

An aerial photograph of a large farm complex. The farm features several large white barns, a tall white silo, and a circular pond. The farm is surrounded by vast green fields, some of which appear to be cornfields. A road runs along the left side of the farm. The overall scene is a typical rural agricultural landscape.

# Feedstocks for Renewable Chemicals and Other Bioenergy

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University of Minnesota



# Perennial Herbaceous Biomass Crops



Switchgrass



Prairie Cordgrass



Polyculture



*Miscanthus x giganteus*

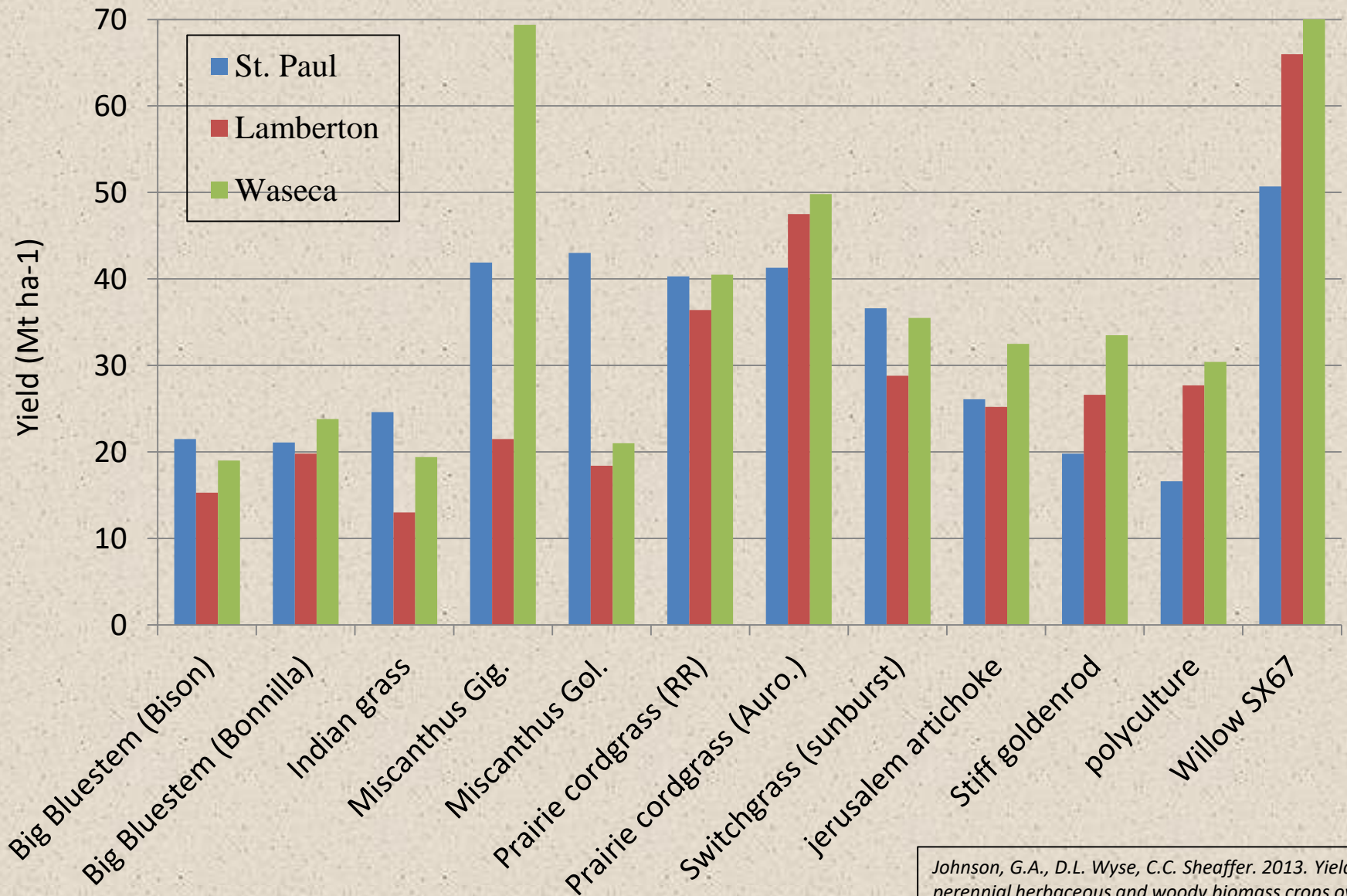


Big Bluestem



Cup plant

# Total biomass production over a 4-year period



Johnson, G.A., D.L. Wyse, C.C. Sheaffer. 2013. Yield of perennial herbaceous and woody biomass crops over time across three locations. *Biomass Bioenergy* 58:267-274.



