Crop Enterprise Budgets for Use in the Working Lands Watershed Restoration Project: Key Results, Spreadsheet Design, and Data Sources

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Last updated 1/30/18

Contents

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Summary and key results

The Minnesota Legislature directed the Board of Water and Soil Resources (BWSR) to conduct a feasibility study of a Working Lands Watershed Restoration Program. Section 4 of SF2711/HF2881 contained the language:

> "…incentivize the establishment and maintenance of perennial crops…an assessment of the contract terms …including consideration of variable rates for lands of different priority or type…"

Under our contract with BWSR, we translated that language into the following research questions:

- Based on the commercial value of a number of alternative perennial crops and cover crops, how would a typical producer's net income per acre compare to that of the annual row crops grown in several pilot watersheds in Minnesota?, and
- Assuming that the alternative crop income is less than income provided by current crops, what subsidy would be required to bring the alternative crop income up to a level equal to the current crop income?

The income measure we use in the analysis is net return to land. That means that all of the usual inputs are included on the cost side including labor but omitting land rent or land ownership expenses such as real estate taxes. Land cost is omitted to simplify the calculations and because it is assumed that the cropland is a sunk cost and is going to be there and under the same ownership and control regardless of the crop grown.

BWSR staff selected six HUC12-scale watersheds for study (see Table 1). It was recognized that crop income for a given crop tends to vary with soil quality as it affects yield, and that environmental sensitivity of different soils varies with factors such as erodibility. We selected the crop productivity index (CPI) provided in the USDA-NRCS soil survey to calculate crop yields. We translated the CPI to yields of the current crops based on the ratio of county average crop yields reported by the USDA National Agricultural Statistics Service to the average CPI for cropland planted to that crop in the county. It turns out that the CPI and actual yields of corn and soybeans is less than perfectly correlated, based on the average yields for 2012-16. The ratio of corn grain yield to CPI ranges from 1.96 for the Rogers Creek watershed to 2.27 bushels for Getchell Creek (Table 3). Soybean yields varied similarly. The ratios of corn grain and soybean yields to CPI were weighted by their percentages in the crop mix and used to calculate the adjustment factors shown in the table. The yields of the alternative crops are varied in the budgets based on the CPI times those adjustment factors in order to be consistent with the corn and soybean yields in the current crop mix. A few of the costs (such as corn drying and phosphorus and potassium fertilizer) also vary with yield, but most costs (such as tillage and planting equipment costs) are independent of yield.

We selected the soil survey land capability classes (LCC) as a measure of environmental sensitivity.

We evaluated crop income at three levels of analysis at income based on yields at:

1) the average CPI for the cropland in the current crops in the entire watershed,

2) The average CPI for cropland in the current crops in LCC 3 and over six percent slope, or in LCC 4-8 at any slope (referred to as "marginal land" below), and

3) The CPI for individual soils as described by the soil survey mapping units.

The results for levels 1 and 2 are discussed in this document. The results for level 3 are described in a separate document, which is only in draft form at present.

Watersheds

Table 1. Pilot watersheds, their average CPIs, percent marginal land, and the average CPIs of the marginal land in each watershed along with the average CPI for the counties surrounding the watersheds

Watershed	Average Crop Productivity Index	Percent marginal (capability class 3+)	Crop Productivity Index, marginal
Rogers Creek	87	7%	55
Shakopee Creek	82	20%	63
Getchell Cr/Co. Ditch 9	79	20%	31
Freeborn Lake-Cobb R	91	22%	77
Watson Creek	80	41%	68
Whiskey Cr, parts of the lower & upper reaches	71	46%	50
Surrounding counties	81		


Whiskey Creek
Getchell Cr/Co. Ditch 9
Shakopee Creek
Rogers Creek
Watson Creek
Freeborn Lake - Cobb R

Crop and livestock enterprises considered

The current annual crops selected for analysis were those that made up at least 90 percent of the annual crop acreage in the counties surrounding each watershed. The crops meeting that criterion were just corn and soybeans for five of the watersheds. Spring wheat and sugar beets along with corn and soybeans met that criterion in the Whiskey Creek watershed.

