MORE THAN BIOMASS: PURPOSEFULLY GROWN FOR ECOSYSTEM SERVICES

Continuing CAAFI webinar series
January 16, 2020

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**ABOUT ARGONNE’S ENVIRONMENTAL SCIENCE DIVISION**

**COMPUTING, ENVIRONMENT AND LIFE SCIENCES DIRECTORATE**

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**EARTH SYSTEMS**

We advocate Earth systems science and climate science, and we improve our understanding of climate risk and resiliency and better understand the effects of climate risks on natural and managed systems, energy availability, human livelihood, and biodiversity.

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**ENERGY AND ENVIRONMENTAL IMPACTS**

We understand and predict the interactions between energy systems and other human activities and ecosystems. We also provide science-based solutions to mitigate unwanted impacts.

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**RESPONSIBLE INNOVATION**

We drive new discoveries and use of natural resources toward responsible outcomes. We embed our scientific knowledge of environmental systems into the design of new materials and processes to preempt unwanted impacts on the environment and to improve our natural capital.
ASKING DIFFERENT KINDS OF QUESTIONS

Responsible innovation: “taking care of the future through collective stewardship of science and innovation in the present”*

Don’t ask what the impacts will be, but design from the start for the enhancement of our natural capital and human wellbeing.

AGRICULTURE’S SUSTAINABILITY CHALLENGE

- Providing food, feed, fiber, and energy for a growing world population
- Conserving soil, water and biodiversity, and decreasing greenhouse gases
- Providing resilience to a changing climate
- The rural-urban tension, urbanization and the loss of soil and land

Source: U.S. Global Change Research Program
http://e360.yale.edu/feature/report_gives_sobering_view_of_warmings_impact_on_us/2166/

E. Detaille, Charge of the 4th Hussars at the battle of Friedland, 14 June 1807 -
http://upload.wikimedia.org/wikipedia/commons/thumb/0/0b/Detaille_4th_French_hussar_at_Friedland.jpg

Seeding Our Future by R. L. Crouse.
SYSTEMS LEVEL PROBLEMS DEMAND MULTIPLE OUTCOMES
ECOSYSTEM SERVICES

THE BENEFITS RECEIVED BY PEOPLE FROM ECOSYSTEMS

CONSTITUENTS OF WELL-BEING

Security
- Personal safety
- Secure resource access
- Security from disasters

Basic material for good life
- Adequate livelihoods
- Sufficient nutritious food
- Shelter
- Access to goods

Health
- Strength
- Feeling well
- Access to clean air and water

Good social relations
- Social cohesion
- Mutual respect
- Ability to help others

Freedom of choice and action

Oppportunity to be able to achieve what an individual values doing and being

Source: Millennium Ecosystem Assessment

(Millennium Ecosystem Assessment, 2005)
WHAT HAS CHANGED IN AGRICULTURE IN THE LAST DECADES? .....DATA AND GEOSPATIAL SCIENCE AND TECHNOLOGY

Crop Yield
(Ground Truth)

VERIS® soil mapping and image provided by Farm Map Solutions, LLC.

Hamada et al. (2016)
BIOENERGY LANDSCAPE DESIGN VS. BUSINESS AS USUAL

- **BAU** focused on providing:
  - One *provisioning* service: yields, profit.
  - *Regulating* services not factored in the economics, called externalities
  - Conceptual focus is how to mitigate the impacts retroactively
  - Non diversified business models concentrates risk

- **Landscape Design** focused on providing:
  - *Provisioning services* – optimize yields of food, feed, fiber, bioenergy, bioproducts
  - *Regulating services*: water quality, habitat, C sequestration, GHG reduction, flood control, etc. are part of the design
  - Economic models accounts for both
  - Conceptual model focuses beyond mitigating impacts, on “how to design”
  - Diversified business model distributes risk
HOW CAN WE LEVERAGE ECOSYSTEM SERVICES IN BIOENERGY?

1. Design of production landscapes
   • Identification of Ecosystem Services goals
2. Quantification
3. Valuation
4. (policy, regulatory, or voluntary action)
5. Payment framework

Decision-making frameworks
• Cost –benefit analysis
• Environmental impact assessment
• Programmatic environmental impact assessment
• Lifecycle analysis
• Risk assessment
• Techno-economic analysis
• Multi-criteria analysis
TOWARDS A TOTAL ECONOMIC VALUATION OF LANDSCAPE MANAGEMENT
ECONOMIC LOSSES AND ENVIRONMENTAL CONCERNS OFTEN GO TOGETHER

Net profit ($/ac)

- ContourStrip
- Field boundary

AVG ($/acre) = 153
STD ($/acre) = 230

Nitrate 6 ft bgs
SOIL WATER NITRATE CONCENTRATION (AT 5 FT BGS) HAS SEASONAL RECURRENCES

Yield map: areas of low (RED) and high (GREEN) yields (bu/ac). Low yield areas coincide with high nitrate losses.
SOIL QUALITY AND GHG EMISSIONS

Significantly lower bulk density under willow than soybean.