# Oilseed Crops

Field Pennycress, winter camelina, and soybean



# Oilseed Crops

	Pennycress	Camelina	Soybean
Oil Content (%)	20-36	36-47	18-22
Pour Point (°C)	-18	-4	-3
C16:0	3.1	6.8	10.5
C18:0	0.5	2.7	4.1
C18:2	22.4	19.6	53.6
C18:3	11.8	32.6	7.7
C20:1	8.6	12.4	T
C22:1	32.8	2.3	0

Adapted from: Moser, B.R., S.N. Shah, J.K. Winkler-Moser, S.F. Vaughn, and R.L. Evangelista. 2009. Composition and physical properties of cress and field pennycress oils. *Industrial Crops and Products*. 30(2): 199-205



# Woody Biomass Crops





# Average willow biomass yield per year after 3 harvest cycles in Waseca, MN

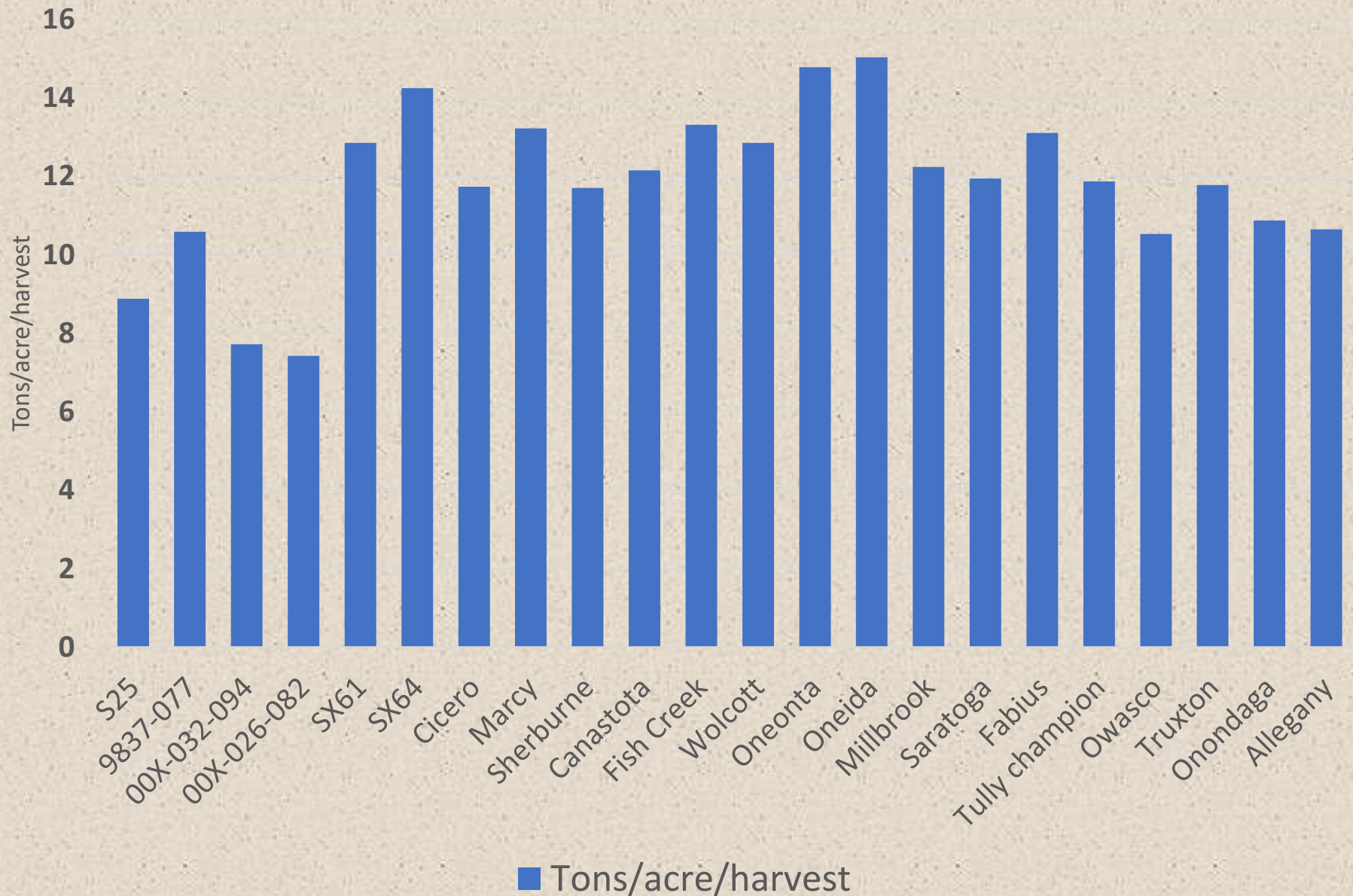


Table 5. Yield and rank of willow cultivars in Waseca, MN for three three-year harvests and total yield. The top five willow cultivars are highlighted.

