Developing High-efficiency Agricultural Systems: A Forever Green Agriculture Initiative

Donald Wyse, University of Minnesota
How did agricultural landscapes lose their diversity?
Figure 19. Cover map of the Winnebago pheasant study area, 1941.
Figure 23. Cover map of the Winnebago pheasant study area, 1976.
Protein efficiency 14%
1lb Pork 1,630 gal water
1lb Potatoes 24 gal water
ETHANOL FROM CORN

Dry Milling Process

Grain

Grind, Enzyme Digestion

Sugars

Yeast, Distillation

ETHANOL

Distillers Grains
Conceptual framework for comparing land use and trade-offs of ecosystem services

What are some of the consequences resulting from the loss of landscape diversity and continuous living soil covers?
Hypoxia in the Gulf of Mexico

- bottom dissolved oxygen less than 2.0 mg/L, July 1999

Rabalais et al. 2000
“It sort of makes you stop and think, doesn’t it.”
Areas of annual row cropping

April 20 – May 3

Areas of perennial vegetation

May 4 – 17

Satellite images of vegetative activity.
Satellite images of vegetative activity.

July 13 - 26

October 5 - 18
Monthly Precipitation in the Cottonwood River Watershed

Annual precipitation = 26.8 in
Oct. through April precipitation = 9.4 in (35.2% of annual)

Source: MN St. Clim. Office
Annual Tile Drainage Loss in Corn-Soybean Rotation

Waseca, 1987-2001

July-March: 29%

April, May, June: 71%
Nitrogen Loads
long-term average
million lbs per year
Statewide nitrogen sources to surface waters

- **Cropland tile drainage**: 37%
- **Cropland groundwater**: 30%
- **Cropland tile drainage**: 37%

Other sources:
- **Atmospheric**: 9%
- **Point sources**: 9%
- **Urban Stormwater**: 1%
- **Septic**: 2%
- **Forests**: 7%
- **Feedlot runoff**: <1%
Long Term Nitrogen Reductions

- 0%
- 10%
- 20%
- 30%
- 40%

N Reduction in water

<table>
<thead>
<tr>
<th>Year</th>
<th>Veg. cover</th>
<th>Tile mgmt.</th>
<th>Fertilizer efficiency</th>
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<tbody>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td></td>
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<td></td>
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<tr>
<td>2035</td>
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- 2020 2025 2035 ?
Adding perennials & winter annuals does four very important things

• Creates value from underused and new resources
• Enhances soil, water, wildlife & biodiversity
• Insures against climate variability
• New economic opportunity
Getting perennials & winter annuals on the landscape by germplasm development, new agronomic practices, commercialization & supply-chain development

- New genetic technologies allow rapid germplasm development
- Develop new agronomic practices (e.g. seeding tech.)
- Commercialization: new market opportunities
- Supply chains: from production to end use
Developing New Perennial and Winter Annual Crops to Enhance Minnesota’s Soil and Water Resources

**PERENNIAL CROPS**
- Intermediate wheatgrass “Kernza” – wheat-like grain, forage, biomass
- Perennial sunflower – edible seeds, oil
- Native polyculture grassland mixtures – biomass, forage, natural products
- Perennial flax – edible oil
- Kura clover – N-fixing cover crop
- Silphium – edible oil

**WINTER ANNUAL CROPS**
- Pennycress – oil, biofuel, cover crop
- Camelina – edible oil, biofuel, cover crop
- Winter barley – food, malting barley
- Hairy vetch – cover crop, N-fixation

**NATIVE WOODY CROPS**
- Hazelnuts – nuts, edible oil
- Shrub willow – biomass
- Elderberry – antioxidant-rich fruit
- Agroforestry – woody and herbaceous crop mixtures for feed, food and fuel
1. Field Pennycress

*Thlaspi arvense*

Enterprises:
- Oil—biodiesel/food
- Protein—food and feed
- Double or relay crop with soybean

Funding source: DOE/USDA, U of MN, MDA, Forever Green Initiative
Thlaspi arvense
Pennycress

