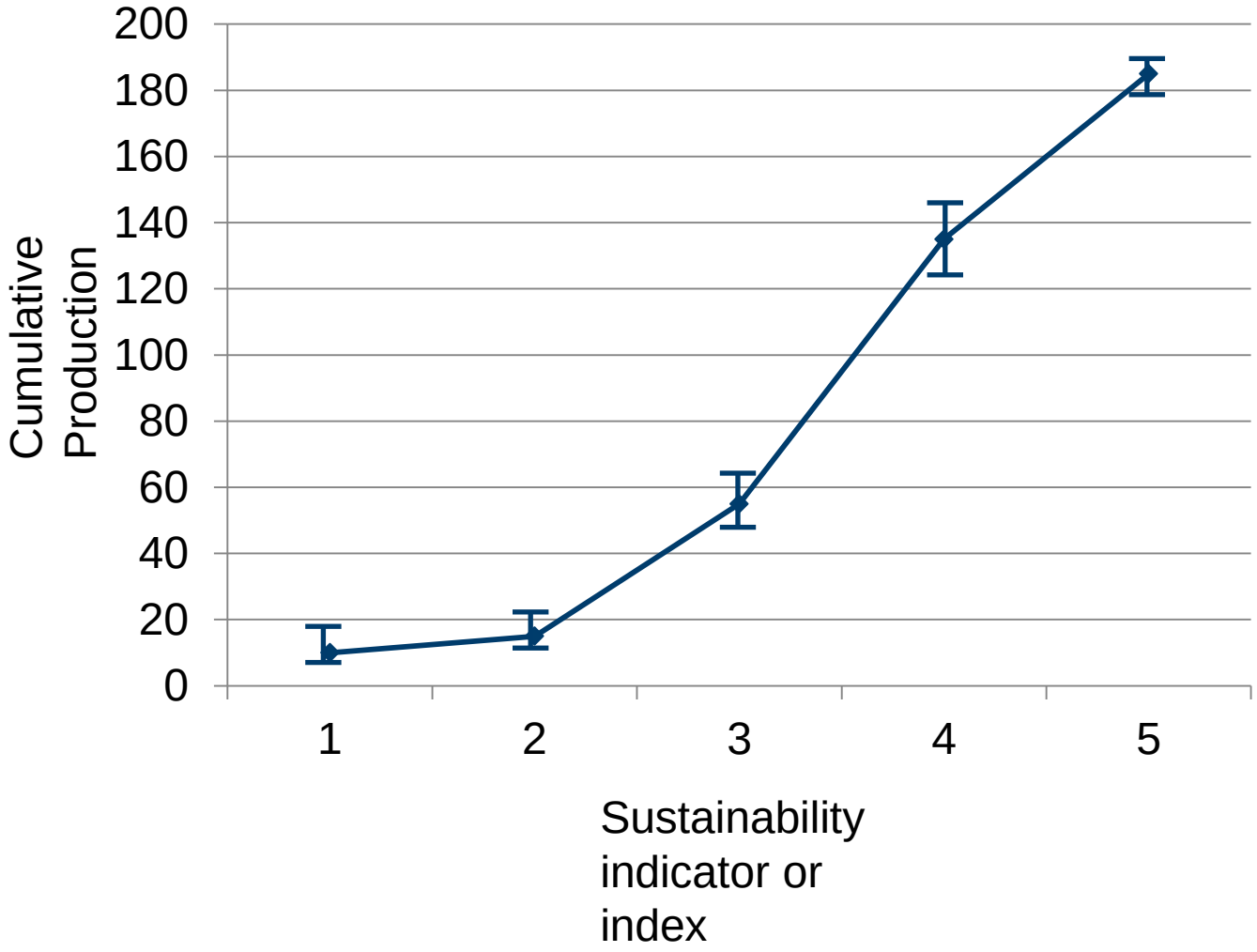
Allocating Production Projections

Crop	Map Unit	Production	Sustain. Index
Corn	A	40	5
	C	80	4
Switchgrass	B	40	3
	D	10	1
Soybeans	A	10	5
	B	5	2
Developed		0	NA

Quantifying Effects



Quantifying Uncertainty of Effects



Soil quality

- Soil quality (Dunn-ANL/Brandt-ORNL)
- Indicator: soil organic carbon (SOC)
- Feedstocks: corn (harvested yield), switchgrass not harvested
- Approach
  - Century's soil organic C dynamics sub-model (SCSOC)
    - Model inputs
      - Soil data from STATSGO
      - Climate: area-weighted monthly normal temperature and precipitation
      - Land-use history at county level (Century does better with system at equilibrium, not year by year; may have to break land transitions in bins—1 transition or 2 over 30-yr period; not clear yet how land use history will be estimated in future)
    - Model outputs: time series SOC at county level
  - Working with Forest Service to identify relevant soil C models
- Results at county scale or possibly below county
  - Soil C under present day scenarios
  - Soil C under 2040 scenarios
  - Allocation of biomass to sub-county to mitigate any soil C losses
- Discussion