Cultivar	Yield after 1 <sup>st</sup> harvest (Mg ha <sup>-1</sup> )		Yield after 2 <sup>nd</sup> harvest (Mg ha <sup>-1</sup> )		Yield after 3 <sup>rd</sup> harvest (Mg ha <sup>-1</sup> )		Total yield after three harvests (Mg ha <sup>-1</sup> )	
		Rank		Rank		Rank		Rank
SX64	30.4	1	34.9	5	30.6	4	95.8	3
Fabius	30.0	2	30.3	10	27.7	6	88.1	6
Oneida	29.4	3	37.1	1	34.5	2	101.1	1
SX61	28.8	4	34.9	4	22.6	15	86.4	8
Marcy	28.7	5	35.1	3	25.0	9	88.9	5
Oneonta	28.7	6	36.1	2	34.6	1	99.4	2
Millbrook	27.3	7	30.7	9	24.3	11	82.3	9
Fish Creek	27.2	8	32.6	6	29.7	5	89.5	4
Canastota	26.9	9	31.4	8	23.4	12	81.7	10
Wolcott	26.9	10	28.8	14	30.7	3	86.4	7
Truxton	26.9	11	29.6	13	22.8	14	79.2	13
Cicero	26.8	12	29.9	12	22.2	16	78.9	14
Saratoga	26.6	13	27.1	16	26.5	7	80.3	11
Owasco	26.5	14	24.8	20	19.4	21	70.8	20
9832-49	26.4	15	25.7	19	18.8	22	70.9	19
Sherburne	25.8	16	30.0	11	22.8	13	78.7	15
Otisco	25.5	17	20.4	21	20.1	19	66.0	21
9837-77	23.9	18	27.1	17	20.2	18	71.2	18
Tully Champion	22.7	19	31.4	7	25.6	8	79.8	12
Allegany	22.5	20	28.5	15	20.5	17	71.6	17
Onondaga	22.0	21	26.4	18	24.7	10	73.1	16
00X-032-094	20.8	22	18.2	24	12.9	23	51.9	23
00X-026-082	20.3	23	19.3	23	10.4	24	49.9	24
S25	19.8	24	20.3	22	19.6	20	59.7	22

Johnson, G.A., T.A. Volk,, K. Hallen, S. Shi, M. Bickell, and J. Heavey. 2018. Shrub willow biomass production ranking across three harvests in New York and Minnesota. Bio. Res.

