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A systems approach to biomass sustainability

Biomass 2009: Fueling Our Future

March 17-18, 2009

National Harbor, MD

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Need: To grow biofuel feedstock sustainably

A tension to manage?
A problem to solve?

Production

- Meet target production
- Economically viable
- Efficient
- Factor externalities

Sustainability

Economic
Feasible

- Provide target production
- Provide income
- Provide needed inputs

Environmental
Habitable world

- GHG reductions
- Water quality
- Water quantity
- Biodiversity

Social
Equitable

- Socially acceptable
- Land use changes
- Foster rural development

Create value for all

To achieve target production with finite resources
(land, water, nutrients)

To create value for all:

seek solutions by including agricultural, energy and environmental sectors as components of the same system

↓

Phrase question:

How can plentiful biomass be produced with positive impacts on environment?

↓

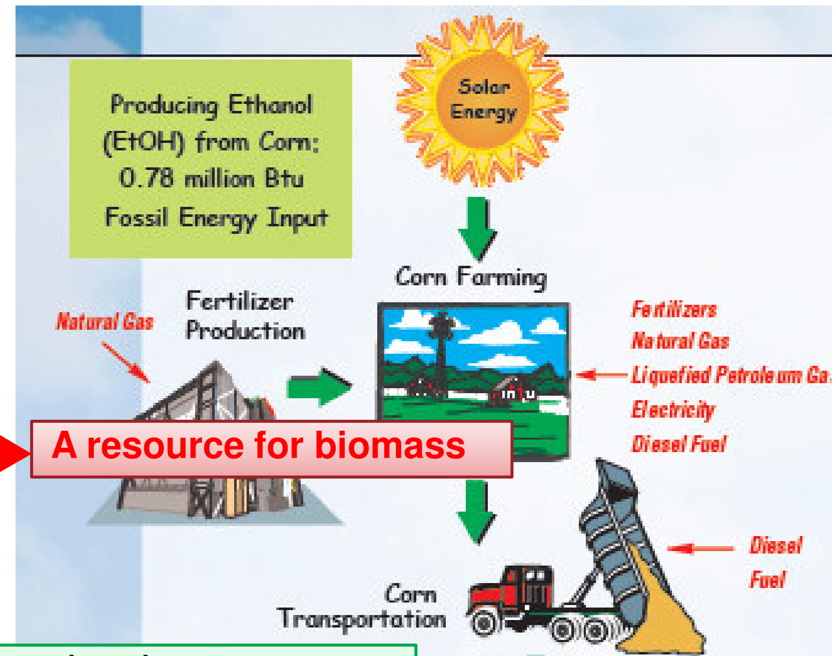
- BY DESIGN incorporate positive services to the environment
- By accounting for it, one sector's waste can be another's resource

← Spatial analysis

The systems perspective

- **One sector's waste is another sector's resource**
- **Converting environmental liabilities to resources**
  and double-dipping for benefits.

An environmental concern ⟷ **A resource for biomass**



•Source: USEPA

Source: ANL GREET

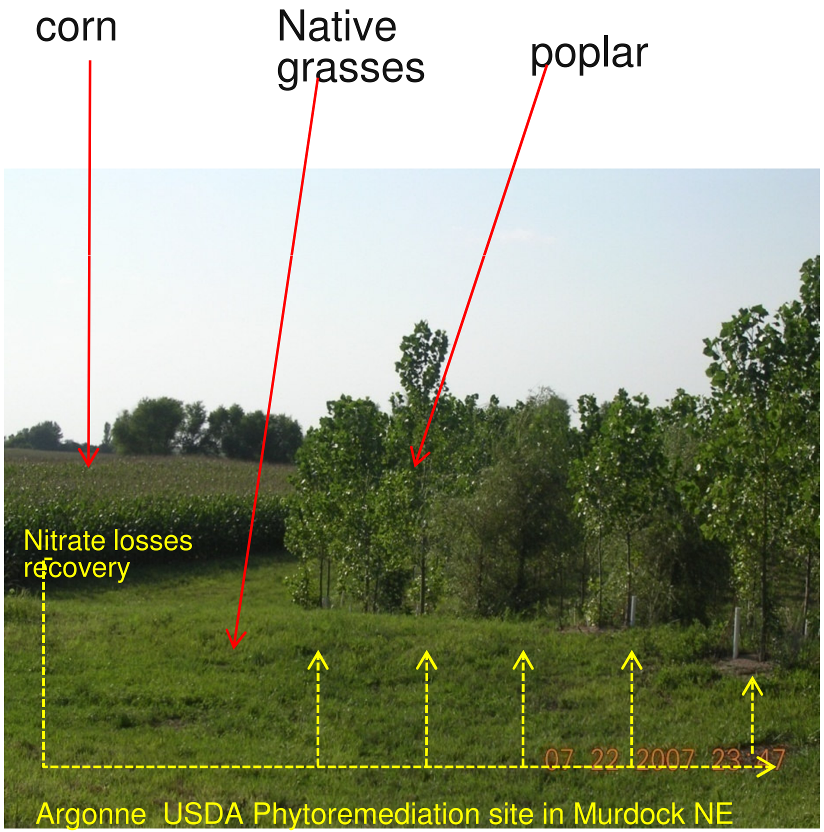
Apply to biomass production
the mantra of green technologies:
- Resource recovery
- Water reuse
- Beneficial reuse