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Greenhouse gas emissions

- **Dunn/ANL**
- **Indicator: CO_2 equivalent emissions (Dunn-ANL)**
- **Feedstock: corn, switchgrass, loblolly pine (need to confirm list)**
- **Approach**
  - **GREET**
    - Model inputs
      - Soil data from STATSGO: soil texture is dominant for county-level analyses as determined by analysis of HWSD data
      - Climate: area-weighted monthly normal temperature and precipitation
      - Land-use history at county level
      - Crop yields (Jennifer is comparing her crop production budgets to those in POLYSYS; corn is operationally harvestable yields at maturity, switchgrass not harvested)
    - Linked model: Century
    - Working with Forest Service to identify relevant soil C models
    - Model output
      - Energy consumed based on yield
- **Results**
  - **County-level or regional emissions under present day scenarios**
  - **County-level or regional emissions under 2040 scenarios**
  - **Any mitigations of emissions**
- **Discussion**

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Air quality

- Zhang and Inman/NREL
- Indicators: $PM_{2.5}$, PM_{10}, carbon monoxide (possible additions: volatile organic compounds (VOCs), sulfur oxides (SO_x), nitrogen oxides (NO_x))
- Approach
  - Feedstock Production Emissions to Air Model (F-PEAM)
  - Model inputs: yields, acreage, production by county; crop budget (fertilizer inputs, machinery usage); USDA data (irrigation, types of fertilizers); emissions factors (production and harvest)
  - Linked models: NonRoad model + emission factors (CO, NO_x, SO_x, VOC, PM, NH_3); fertilizer emissions (NOx, NH3); pesticide emissions (VOCs); fugitive dust (PM)
  - Forestry equipment assumptions from Dana Mitchell
  - Model outputs: Inventory of air emissions for corn, corn stover, wheat straw, forest thinnings
- Results
  - County-level mass emissions under present day scenarios and comparison to National Emissions Inventory
  - County-level mass emissions under 2040 scenarios
  - Potential impacts in nonattainment areas
  - Any mitigations of emissions
- Discussion
- Appendices (e.g., data on operations involved in the production and harvest of a given feedstock, and the type of machinery used—provided by Anthony Turhollow and used to build F-PEAM model)

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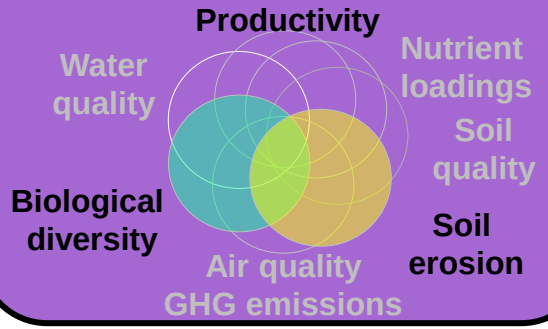
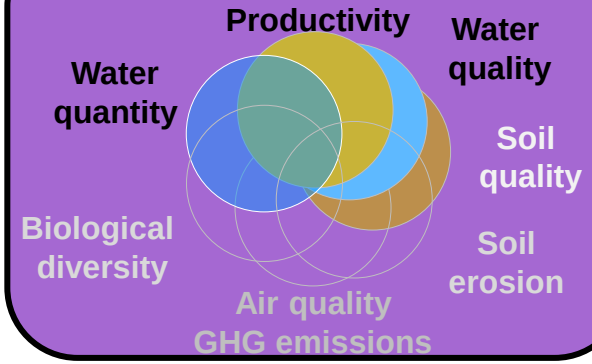
ORNL Sustainability Modeling Support for Billion Ton 2016