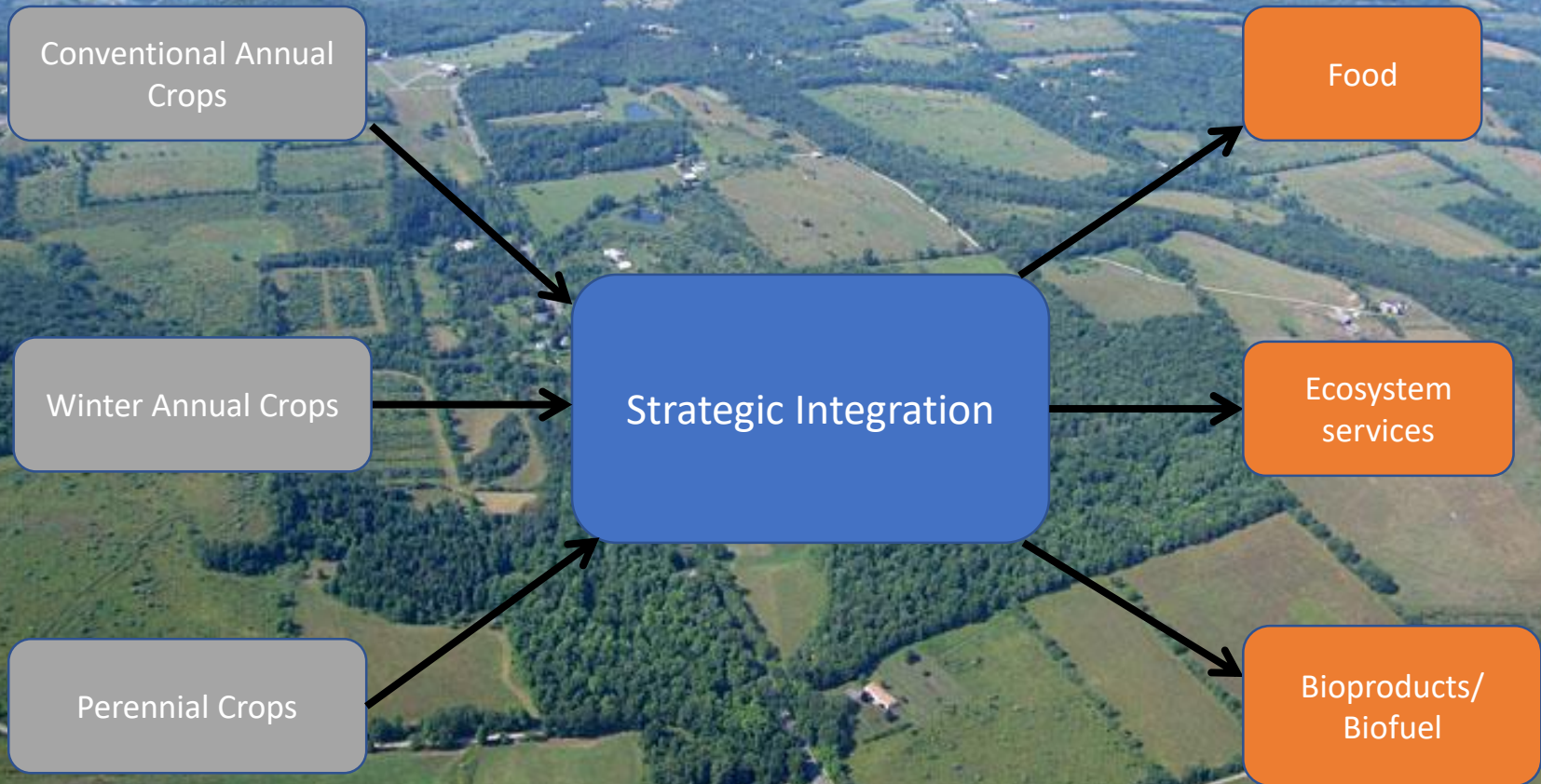


# Landscape Design



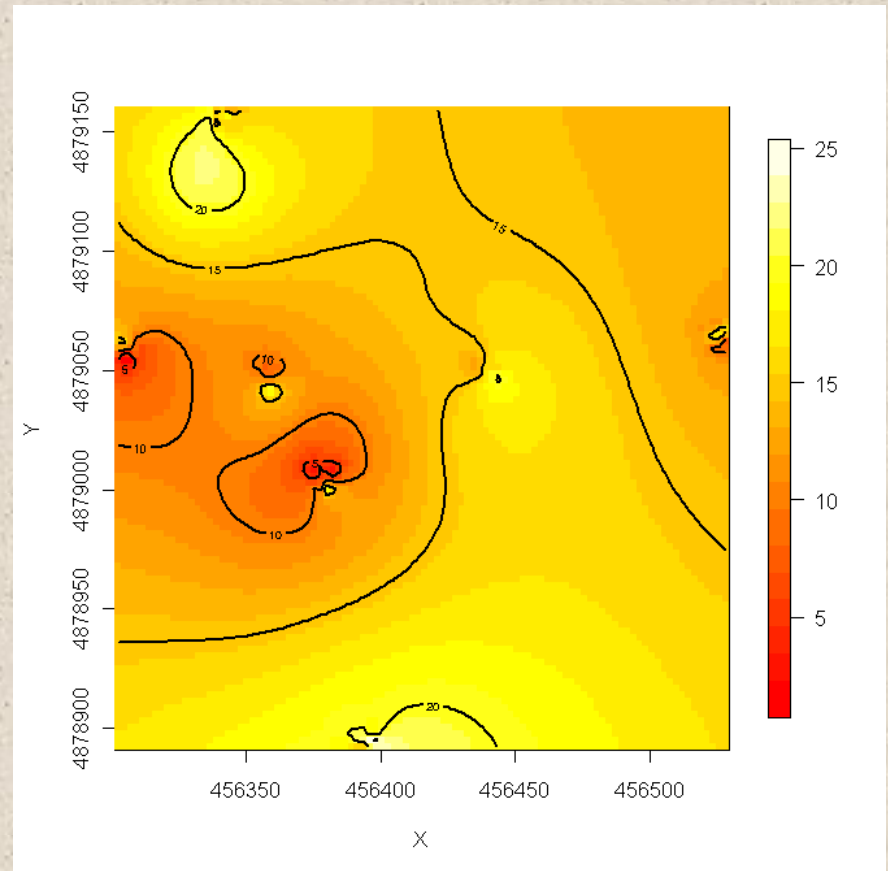
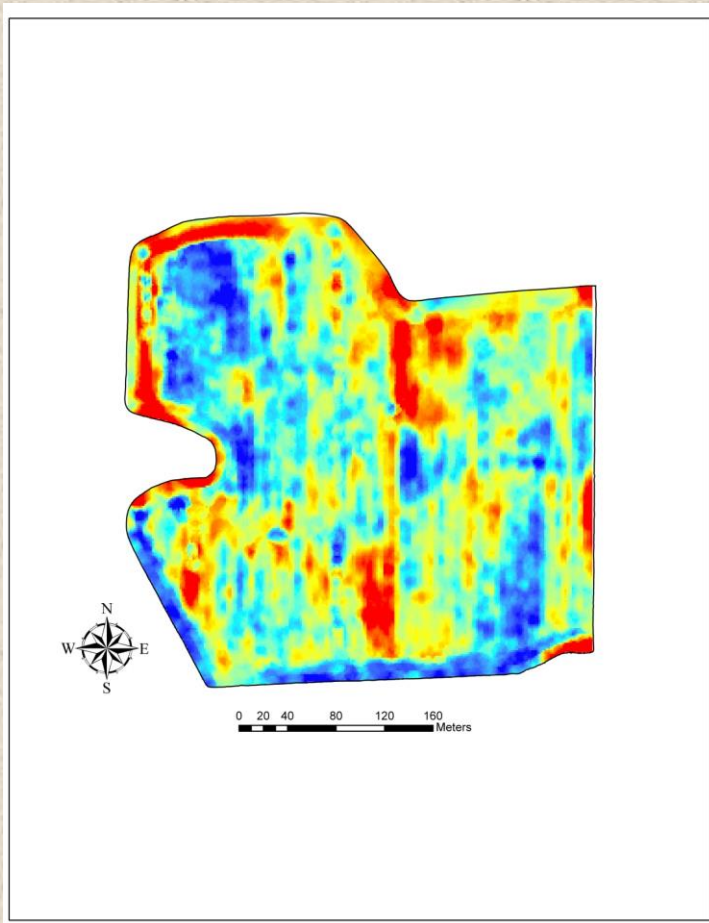