Goals and Objectives

Goal:
To develop and analyze system-based resource recovery strategies to increase biofuel feedstock production that by design offer substantial improvements in sustainability.

Objectives:

- Import environmental technology/stewardship approaches to biomass production processes
- Inventory alternative land, water and nutrients resource base for recovery, to advance the production goals of the MYPP
- Evaluate the potential benefits from resource recovery strategies in terms of feedstock productivity and sustainability gains
- Interact with stakeholders to leverage potential socioeconomic opportunities and overcome barriers to proposed strategies.



Searching for alternative sources of water and land using GIS - A case study

- Spatial analysis critical to assess availability of alternative resources individually and synergistically
- Important to provide a quantitative measure of opportunities available
- Allow us to formulate and select best strategies
- Allow us to analyze logistics

Approach

Field project in Nebraska and experience in environmental technologies provided basis and insight – but not limited to this case

- Determine types of alternative land and degraded water resources available with minimal logistics
- Develop spatially explicit datasets combining data from multiple agencies (USDA, EPA, NDEQ, USGS)
- Estimate availability, spatial distribution and overlap of these resources

- *Optimize plausible scenarios for one State*
- *Expand analysis for Agricultural Region (USDA Region 7)*

Scale and resolution

- Start analysis from regional scale, pilot on one State, then expand to Agricultural Region
- State of Nebraska selected for pilot analysis
  - *Largely agricultural state, large fertilizer use*
  - *Significant irrigation of cropland, 80% of the irrigation uses groundwater*
  - *Has significant water quality impacts and aquifer vulnerability*

Results: Water and nutrient resources

NO_3 contaminated groundwater and livestock waste overlap significantly, found primarily in the eastern section of the state.

Liabilities

- *Groundwater:*
  - ✓ *~ 90% from areas with shallow groundwater, Nitrate concentrations 10 – 70 mg/L*
  - ✓ *Total contaminated groundwater in that area ~ 186 million acre-ft , ~ 0.4 tons of N/ acre (preliminary)*
- *Livestock waste:*

✓ Hundreds to millions of gallons of wastewater per day depending on the type and number of animals – pending regulations

✓ N and P from animal manure estimated around 133 million tons/year for the U.S. (USEPA 2001, Bradford et al 2008)

Inputs

N fertilizer (organic and inorganic) used by farmers in Nebraska

✓ 1.44 million tons/year N (USDA 2002 census). Corn average:138 lb/ac N (USDA).

✓ *N losses via leaching as high as 50% depending on precipitation patterns and timing (to surface and groundwater)*