1. Economic allocation (POLYSYS)

2. Sub-county allocation



3. Conservation practices



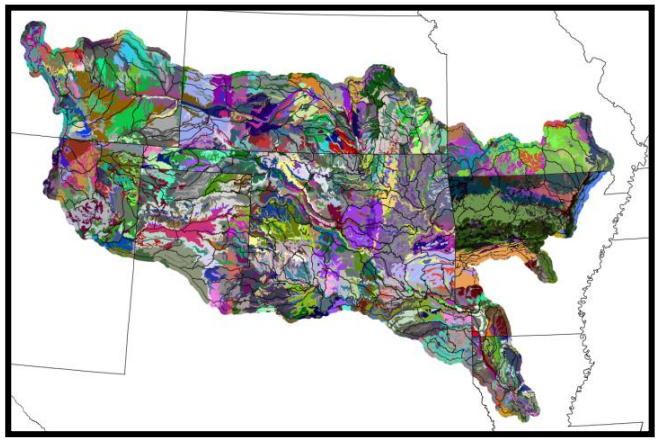
Task	Spatial extent	Spatial resolution	Type of problem	Sustain-ability indicators
Economic allocation (POLYSYS)	National	County	Crop - spatial allocation	Production
Sub-county allocation (Downscaling)	National	Land unit (CLU) within county	Crop – spatial allocation	Production Erosion **Biodiversity**
Conservation practices	Miss. river basins	HRUs in HUC8 watersheds	Minimize trade-offs among indicators via conservation practices	**Production** **Nutrients** **Sediment** **Water yield**

- Quantify loss of productivity due to environmental sustainability constraints (trade-offs)
- Minimize loss of productivity through smart spatial allocation of crops (2) and conservation practices (3).

Water quality

Goal: Demonstrate ability to reduce nutrient and sediment loadings with minimal loss of feedstock supply and water yield

- **Quantify sustainability indicators using SWAT**
- **Two large river basins within the Mississippi river basin (Missouri & Arkansas-White-Red) with contrasting cellulosic feedstock potential**
- **Approach: Generate database, simulated effects of conservation practices for HRUs:**
  - **Stover removal**
  - **Tillage practices**
  - **Fertilizer application**
  - **Cover crop**
- **Quantify trade-offs among water indicators and feedstock supply**



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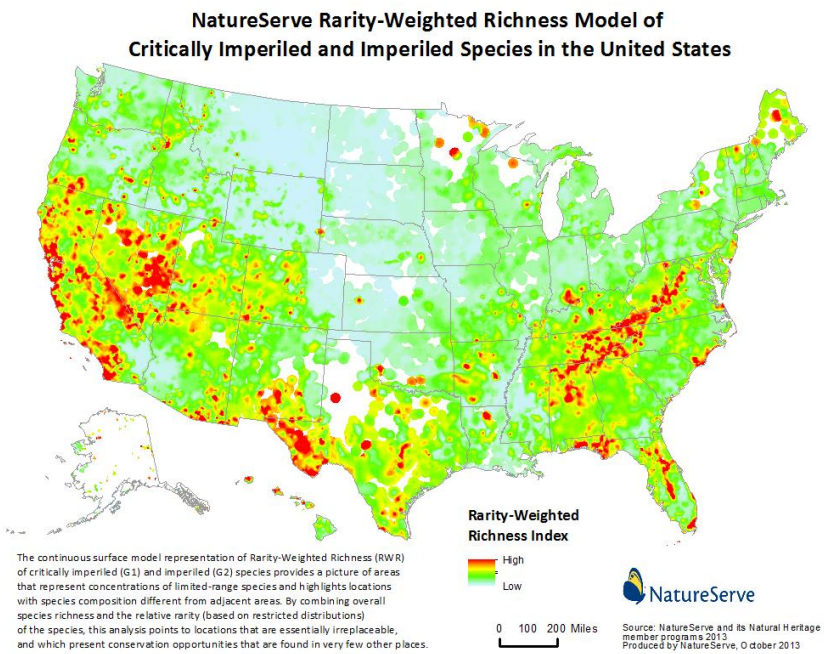
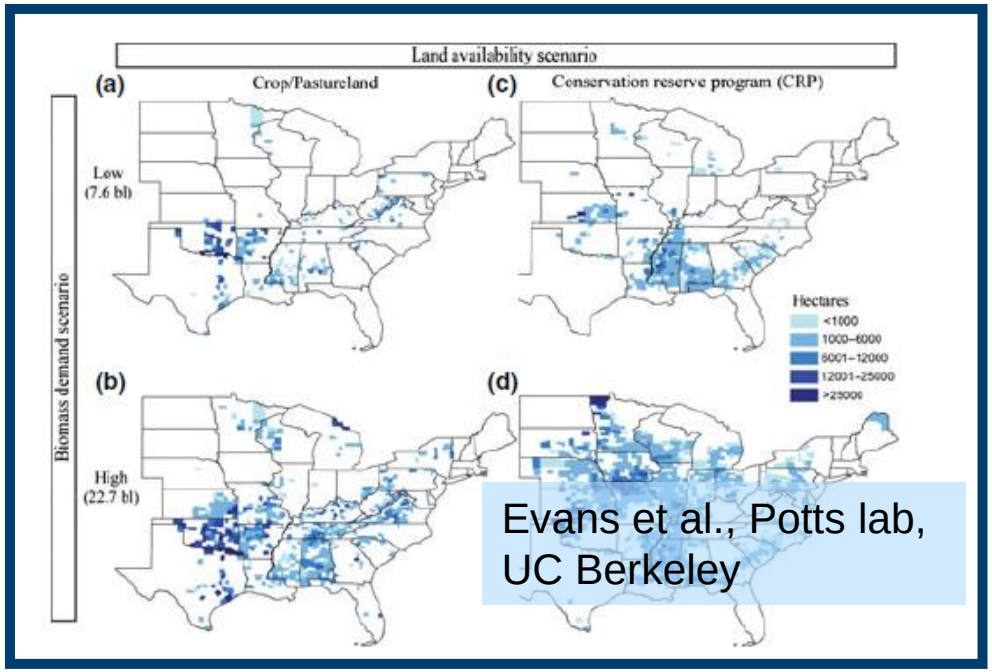
Biodiversity