➤ How can agricultural systems be organized around multiple values, e.g. the production of food, bioproducts, and ecosystem services?





- ✓ Corn's sensitivity to changing landscape position presents opportunities to increase overall landscape productivity by integrating other crops into the landscape.



# Productivity Matrix for Biomass Crops

	Summit	Depositional	Flat	W hillslope	S hillslope	SW hillslope	N hillslope
Switchgrass	+	-	-	+	-	-	-
Alfalfa	+	-	+	-	+	+	+
Corn Stover	+	-	-	+	+	+	+
Corn Grain	+	-	-	+	+	-	+
Willow SX67	-	+	+		-	+	-
Willow 9882	-	+	+	-	-	-	-
Cottwd.D125	+	+	+	+	+	+	+
Poplar NM6	+	-	+	+	+	+	+



# Spatial Intensification

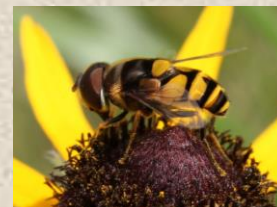


Resource availability  
Plant diversity  
Structural diversity  
Harvest timing





- ✓ Combine the benefits of bio-feedstock production with tangible ecosystem services in a way that provides greater value.





# Temporal Intensification



Field pennycress or camelina  
planted into corn, sweet corn,  
dry beans, sugar beets, etc.