Results: Land resources

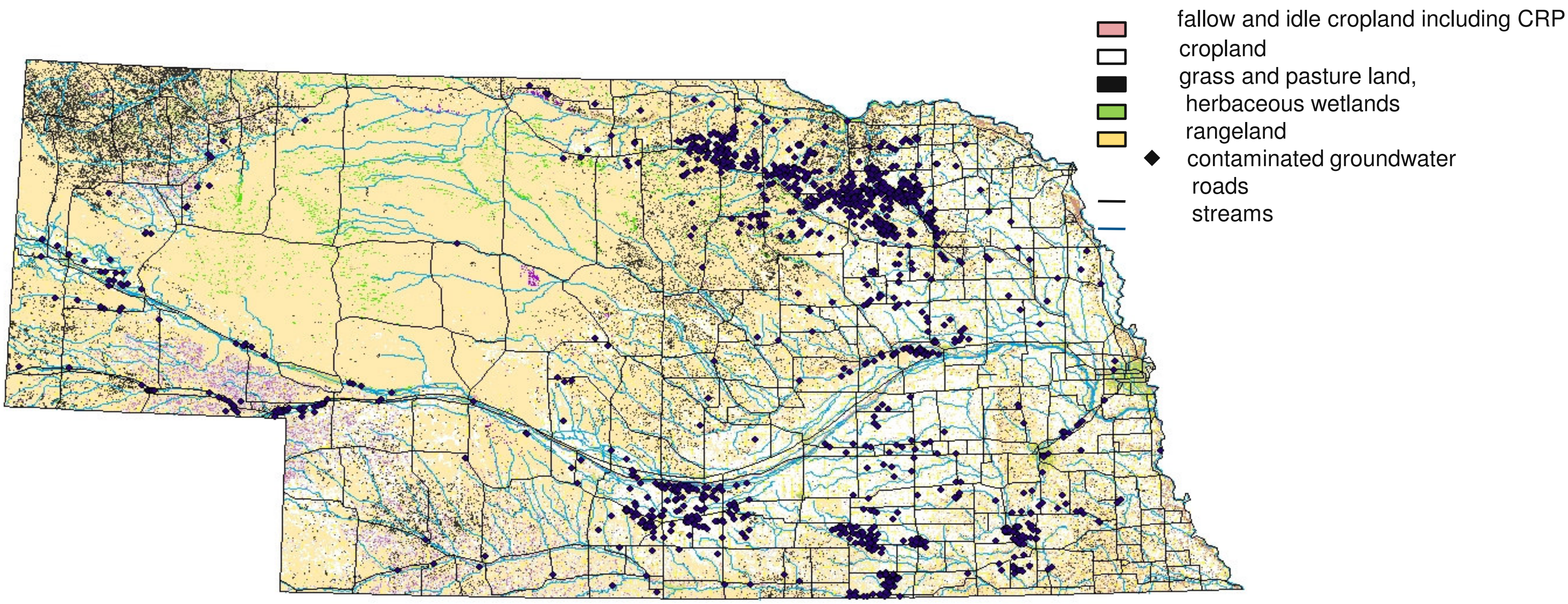
- CRP and idle cropland: Primarily in the western section of the state
- Roadway buffer strips*: Distributed throughout the state
- Riparian buffer strips*: Primarily in the south and east
- Brownfields: Negligible in NE, mine land reported by NREL 2003.

**resolution scale uncertainty*

Nebraska Land	Million Acres	Million Dry tons	M dry tons with resource recovery (water and nutrients)
CRP and idle agricultural land	**1.5**	**7.5**	**na**
All roadway buffers*	**1-5**	**5-25**	**10-50**
All riparian buffers*	**0.5-2**	**2.5-10**	**5-20**
Other references			
NREL 2003 poplar on CRP		***1.9***	
NREL 2003 switchgrass on CRP		***3.3***	
Riparian Forest and other forest (CALMIT 2007)	***1.5***		

assumes a 10-50 m buffer width

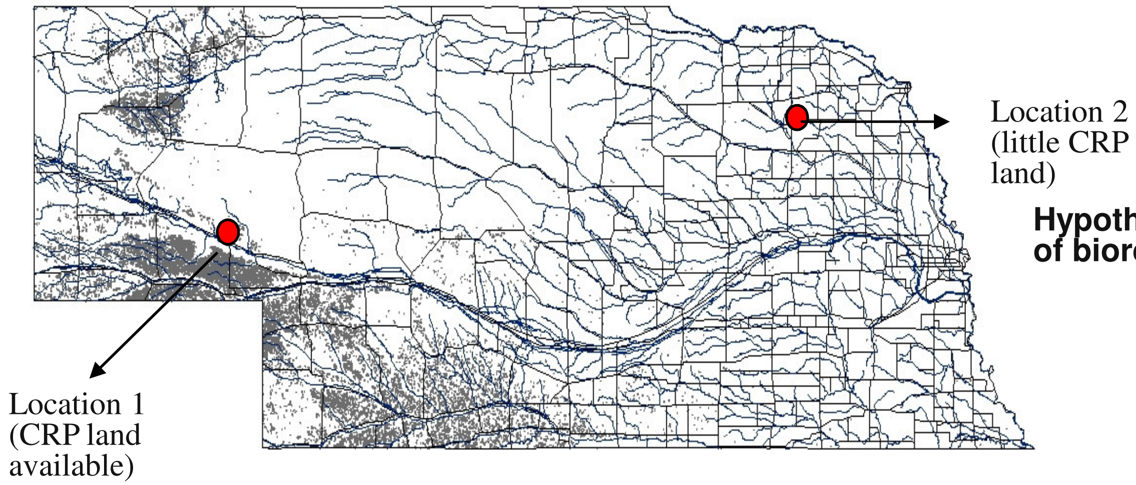
Overlap of marginal land and water resources



