Perennial Biomass Crops for Multiple Ecosystem Services in Corn—Soy Landscapes

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Overview

Steve:
• Lessons from 20th Century agricultural history
• Multifunctional perennial cropping systems
• Preliminary thoughts on a Perennial Biomass Initiative

Madhu:
• Experimental and model-based evidence on energy crop system performance
• Incentives and barriers to energy crop production
• Policy and market incentives

Questions – Comments – Discussion
Soybean pioneer: Farmer

**Charles Meharry** started planting soybeans on his Champaign County farm in 1909. Later, he hosted field days with university agronomists.

"We threshed 19 acres of beans [in 1909] and got 382 bushels. The rest was made into hay. These were the first beans grown on a considerable scale in Illinois and Charlie Meharry was a real pioneer in growing them."

**C.W. Oathout, farm manager**
In 1922, A.E. Staley’s Decatur soybean plant started a landscape transformation.

Market demand drove acreage increase.

A. E. Staley Company
soybean promotion & product research

A. E. (Gene) Staley

Crop acreage in Macon, Piatt, Champaign Counties

Credit: Greg McIsaac, from NASS data
After WW II, inorganic nitrogen fertilizer helped give rise to the feedlot system and grain-only farming.

Small grains and hay/pasture acreage declined sharply in this period.

Drivers of this transition:
- Industrial nitrogen fixation
- Hybrid corn
ADM made U.S. agriculture a source of energy, 1978

Another Decatur-based company helps to transform the agricultural economy.

ADM begins ethanol production, 1978

1st generation biofuel feedstocks: corn, soybeans, sugarcane

Advanced bioenergy feedstocks:
- Crop residues
- Dedicated bioenergy crops

Perennial crops may drive the next landscape transformation.
Lake Decatur Watershed

- 925 square miles
- 87% row crops
- Tile drainage
- CRP acreage ≤ 1.5% of cropped acres
- Decatur Sustainability Plan Year 2020 target: 10,000 acres of biomass crops ≈ 3% of watershed below Monticello (red line)

Map credit: ISWS
Watersheds exporting high nitrate loads to the Gulf are mainly the tile-drained croplands of Illinois, Iowa, and Indiana.

USEPA has required States to adopt nutrient reduction strategies to shrink the Gulf of Mexico dead zone.
Multifunctional Perennial Cropping Systems can produce food, feed, fuel, & fiber PLUS clean water, habitat, GHG reduction, soil health

Kathleen Bell farm: Water quality, wildlife habitat, and (someday) heating fuel

Allen Williams: Organic field border; potential for warm season hay

Cat—AWI Prairie for Bioenergy plots: Annual field day site; harvested for hay & bioenergy
Perennial Biomass Crops

- Switchgrass
- Miscanthus
- Other perennial grasses
- Grass/forb polycultures
- Willows; short-rotation trees

To learn more about perennial crops, visit the AWI—U of I exhibit at the 2017 Farm Progress Show.

Energy grass plots at Progress City:
Switchgrass (L); Miscanthus (R)
Switchgrass

Annual wheat (left)  
Kernza perennial wheatgrass (right)

*Our most fertile soils developed under tall grass prairie vegetation.*

Photos courtesy of The Land Institute
Planting 10% of a sloping field in contour grass strips greatly reduces soil and nutrient loss and produces harvestable forage or biomass.

*Slide courtesy of Matt Helmers, Iowa State*

**Four treatments:**
- 100% crop (no-till)
- 10% buffer, at toe slope
- **10% buffer, in contour strips**
- 20% buffer, in contour strips
Converting acreage from annual crops to perennials to reduce nutrient and soil loss

- Converting from annual crops to perennials can reduce nutrient loss by 90% +/- . Also reduces runoff & sediment.