Pennycress seeded into corn



Pennycress mid- May



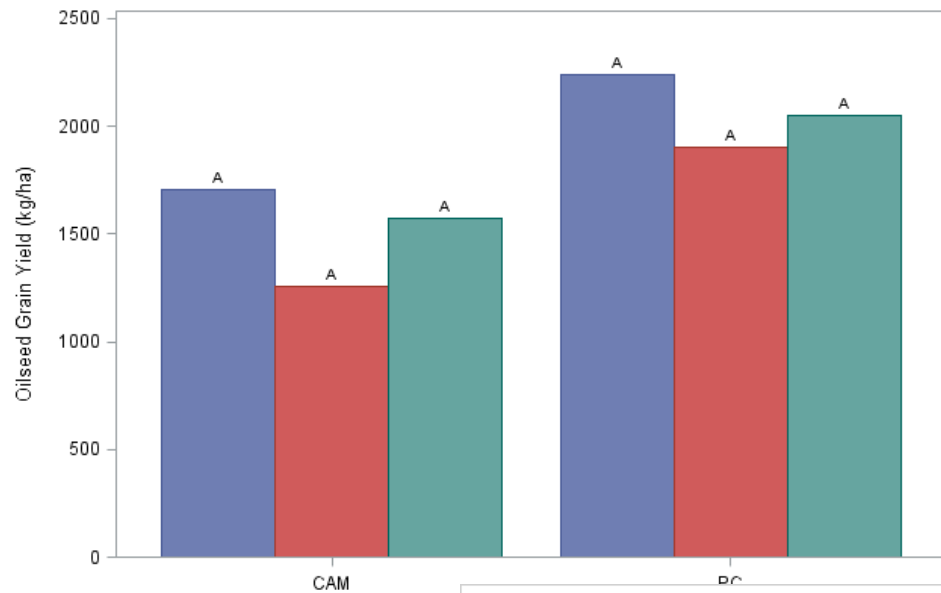
Relay cropping



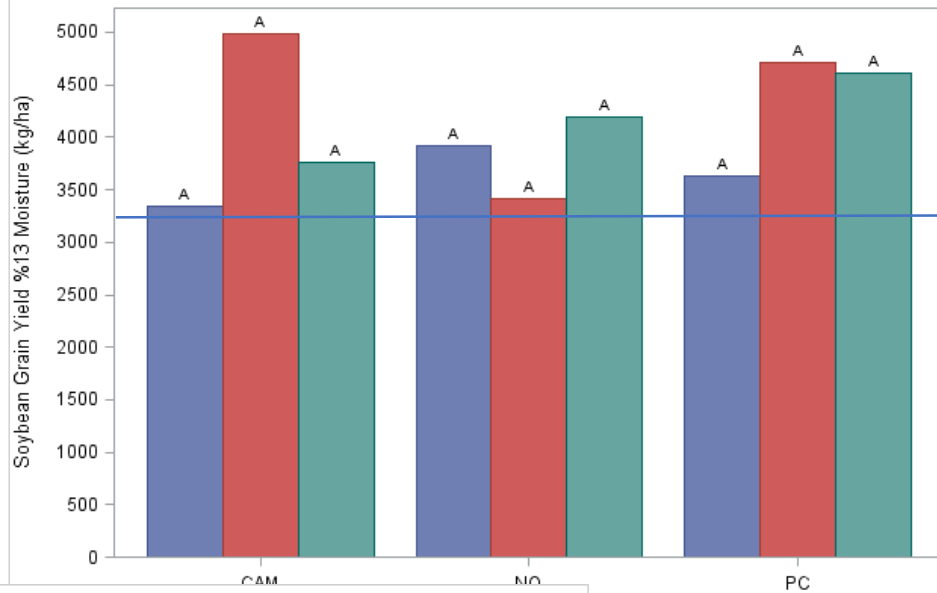
Double-cropping



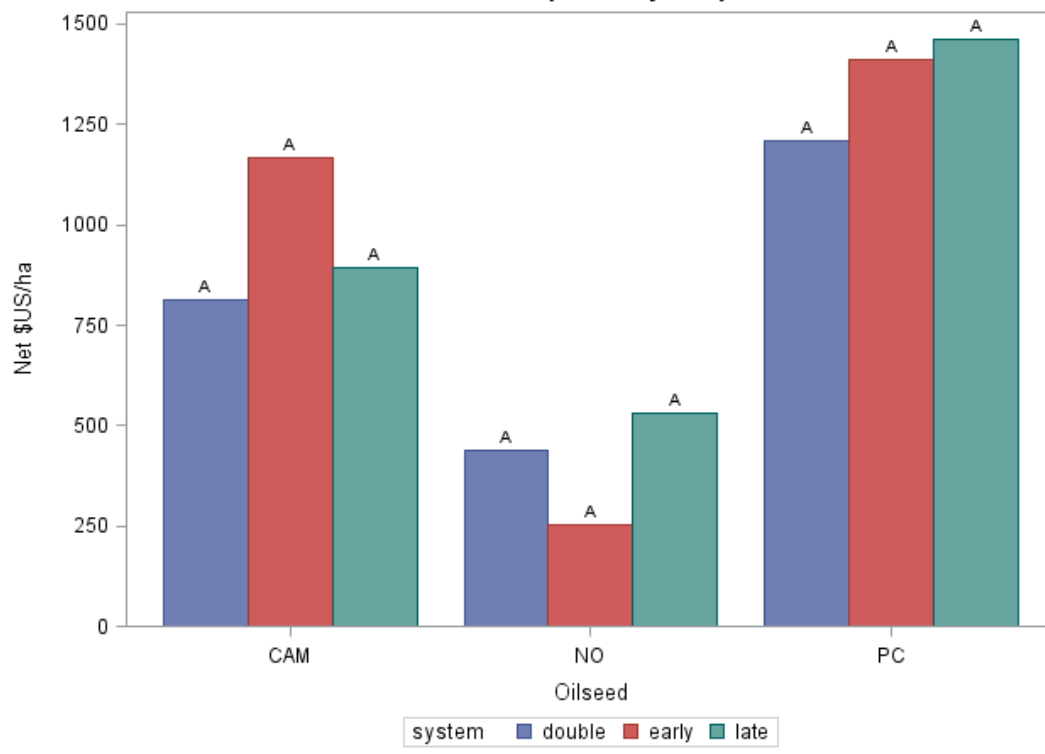