Table 2. Alternative crops evaluated

General category	Specific crop and rotation
Perennial crops for biomass energy	Switchgrass
	Miscanthus
Dual purpose perennial crop providing both grain and biomass	Kernza
Cover crop providing soil health benefits but not a product for cash sale	Covercrop in a rotation of corn, soybeans, and a small grain
	Covercrop in a corn-soybean rotation
"Cash" cover crop with a product for cash sale	Camelina in a corn-soybean rotation
	Camelina in a corn-wheat-soybean rotation
	Pennycress in a corn-wheat-soybean rotation
Livestock enterprise including grazing of perennial pasture and cover crops	Grass-fed beef
	Beef cow-calf
	Grazing dairy (organic)
	dairy heifers in a production contract or for cash sale
Perennial crop for cash sale as livestock feed	Alfalfa hay for sale

Some of the alternative enterprises are already produced in the state, namely the livestock enterprises, alfalfa, and the cover crops for soil health. For those crops, the idea of the program subsidies would be to expand acreage, because current acreage is limited by market conditions or costs. On the other hand, the biomass energy crops and the cash cover crop budgets are "hypothetical" in the sense that processing plants and significant markets do not yet exist in the state. They are included in order to show what the potential might be if markets do develop. A small market has already developed for Kernza, but acreage is so far too small to have significant environmental benefits.

A set of crop enterprise budgets was developed in Microsoft Excel 2016 for use in the evaluation. The organization of the spreadsheet and the data sources are described below. The main data source for the current crops, the livestock enterprises, and alfalfa was the FINBIN farm business and financial database. Crop insurance premiums and indemnities are omitted for simplicity, because over time those two items should balance out. Government commodity payments are also omitted.

The data for the other alternative crops came from a variety of sources. Other documents in this project make reference to mixed crops for biomass energy or feed. The budgets assume that the switchgrass and miscanthus are monocultures, for simplicity. One mix often mentioned for biomass is a mix of switchgrass, big bluestem, and indiangrass. The spreadsheet could be expanded to include those other two species, but that has not been done so far because it is not likely to change the overall costs and net income very much compared with the switchgrass monoculture.

Price scenarios

As of this writing, the prices of most agricultural commodities are depressed compared to where they were a few years ago. Two price scenarios are included in the spreadsheet default inputs. Users can toggle between them to see how the calculated subsidies and other results are affected. The two price scenarios are: 1) current and 2) five-year average of 2012-16. The "current" scenario is based on our best estimate of prices for next year (2018) based mainly on 2017 except where we could identify a price forecast that is different from 2017. One example of this is in organic milk, where indications are that the organic premium has declined recently. The "current" price scenario may be the most realistic one to expect for the next year or two. The BWSR staff indicated that the project team should consider a timeframe of around five years. It is possible that prices will recover over that timeframe, especially if a major weather event such as a drought were to occur somewhere in the world. The 2012-16 scenario reflects that possibility. The most recent data in FINBIN is for 2016. The costs in the budgets for the current crops, the livestock, and alfalfa are based mainly on FINBIN, using the 2016 data for the current price scenario and the 2012-16 average for that scenario. One expense that appears to be fairly responsive to crop prices and so has declined, is fertilizer. The prices and costs used in the budgets are shown in Table 3. The switchgrass, miscanthus, and Kernza prices were kept the same in both scenarios due to lack of information.

In a long-range equilibrium in a perfectly-competitive market, producers would be expected to bid land rents up or down until they are closely aligned with returns to land with current crops. If the CRP rates are aligned with local cropland rental rates, then the CRP rates should be closely correlated with current crop returns. Table 4 shows how closely the land returns in our budgets with the current crop mix correlate with land rents reported by producers in FINBIN and with the weighted average CRP rates in the counties that either surround the pilot watersheds or are centrally located in them (Hachfeld, Lazarus et al. 2017, Steinhilber 2017).