- Riparian and roadway buffer strips overlap 48 – 50% with degraded groundwater resources
- Little overlap between the areas of nitrate contaminated groundwater & livestock facilities with CRP land (2% of CRP land overlaps)
- Resource recovery by N-scavenging perennials (woody, other) could address surface and groundwater quality and GHG emissions through direct and indirect N_2O control.

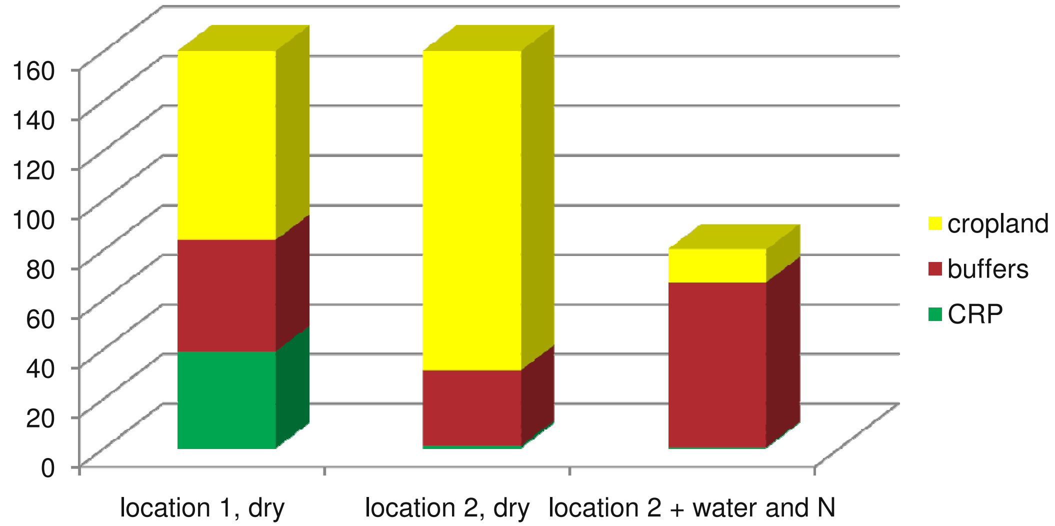
Intensification of feedstock supply to biorefineries

assuming a 25 mile radius supply area, for a 80 MGY ethanol plant (~2200 t/day biomass)