- Strategically located perennials + drainage modifications can increase WQ benefits by treating water that drains across the area converted to perennials:

  - Contour strips & toe-of-slope buffers
  - Harvestable saturated buffers or slopes
  - Harvestable seasonal wetlands
Prairie cordgrass (*Spartina pectinata*):

- High yielding warm season native
- Starts growing in early spring
- Thrives in wet conditions
- Could be grown in harvested seasonal wetlands
- Promising candidate for nitrate removal / utilization

U of I agronomist D. K. Lee developed the ‘Savoy’ cordgrass cultivar as a bioenergy crop
Perennials to reduce GHG emissions:

- Net GHG reduction from replacing fossil fuels with cellulosic biofuels – Need LCA to score this reduction
- Perennials reduce fossil fuel use for farming operations – Less tilling, less planting, less pesticide use
- Reduce fossil fuel use for producing nitrogen fertilizer – Perennials need less N; capture N lost by corn; polycultures with legumes
- Reduce N$_2$O loss from perennials vs annual grains in targeted locations such as poorly drained soils – Research needed
- Increase organic carbon sequestered in soils under deep-rooted perennial grasses and trees
Thoughts on a new agricultural paradigm

Climate change, renewable energy, & Gulf hypoxia may drive a paradigm change comparable in scale to the introduction of inorganic fertilizer after WW II.

Biomass crops are the only source of renewable energy that can provide landscape-scale ecological benefits → clean water, wildlife habitat, GHG reduction, soil health, etc.

Multifunctional Perennial Cropping Systems can meet human needs while protecting the environment.

Transition to MPCs will require “Staleys” & “Meharrys”, plus government/academic/NGO partners.

Watershed “landlabs” can be used for on-farm R&D and testing of policy innovations.
Perennial Biomass Crops and Economic Development

This will take:

- Uses & markets
- Patient capital
- Green payments

Need 21st Century **Staleys** with passion to develop uses & markets for perennial crops.

_Ecosystem service incentives can be designed to enhance economic viability of PBCs and achieve environmental goals._

**Ernst Biomass** in PA makes grass pellets from biomass left after they harvest prairie seed. With no market for use as a heating fuel, they sell pellets to the fracking industry for use as absorbent.

**Show Me Energy Co-op** in MO succeeded in technical/environmental terms. But when low natural gas prices made grass energy pellets Unprofitable, the co-op folded and the facility was sold.
AWI and Green Lands Blue Waters are organizing a Perennial Biomass Initiative to bring about a paradigm shift comparable in scale to 20\textsuperscript{th} Century transformations.

**Long-term Goal:** 10 to 15\% of farmland in perennial crops that produce food, feed, fuel, and fiber AND ALSO achieve
- greenhouse gas reduction
- clean water
- healthy soil
- wildlife habitat

**Theory of change:** Expand uses and markets for perennial crops and policy to incentivize ecosystem services. We seek engagement with farmers, landowners, entrepreneurs, industry, investors, and philanthropists that share this vision.
Experimental Research on Energy Crops

- Over 15 years of experimental research at the 300 acre Energy Farm at the University of Illinois and several other locations in the rainfed US with Miscanthus and Switchgrass

Used to calibrate and validate the DayCent Model to simulate crop yields and soil carbon sequestration across the rainfed US

Funding for this research provided by USDA/NIFA, Energy Biosciences Institute, UC Berkeley USDOE; Illinois Council for Food and Agr. Research
Potential to Provide Significant Environmental Benefits

• High yielding and can be grown productively on low quality land
• Low input perennials
• Can be grown rainfed
• Non-invasive varieties
• Sequester substantial soil carbon
• Reduce soil erosion and nitrate run-off
County-level Average Yield with 30 years of Weather Data Using DAYCENT Model
Lower Nitrate Run-off Compared to Corn

- Nitrate run-off declines to zero after establishment of energy crops

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Smith et al 2013

Fig. 1. Annual nitrate N leaching (April to April) at 50 cm soil depth using resin lysimeters for all biofuel crops (mean ± SE). Means by year across crop types with the same capital letter are not significantly different at the 0.05 level. Means by crop type across years with the same lowercase letter are not significantly different at the 0.05 level.
Effects of Land Use on N runoff

- 15 billion gallons of corn ethanol estimated to increase N export by 10-18% relative to control
  - Increase largely in corn belt states

- Replacing 40% of land currently used for corn ethanol with miscanthus or switchgrass could reduce N run-off by 5-15%