Subsoil samples collected from the bottom 6 inches of a 4-foot core. Zumpf et al. (2017)

Environmentalscience Division

SOIL QUALITY AND GHG EMISSIONS

Subsurface Soil Organic Matter

(%)

NC Grain
NC Willow
SE Grain
SE Willow

2011 2015 2016 2017 2018

Average N2O flux (µg N m⁻² s⁻¹)

Year

2013 2014 2015 2016 2017 2018

N2O FLUXES

Average of Wet Density: Bulk Density

lbs/ft³

0.013

0.045

Middle Soybean
NC Soybean
NC Willow
SE Grasses
SE Willow
SE Soybean
Southern Soybean

Significantly lower bulk density under willow than soybean

Troxler 3440 moisture-density gauge on June 14th and June 15th, 2017

Soil organic matter

Yearly means and standard error.

Subsoil samples collected from the bottom 6 inches of a 4-foot core. Zumpf et al. (2017)

Average N2O flux (kg N ha⁻¹ yr⁻¹)

Year

2013 2014 2015 2016 2017 2018

Average Number of Species

Unknown
Pest
Beneficial
Pest control
Pollinator
Pest control + pollinator

CANOPY INSECT BIODIVERSITY

BY FUNCTIONAL GROUPS

Subsoil samples collected from the bottom 6 inches of a 4-foot core. Zumpf et al. (2017)
EXAMPLE: WATER QUALITY

Late spring..........................summer..............................early fall

Nutrient trading and the Gulf hypoxia

Net profit ($/ac)
Watershed design increases ES in marginal land

Current land use

Surface water ponding
Crop productivity index
Soil drainage
Nitrate leaching
Pesticide leaching
Flooding frequency

Design including bioenergy and water quality

Tile- nitrate leachate
Sediment yield
Pollinator nesting index (InVEST)

Ssegane et al., 2016
Ecosystem Services framework implies system level thinking to maximize benefits.

Meehan et al., 2013
Bioenergy buffers - cost competitive as a conservation option and GHG-sparing

GHG emissions from producing willow on marginal land were less than half of those from producing corn on that land.

- Most benefit is due to less fertilizer, energy, agrichemicals in willow plots
- Sensitivity analysis: results most sensitive to willow yield

Adapted from Christianson L, Tyndall J, Helmers M. (2013)
1. **Market price method** – can be applied to commodities traded on the market, e.g. oil, corn etc.
2. **Productivity method** – can be used for ecosystem services that contribute to the production of commodities, e.g. fresh water in an aquaculture pond.
3. **Hedonic price method** – can be used for ecosystem services that affect the economic value of other commodities, e.g. a forest which increases the value of properties around it.
4. **Travel cost method** – can measure the value of recreational areas by calculating how much people will pay to travel to and visit those sites.
5. **Damage cost avoided, replacement cost and substitute cost methods** – can measure the cost of avoided damage to ecosystem services, of replacing or providing substitutes for those services, e.g. the cost of artificial crop pollination in the absence of bees and other pollinating insects.
6. **Contingent valuation method** – can be used to elicit the value of any ecosystem service based on asking people to choose between ecosystem services.
7. **Benefit transfer method** – estimates the value of ecosystem services based on an already completed valuation in another place.

http://www.ceeweb.org/work-areas/priority-areas/ecosystem-services/how-to-value-ecosystem-services/
### Provisioning Revenue Under BAU and ABL Landscape Scenarios - Vermilion Watershed

<table>
<thead>
<tr>
<th>Crops</th>
<th>Yield (kg/ha)</th>
<th>Production (Mg)</th>
<th>Value (2016 $ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Business as usual (BAU) scenario</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>8,428</td>
<td>5,695,861</td>
<td>769.11</td>
</tr>
<tr>
<td>Soybeans</td>
<td>3,504</td>
<td>1,561,799</td>
<td>565.20</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>1,334.31</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crops</th>
<th>Yield (kg/ha)</th>
<th>Production (Mg)</th>
<th>Value (2016 $ million) at switchgrass price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>$20/Mg</strong></td>
</tr>
<tr>
<td><strong>Alternative bioenergy landscape (ABL) scenario</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>8,513</td>
<td>5,626,550</td>
<td>759.75</td>
</tr>
<tr>
<td>Soybeans</td>
<td>3,505</td>
<td>1,527,733</td>
<td>552.87</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>7,604</td>
<td>223,432</td>
<td>4.47</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>1,317.09</strong></td>
</tr>
</tbody>
</table>