**Oilseed Yield: STP2014**



**Soybean Yield: STP2014**



**Total Net \$US/ha (Oil + Soybean): STP2014**



system

early late

*Slides courtesy of  
Dr. Scott Wells*

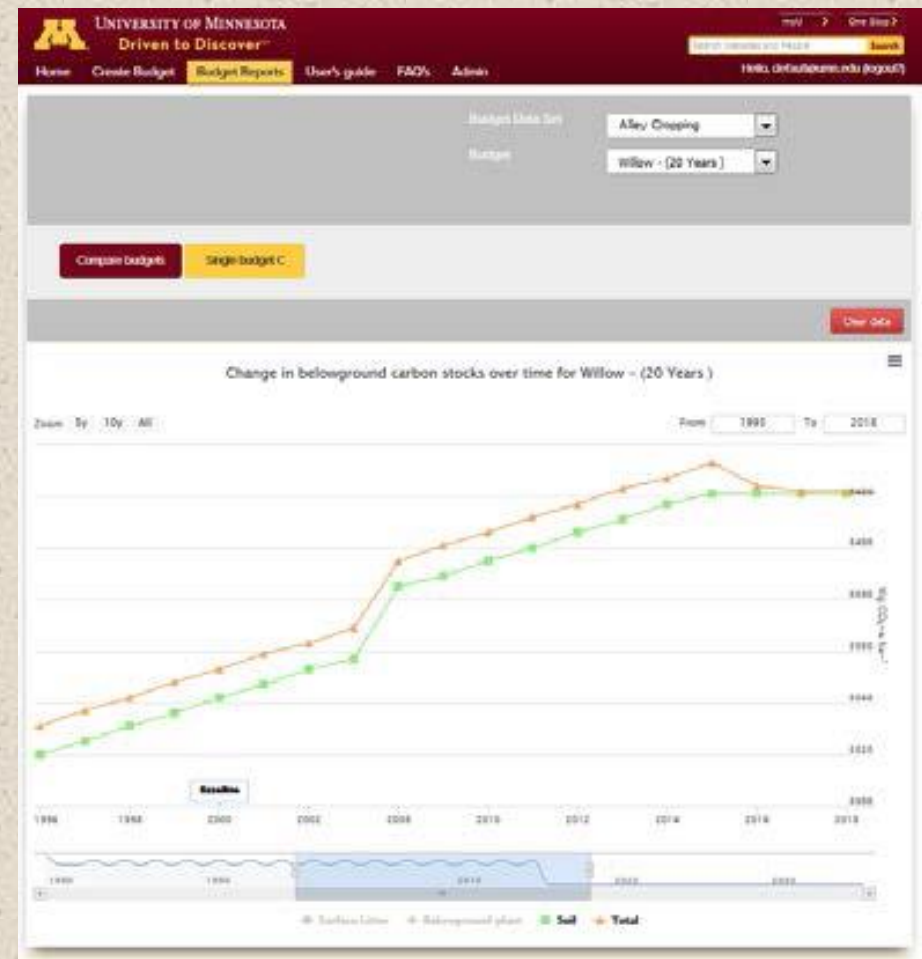
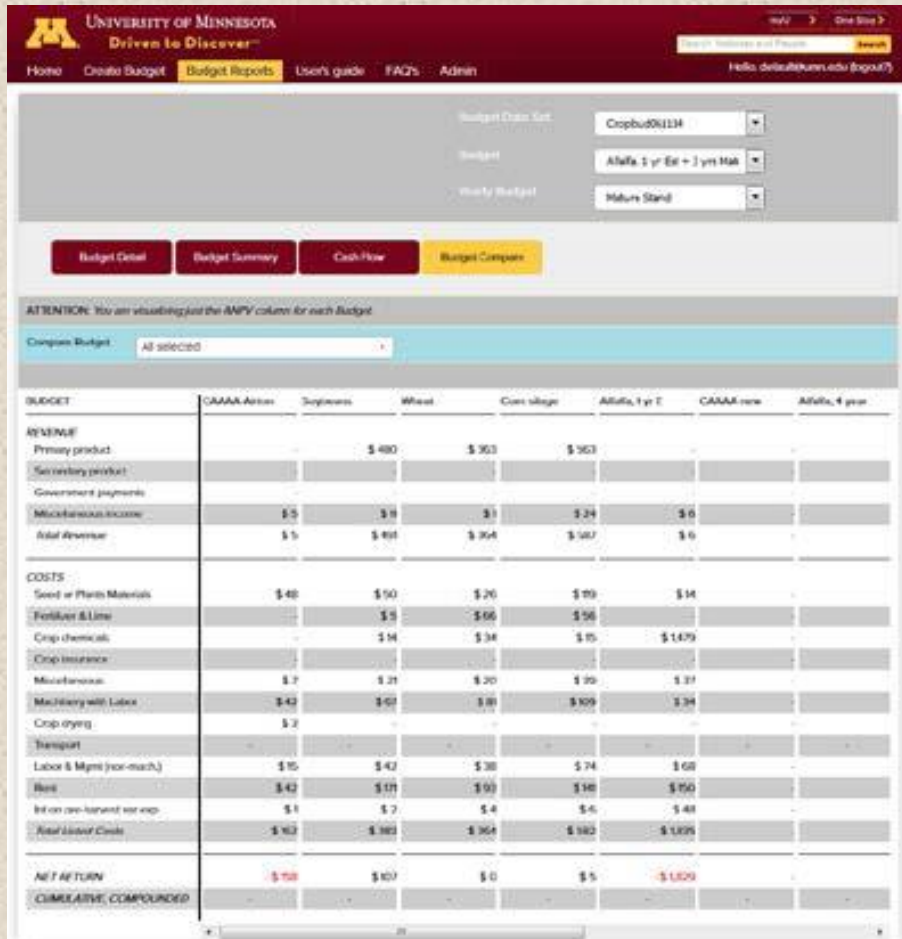