- Identify land covers replaced / more-intensively harvested
- For each spatial planning unit, count species of concern (SOC) that use land cover in baseline map.
- Allocate bioenergy crops within county:
  - Minimize impact on SOC habitat
  - Minimize maximum contraction in individual species' ranges

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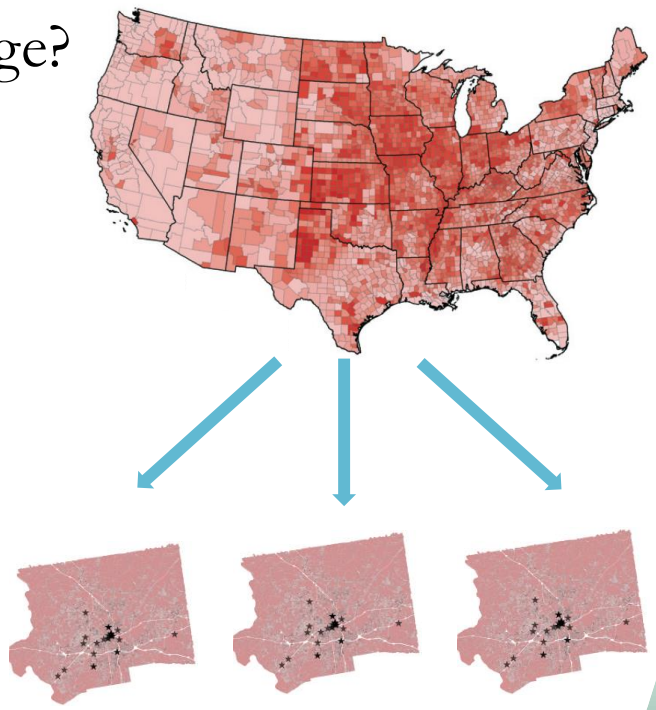
Given county-level acreage of biofuel crops across the United States, allocate production to individual farms (parcels) within a county such that we (1) minimize habitat loss for species of concern on parcels selected for biofuel production within county *k*, and
(2) Minimize maximum decrease in species range?



$$S_k = \sum_i (1 - b_i) \sum_j \lambda_{ij} s_{ij}, \quad P_k = \frac{\sum_i b_i}{B}$$

$s_{ij} \equiv \textit{incidence of species } j \textit{ in parcel } i$

$b_i \equiv \textit{bioenergy crop in parcel } i$

$\lambda_{ij} \equiv \textit{ratio habitat quality } b_i : \textit{original for species } j$

$$S_{\Delta range} = \max_j \sum_i b_i s_{ij}$$

$$\textit{Maximize: } Y = \sum_k \left(S_k + P_k \right) + S_{range}$$

$$s.t. \sum_i b_i \le B_k \vee k$$

subject to biomass production constraint B_k from POLYSYS within each county *k*.

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Related aspects in other chapters

- ***Towards commercialization*: Potential of precision agriculture to improve water quality and soil quality indicators while producing more agricultural residues.**
- ***Municipal solid waste*. Represents sustainable handling of waste**
- ***Climate variability and climate change*: (Preston) Effect of climate change on yield: link of climate change to sustainability, e.g., disturbance regime, (desertification, erosion and/or changes) in locations suitable for particular crops.**

Summary

- **Broad effort across labs and agencies**
- **Expanding on BT2**

- **Dynamic visualization**
- **Depot analysis**
- **http://ornl.adobeconnect.com/langholtz/**

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