Marginal land identified in Upper Vermilion: 29,300 ha
<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Source</th>
<th>2016 Dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate reduction</td>
<td>Ribaudo et al. (2005)</td>
<td>$38.37 per kg nitrogen</td>
</tr>
<tr>
<td>Sediment reduction</td>
<td>Hansen and Ribaudo (2008)</td>
<td>$4.35 per Mg</td>
</tr>
<tr>
<td>Carbon sequestration</td>
<td>Interagency Working group (2016); Bhattarai et al. (2017)</td>
<td>$209.10 and $61.07 per ha per year*</td>
</tr>
<tr>
<td>Water-based recreation</td>
<td>Baylis et al. (2002)</td>
<td>$3.45 to $8.21 per ha</td>
</tr>
<tr>
<td>Wildlife viewing</td>
<td>Feather et al. (1999)</td>
<td>$42.36 per ha</td>
</tr>
<tr>
<td>Pheasant hunting</td>
<td>Feather et al. (1999)</td>
<td>$9.97 per ha</td>
</tr>
</tbody>
</table>

*Based on Price of $33.19 per Mg CO2eq (Interagency Working group 2016), and Quantity of 6.3 Mg CO₂eq per ha per year for continuous corn to switchgrass, and 1.84 Mg CO₂eq per ha per year corn-soy rotation to switchgrass (Bhattarai et al. 2017)
VERMILION WIDE BIOENERGY DESIGN ECOSYSTEM SERVICES VALUE

- Nitrate reduction: $70,000,000
- Sediment reduction: $0
- CO2 reduction (corn-soybean): $1,000,000
- CO2 reduction (continuous corn): $6,000,000
- Water-based recreation: $0
- Wildlife viewing: $1,000,000
- Pheasant hunting: $0

Dollars
Replacement of commodity crops in marginal land by switchgrass results in slightly decreased overall value for the commodity crops.

However, inclusion of ES valuation could change situation to a positive.

Value of reduced nitrate alone would create a net gain of $20 to $90 million, depending on market for nitrate reduction. (others examined: nitrate loss reduction, erosion/sedimentation, GHG, water-based recreation, wildlife viewing, hunting, and pollinator services)

ANY CHANCES IT COULD HAPPEN?
PRIVATE-PUBLIC MECHANISMS FOR ECOSYSTEM SERVICES PAYMENT

- i2 Capital’s project, with The Nature Conservancy, Quantified Ventures, and other partners in the Brandywine-Christina watershed (Delaware, Maryland, and Pennsylvania).
- American Rivers - in partnership with Environmental Defense Fund and other non-profits, agencies, and utilities - created the Central Valley Habitat Exchange.
- Ohio River Basin Interstate Water Quality Trading Project (funded by EPRI)
- Fox River Valley Phosphorus Trading Program, Fox-Wolf Watershed Alliance, Brown County, Outagamie County Land Conservation Department, the Wisconsin Department of Natural Resources, Great Lakes Commission, and the USDA NRCS.

Source: http://nrcs.maps.arcgis.com/apps/Cascade/index.html?appid=769a0ef44b1b4d7b85d6e02c0ba7630d
THE PATH FORWARD

- Learning from examples, the good AND the bad

- Research needs to address many unknowns:
  - Understanding lag times and permanence of ES
  - Cumulative effects and buffering
  - Scales of resolution – are current methods scalable and appropriate for the precision required?
  - Working on trust, understanding and reducing uncertainties

- An opportunity: the ES of resilience to extreme events, tipping points and climate change

- Social science needs to drive the change!
PATH FORWARD 1: MAKING SCALING UP FASTER AND EASIER
PATH FORWARD 2: SENSORS AND DATA
THE CONCEPT OF OBSERVATORY FOR SYNERGISTIC RESEARCH

- Strength is in the numbers: data, data and more data
- Remote sensing, proximal sensing, distributed sensing, and edge computing
- Observatory concept allows for more leveraging of research investments, larger opportunities for meta-studies – learning from existing examples to bring bioenergy field trials together.

Source: Argonne National Laboratory

Source: USDA LTAR
Acknowledgements

- Herbert Ssegane, Jules Cacho, Patty Campbell, Colleen Zumpf, John Quinn, Nora Grasse, Argonne National Laboratory
- The many students who help us every summer in the field
- John Graham and Joan Nassauer, University of Michigan
- Silvia Secchi and Justin Kozak, Southern Illinois University
- Kristen Johnson and Alicia Lindauer, DOE-BETO
- Paul Kilgus and Ray Popejoy, Fairbury IL
- The Livingston County IL SWCD and NRCS

This work was funded by the US DOE, EERE, Bioenergy Technologies Office.