# Crop Enterprise and Environmental Budgeting Tool (CE<sup>2</sup>T)

- ✓ Designed to estimate the breakeven price needed to cover the costs of producing biomass/grain from conventional and alternative feedstocks as well as provide environmental information for broader decision-making.



- ✓ Reports are generated comparing the economics and environmental benefits between your current management practices and future scenarios.





# Forever Green Initiative

www.forevergreen.umn.edu



## Forever Green

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### Pennycress: Seed to Seed

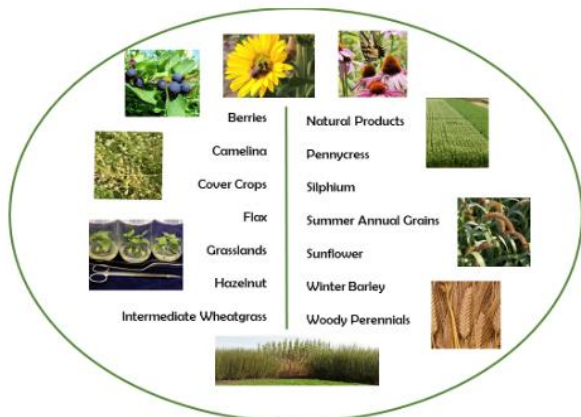
**Pennycress** is a winter annual oilseed; planted in the fall, dormant over winter, flush of growth in spring, maturity and harvest in time to plant a late-spring crop of soybeans.

Photo: Kayla Altendorf, U of MN



Working together we can enhance and develop new agricultural systems that will improve natural resources and provide new economic opportunities. Our team consists of experts in the areas of genomics, breeding, agronomics and commercialization.

The Forever Green Initiative is a University of Minnesota and USDA Agriculture Research Service (ARS) program to develop new crops and high-efficiency cropping systems. [READ MORE](#)



## Minnesota Long-Term Agricultural Research Network

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- Data

» ABOUT MN LTARN

### About MN LTARN

Society is challenging agriculture to provide an abundant, safe and healthy food supply along with a range of other products like animal products and bio-industrial feedstocks on an ever-shrinking resource base. Current agricultural practices are also facing acute challenges such as an increasing weed and insect resistance to pesticides and greater volatility in input costs and crop prices. It is important that our response to these issues does not compromise key ecosystem services or the natural resource base.

To better address the comprehensive and integrated nature of these challenges, the University of Minnesota recently initiated a Long-Term Agricultural Research Network (LTARN) that provides a regional platform for the development of novel and adaptive agricultural production strategies. Specifically, the LTARN is focused on strategies that facilitate the study of critical biophysical interactions among plants, soils, and microbes with goal of improving overall system efficiency, productivity, and stability. Understanding tradeoffs among the need for 1) greater productivity per unit area, 2) reduced short and long-term risks, and 3) greater system stability/resiliency of agriculture is a critical component of this work.

The LTARN currently comprises three research sites located across Minnesota – Waseca (south central), Lamberton (southwest), and Grand Rapids (northeast). A series of six cropping system models, including both annual and perennial crop sequences, are established at all network nodes in a large-plot replicated design. Cropping system models range from simple 2-crop rotation to complex perennial-based cropping systems. Multidisciplinary research within the LTARN employs both short- and medium-term studies to predict the long-term trends key to sustainability. Our network model provides uniformity and continuity to research across locations and over years. Our approach is also strongly linked to education and outreach.



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### Working Lands Watershed Restoration Feasibility Study and Program Plan

Report to the Minnesota Legislature  
February 1, 2018

# Minnesota LTARN

LTARN.cfans.umn.edu