Donner et al., 2008

Figure 4. Simulated mean annual percent difference (Scenario – Control) in N export in the Mississippi-Atchafalaya River Basin for the miscanthus (a,d) and switchgrass (e, h) scenarios at 5% (a,e) replacement levels and at levels where 40% of maize is replaced by miscanthus (d) or switchgrass (h) for the 33-year period spanning 1970 to 2002 (Vanloocke et al., 2016).
Change in Soil Carbon with Energy Crops vs. with Corn Stover Removal

Dwivedi et al., 2015
Potential to Reduce GHG Emissions Compared to Gasoline

- Miscanthus and switchgrass based ethanol have 100%-160% lower carbon intensity compared to gasoline
- But significantly more expensive than gasoline

(Dwivedi et al., 2015)
Returns and Risks with Energy Crop Production: Supply-side

- Life-span of 10-15 years or more: Long term commitment
- Upfront establishment costs: Liquidity/credit constraints
- May require crop-specific equipment
- Expose farmers to various risks; differ from those of annual crops
  - Price linked to fossil substitutes
  - Yield risks, establishment risk
    - low correlation with annual crops
    - benefits of diversification of crop portfolio
  - Foregone profits from annual crops
    - Commodity program payments
    - Subsidized crop yield/revenue insurance
Breakeven Prices of Miscanthus and Switchgrass $ per ton

**Miscanthus**

![Graph showing breakeven prices for Miscanthus on marginal land and cropland across different regions.](image)

**Switchgrass**

![Graph showing breakeven prices for Switchgrass on marginal land and cropland across different regions.](image)
Risk Premium $ per ton

Ratio of Coefficient of Variation of Energy Crop to Corn Yield

Miscanthus

Switchgrass
Demand-side Risks with Energy Crop Production

- Thin markets with limited processors
- Emerging nascent alternative uses other than bioenergy: high value bio-products
- Refinery shutdown
- Low density, bulky to transport long distances
  - High costs of long distance transportation
- Reliance on policy incentives for bioenergy consumption
  - Uncertainty about policies
Economic Factors Affecting Farmer Incentives to Grow Energy Crops

• Yield and price riskiness of energy crops
• Risk Preferences
• Time Preferences
• Availability of Credit
• Availability of low quality land
• Contractual arrangements
Survey: 450 Farmers in IL, IN, MO, KY, TN

Idle Land Availability

% of Farmers with Crop Insurance

Risk Preferences

Rate of Time Preference
Need for Policy and Market-Based Incentives for Farmers to Plant Energy Crops

• Establishment cost share subsidy
• Biofuel mandate with assured demand for cellulosic biofuels
• Production tax credit for cellulosic biofuels
• Renewable Portfolio Standard for demand for bioelectricity
• Crop insurance for energy crops
• Long term contracts for biomass
Current Policies

• Biomass Crop Assistance Program
  – Cost share, cost of land coverage during establishment
  – Matching payment for collecting and supplying

• Renewable Fuels Standard: annual volumetric mandate

• Cellulosic Biofuel Producers Tax Credit: $1 per gallon

• Low Carbon Fuel Standard in CA: Standard for GHG intensity of fuel
Policy Limitations

• Policies not based on ecosystem service provision

• RFS, RPS treat all biomass as same

• BCAP: Low funding level- $25M a year for 5 years
  – 50% of funding can be spent on crop and forest residues
  – No distinction among different energy crops
    • Crop residues treated the same as miscanthus

• Significant policy uncertainty
Performance-Based Policies

- Government payments for carbon reduction credits, nitrate reduction credits
  - Implemented as supplements to RFS, RPS and BCAP
  - Payments would be site-specific
  - Key challenge is monitoring and measuring nitrate reduction, soil carbon sequestration
    - Using models vs measurement
    - Determining additionality
    - Stacking vs bundling

- Carbon taxes on fossil fuels/Clean Power Plan

- Low Carbon Fuel Standard
Market-Based Incentives

• Long term contracts between refineries and growers to share the risks
  – Fixed price, land leasing, profit sharing

• Nutrient trading programs between point sources and non-point sources

• Cap and trade program for carbon mitigation

• Developing demand for bio-based products based on consumer willingness to pay
Summary

• Energy Crops: Significant potential to provide fuel without conflicting with food production

• Multiple ecosystem service provision

• High fixed costs, risks of production of energy crops

• Need for significant policy and market incentives to induce conversion of land to produce energy crops
Questions
Comments
Discussion