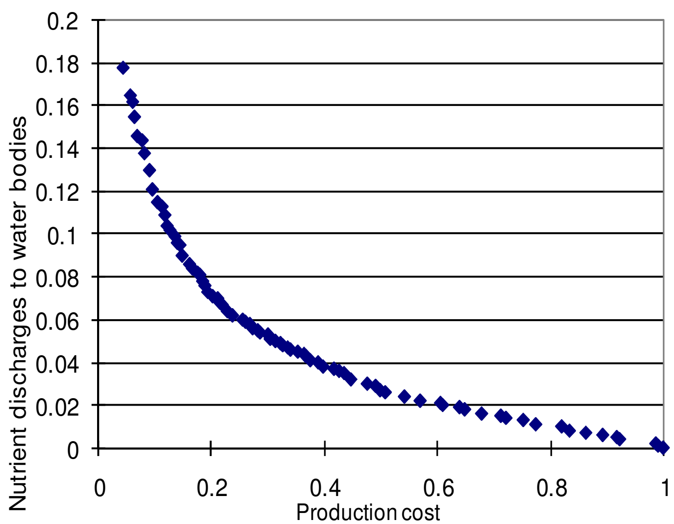
Hypothetical locations of biorefineries

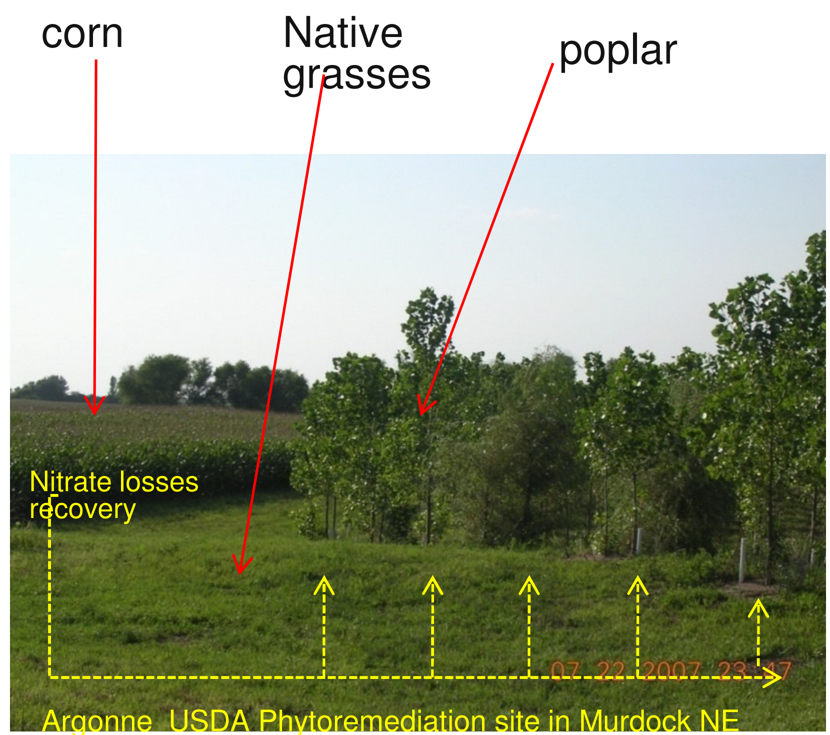
Acreage required (thousand acres) to supply a 80 MGY ethanol plant



Future Work

- Address resolution issues
- Expand analysis to Agricultural Region
- Complete optimization
- Life cycle analysis for selected optimized strategies
- Watershed – level modeling
- Field validation!!





Successes and challenges

- GIS useful to provide and validate quantitative measures of resource recovery strategies, logistics
- Basis for evaluating tradeoffs in productivity and environmental services of different strategies
- Other States may have different opportunities – expand to Region
- Lack of uniform, digitized databases, definitions for all states on alternative land and water resources
- Resolution scale, uncertainty in classification
- **Field validation needs to be conducted**
  - Accuracy of the GIS maps at the field scale
  - Quantify environmental benefits and feedstock productivity

Summary - 1

- GIS study proposes effective solutions to overcome "sustainable production" barriers to achieving the EISA 2007 biomass production targets.
- A systems approach that recovers externalities from the agricultural sector as a resource for biomass promises significant environmental and sustainability gains, and significant production potential
- In Nebraska, a hypothetical biorefinery drawing biomass from land in buffer strips could halve the number of acres and minimize the use of cropland needed to grow its biomass

Summary - 2

- Doubling yields of cellulosic feedstock are possible through the use of nutrients and water from N-rich, degraded water resources

- Positive environmental services and energy savings from reusing water and nutrients may include:

  - *Clean water*
  - *Reduction in GHG (CO_2 and N_2O) emissions*
  - *Energy savings from fertilizer production and application*
  - *Biomass diversification, habitat creation*
  - *Energy and cost saving from avoided environmental cleanup*
  - *Rural development opportunities in GHG trading?*

Acknowledgements

Sponsors

- U.S. DOE- EERE/OBP
- USDA – CCC
- U.S. DOE - EM

People

- Lorraine LaFreniere
- Norbert Golchert
- Larry Moos
- Paul Benda
- Sabeen Ahmad
- John Quinn
- Robert Sedivy
- Eugene Yan
- Jorge Alvarado
- Candace Rose
- Carol Rosignolo

Argonne DOE –EM site 2006

Argonne USDA site 2008

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