Designing a multi-functional sustainable agricultural system at the farm scale using energy crops

Gayathri Gopalakrishnan*, M. Cristina Negri, Meltem Urgun-Demirtas, Dimple Kundiayana, John Quinn

Argonne National Laboratory, 9700 S Cass Avenue, Argonne, IL
*ggopalakrishnan@anl.gov
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 production inefficiency

A resource for biomass

76 to 85% of hypoxic zone root causes start at the farm field level
68 % of 2008 N₂O emissions in U.S. are from soil management practices

(USEPA 2010)
Marginal land and water resources in the Midwest and Upper Midwest regions (USDA regions)

Can be used to supply approximately 23 billion gallons of ethanol

Land use and impaired streams

- Red: Fallow and Idle cropland, including CRP
- Light Green: Rangeland and grasslands
- Yellow: Cropland
- Dark green: forests
- Dark blue: Impaired surface water bodies

Sources: USGS model of probability of nitrate contamination in shallow groundwater (<5 ft), Impaired surface water bodies (USEPA), Land use and land cover (USDA NASS)
Potential production and feedstock intensification

Biomass from all “Marginal” Land

- Total Biomass: 389 M dry tons, or 23 B gallons ethanol

Gopalakrishnan, Negri et al., Environmental Science and Technology, 2009
Gopalakrishnan, Negri and Snyder, Journal of Environmental Quality, 2011
Redesigning agricultural landscapes for sustainability and bioenergy

Research objectives

• Grow bioenergy crops on marginally productive agricultural land
• Capture and in-situ reuse of nutrient enriched runoff and leachate
“Phytotechnologizing” Biomass production

Potential environmental benefits + crop yields increases in bioenergy buffers

DNDC Model Results:
• Nitrate leached reduced by 60-70% in buffer zones
• Nitrous oxide emissions reduced in buffer zones by 65% - 93%.
• Yields of energy crops comparable to yields with fertilizer application.

Gopalakrishnan, Negri and Salas, Global Change Biology Bioenergy, 2012
A model of productive, diversified, sustainable biomass from riparian land

Enhanced biomass productivity and better use of resources through landscape engineering. Can we achieve 100 % NUE at the farm scale?

NUE: Nitrogen Use Efficiency

Putting the system together in Fairbury, IL
Biomass production and nitrate recovery in the Indian Creek Watershed

- Producing bioenergy crops with minimal competition with food and feed crops
- Biomass crops would be productive where corn is less
- This approach could save on crop insurance, provide clean water, and reduce greenhouse gas emissions.

Short rotation willows will be planted and harvested with modified farming implements

Photo credit: Dr. Tim Volk, SUNY ESF.
Existing data from Fairbury

USDA Soil map:
Blue area: Comfrey loam, frequently flooded
294C2: Symerton loam, eroded, 4-9% slopes

Data from ILEPA for the Indian creek shows nitrate concentrations 7-54 ppm (2010)

Site geology from soil borings collected at the target farm

Model and data provided by John Quinn, EVS, Argonne National Laboratory
Getting baseline data at the field - 2011

- **Sampling**
  - Soil moisture samplers (Rhizons) used to collect soil water
  - Rhizons inserted at approximately 4 ft depth in 2” PVC tubes
  - Rhizons consist of 9 cm porous material with a 4.5 mm diameter outside, strengthened by a glass fiber epoxy
  - Sampling is done using evacuated syringes (60 ml vacuum)
  - The yield in wet soil is typically 7 ml in 0.1 - 2 hours, depending on soil properties.
  - Low-flow sampling used to collect groundwater samples
  - Soil samples collected at 3 depths using geoprobe

- **Analysis**
  - Nitrate concentrations in water using HACH spectrophotometer
  - Nitrous oxide concentrations in water measured using headspace analysis in a 5890 HP Gas chromatograph
  - Corn and soil samples analyzed for nitrogen, TOC, pH by Servitech Laboratories, KS
Nitrate in soil water

Where is the highest nitrate concentration and what contributes to it?
30 sample locations spaced on a 50mx50m grid used to collect statistically significant data

Buffer = 10-50 ppm

Highest spot = 60 – 400 ppm

MW6 = 24-30 ppm
Yield maps

Corn yield: dark green areas = 175-200 bushels/acre, yellow-red areas = 70-90 bushels/acre
Final field design - contour strip

Contour strip

- Based on baseline data and model efforts
- Marginal land from the farmer’s perspective – where yield is lowest
- Availability of subsurface nitrate from the corn for ferti-irrigation of the bioenergy crop
- The experiment will be conducted with corn plots acting as controls and with a control plot of willows (W-control) that will be fertilized
- Crop yield, GHG emissions reductions, water quality to be monitored
Acknowledgements

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

People
Alison Goss-Eng
Zia Haq
Seth Snyder
Lorraine LaFreniere
Michael Wang
John Quinn
Robert Sedivy
Jorge Alvarado
Candace Rose
May Wu
Eugene Yan
Norbert Golchert
Larry Moos
Sabeen Ahmad
Carol Rosignolo