Brassicaceae
(mustard family)

Extremely cold tolerant
winter annual

Rapid seed maturity

High oil content

Double or relay cropping
potential with soybean

Diploid/good breeding
potential
Pennycress seeded into corn

Fall soybean with pennycress regrowth

Soybean planted no till into pennycress stubble 1st week of June

Pennycress mid-May

Pennycress late fall

Corn/PC/Soybean Rotation
1. Plant cover crop in corn
2. Harvest corn over cover crop
3. Cover crop lies dormant
4. Plant soybean into cover crop
5. Harvest cover over soybean
6. Summer crop grows
Relay planting soybean into oilseed cover crops
Weeds/no pennycress vs Weeds/pennycress
2014 Soybean and Oilseed yield St. Paul

Yield (Bu per acre)

- Control plot- Full season
- Control plot- Sequential
- Pennycress- Sequential
- Pennycress- Early harvest
- Pennycress- Late harvest
- Camelina- Sequential
- Camelina- Early harvest
- Camelina- Late harvest

Yield categories:
- Oilseed yield potential
- Soy yield
Translation of Arabidopsis-based knowledge to pennycress

Low seed dormancy
Faster flowering
Improved seed characteristics
Flowering time pathway

GTR1/GRT2
Oil content

DOG1
GA/ABA Pathways

Low seed dormancy
Faster flowering
7. Intermediate Wheatgrass
Kernza™
*Thinopyrum intermedium*

Enterprises:
Beer/Whiskey
Food
Biomass
Grazing

Funding: IREE, MDA, Forever Green Initiative, The Land Institute
Intermediate wheatgrass

---- Environment services

- Reduce erosion and soil nitrate leaching
- Reduce inputs of energy and pesticide
- Increase carbon sequestration
Intermediate wheatgrass in Minnesota

St. Paul Campus
Intermediate wheatgrass

---- Agronomic traits

Large seeds

---- 10-15g/1000 seeds

Large biomass

---- comparably to big bluestem and switchgrass

Disease resistance

---- Lr38, Sr43, Sr44, Pm40, Pm43...

Favorable end-use food

---- wheat-wheatgrass blends
Intermediate wheatgrass

Our goal

— Obtain a commercially viable perennial grain/biomass crop

Wild Perennial

Domestication

Perennial Grain

Increase grain yield and biomass

Enhance grain quality for food
Breeding nurseries in St. Paul

2000 spaced plants

440 yield plots
Intermediate Wheatgrass improvement

<table>
<thead>
<tr>
<th>Seed weight (mg)</th>
<th>Wheat</th>
<th>Wheatgrass Current</th>
<th>Wheatgrass Forage</th>
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<td>35.1</td>
<td>15.0</td>
<td>12.4</td>
<td>4.8</td>
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Large seeds
Kernza grain yield--2014

- Significant variability in mean grain yield across locations.
Soil moisture beneath annual and perennial crops

Soil moisture content 100 cm below soil surface in corn, Kernza, and switchgrass at Waseca in 2015.

Jungers et al., unpublished
Soil water nitrate concentration beneath annual and perennial crops

Nitrate content in soil water 50 cm below soil surface in corn, Kernza, and switchgrass when fertilized with 160 kg N per ha (state average for corn) in 2013, one year after seeding.

Jungers et al., unpublished
Soil water nitrate concentration beneath annual and perennial crops

Nitrate content in soil water 50 cm below soil surface in corn, Kernza, and switchgrass when fertilized with N rates optimize for grain production in 2014.

Jungers et al., unpublished
Evaluation of intermediate wheatgrass grain for food use
Starch functionality

Less starch – less viscosity
Flavor Development in IWG

<table>
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<tr>
<th>Aroma Compound</th>
<th>Concentration (ug/kg)</th>
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<tr>
<td>2-acetyl-1-pyrroline</td>
<td>5.4</td>
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<tr>
<td>2-ethyl-3,5-dimethylpyrazine</td>
<td>0.17</td>
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<tr>
<td>methional</td>
<td>547</td>
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<tr>
<td>acetyl formoin</td>
<td>1241</td>
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<tr>
<td>e-2-nonenal</td>
<td>0.82</td>
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<tr>
<td>2-acetyl-2-thiazoline</td>
<td>37</td>
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<tr>
<td>e,e-2,4-decadienal</td>
<td>0.69</td>
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<tr>
<td>2-phenylethanol</td>
<td>32</td>
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<tr>
<td>furaneol</td>
<td>2296</td>
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Food products

Cookies are good
Food products

Muffins are OK
Food products

Yeast bread is not good alone
However,

20 to 50% IWG produces a good bread product
9. Hazelnut

*Corylus americana*

*Corylus avellana*

Enterprises:

Nuts

Oil

Biodiesel

Funding source: NIFA-USDA, IREE, SARE, MDA, Forever Green Initiative, Mary Page Community-University Partnership
Native Hazelnut: a new crop for the Upper Midwest
North American Hazelnuts

- Two hazel species native to Minnesota
  - *Corylus americana*, American hazel
  - *Corylus cornuta*, beaked hazel
- Traditional staple food of indigenous people
- Common in central Minnesota

*Corylus americana, American hazel*  
*Corylus cornuta, beaked hazel*
Hazelnuts

European Hazel (*Corylus avellana*)
- Large nut size
- Thin shells
- Not cold-hardy
- Susceptible to Eastern Filbert Blight (EFB)

American Hazel (*Corylus americana*)
- Smaller nut size
- Thick shells
- Cold-hardy
- EFB tolerant
Delicious, Nutritious Hazelnuts

• Excellent source of nutrition
  • Protein
  • Monounsaturated fats
  • Dietary fiber
  • Vitamins E and B₆

• Raw or toasted
• Confections
• Chocolate-hazelnut spread
New Economic Opportunities

• Local Food Movement
• “Olive oil of the Midwest”
• Unique opportunities for smaller American hazelnut

www.midwesthazelnuts.org
Hazelnuts as Part of the Forever Green Initiative

- Do not require annual tillage
- Strips between rows can be planted with grass or clover
  - Pollinator habitat
  - Continuous living cover
- Riparian buffers
- Windbreaks
- Living snow fences
Hazelnut Germplasm Improvement

Identification of superior hybrid hazels
- Identify hybrids from on-farm plantings with best kernel quality, yield, EFB tolerance, and cold-hardiness.
- Evaluation in replicated performance trials.

Domestication of American hazel
- Screen wild populations for superior plants.
- Evaluation in replicated performance trials.

The best of the best will be released to growers as a new cultivar.
A Challenge
Too much variability between seed-propagated hazel plants is agronomically unmanageable.

Example: Nut maturation dates
Solution: Vegetative Propagation to produce genetically identical plants
3. Winter Barley

Enterprises:
Barley malt
Livestock feed
Double crop with soybean
Developing Winter Barley for Minnesota
Soybean

Barley

1990

2010

Challenges
US Malting Infrastructure

Challenges
Climate Change

Climate moves over time
• Westward movement in dust bowl years
• Northward movement in recent years
• 1980 – 2010 rate is 5 miles/year

North

Climate Tracker Website
http://www.cbs.umn.edu/climatetracker/

Challenges
Winterhardiness

Challenges
Agronomic Benefits

Increased Yield, Disease Avoidance, Weed Suppression, Water Use Efficiency

Fall Planted

Spring Planted

Opportunities
Ecosystem Services

Carbon Sequestration, Nutrient Cycling, Reduced Erosion, Wildlife Habitat
Producer/Industry Benefits

Crop Diversity, Spread Out Field Activities, **Double Cropping**, Earlier Harvest
RESEARCH ACTIVITIES

• Screening wide collection (over 1400 accessions) for winter hardiness
• Generating genomic prediction models to estimate trait phenotypes with genetic markers
• Implementing rapid cycle breeding to accelerate development of winter varieties
• Coordinating national winter barley trial at 14 locations in U.S.