Crop enterprise budget net returns to land and rental rates for the pilot watersheds

Tables 5 and 6 below shows that nonland costs at the 81 average CPI are 67 percent of gross revenues for the current crop mix at the 2012-16 five-year average crop prices and costs and 75 percent at current prices and costs. For the alternative enterprises that do not include livestock, costs vary from 54 percent for alfalfa to 107 percent for miscanthus. Note that the costs considered in this comparison are just nonland costs. Including land costs would make the margin over total costs much tighter than shown here.

Table 3. Price and cost scenarios

Crop	Units of measure	Current	Avg 2012-16
Corn grain	per bu	$3.50	$4.31
Corn grain total nonland costs	per acre	$509	$563
Soybeans	per bu	$9.00	$10.72
Soybeans total nonland costs	per acre	$263	$271
Wheat	per bu	$5.50	$6.05
Wheat total nonland costs	per acre	$247	$280
Sugar beets	per ton	$35.00	$44.32
Sugar beets total nonland costs	per acre	$964	$1,010
Switchgrass	per dry ton	$40.00	$40.00
Miscanthus	per dry ton	$40.00	$40.00
Kernza	per pound	$0.75	$0.75
Camelina	per pound	$0.15	$0.18
Pennycress	per pound	$0.15	$0.18
Alfalfa hay for feed on-farm	per ton	$121	$157
Alfalfa hay for feed, organic	per ton	$146	$162
Alfalfa hay for sale	per ton	$81	$144
Grass hay	per ton	$67	$91
Grass hay, organic	per ton	$92	$122
Pasture, intensive	per AUM	$26	$26
Pasture, organic	per AUM	$35	$39
Grass-fed beef, gross margin	$/head	$547	$685
Grass-fed beef, nonland costs	$/head	$554	$695
Beef cow-calf, gross margin	$/head	$700	$893
Beef cow-calf, nonland costs	$/head	$734	$867
Grazing dairy (organic)	per cwt milk	$22.34	$28.05
Grazing dairy (organic) nonland costs	per head	$3,552	$3,468
Dairy heifers, gross margin	$/head	$758	$564
Dairy heifers, nonland costs	$/head	$758	$774

Table 4. Watershed budgeted land returns compared with land rental rates with the current crop mix and Conservation Reserve Program rates for surrounding counties

Watershed	CPI	Corn %, 2016	Corn yield/ CPI	Adjust-ment factor	Land return, 2012-16 prices & costs	Land return, current prices & costs	County	FINBIN Rental rates, 2016	CRP rates (weighted average)
Freeborn Lake-Cobb R	91	57%	2.05	0.99	$281	$187	Freeborn	$247	$183
Shakopee Creek	82	61%	2.09	0.98	$215	$133	Kandiyohi	$220	$183
Getchell Cr/Co. Ditch 9	79	58%	2.27	1.06	$231	$147	Stearns	$183	$130
Rogers Creek	87	62%	1.96	0.95	$219	$135	Nicollet	$231	$177
Watson Creek	80	67%	2.22	1.06	$236	$149	Fillmore	$205	$190
Whiskey Cr, part L & U	71	31%	2.11	0.96	$117	$51	Clay	$137	$117
Surrounding counties	81	53%	2.12	1.00					

Table 5. Enterprises sorted by cost percent of gross revenue, 2012-16 prices and costs

	Gross revenue/ acre	Nonland cost/ acre	Nonland cost % of gross	Return to land/acre @ 81 CPI
Current crop mix, surrounding counties	$647	$434	67%	$213
Alternative enterprises, non-livestock				
Alfalfa hay for sale	$676	$363	54%	$313
Pennycress	$594	$380	64%	$214
Camelina Corn-Wht-Soy	$594	$380	64%	$214
Camelina Corn-Soy	$672	$489	73%	$183
Covercrop Sm Grain	$625	$408	65%	$217
Switchgrass	$162	$107	66%	$55
Covercrop Corn Soy	$672	$489	73%	$183
Kernza	$206	$159	77%	$47
Miscanthus	$284	$304	107%	-$20
Livestock enterprises				
Grazing dairy (organic)	$2,047	$1,715	84%	$294
Beef cow-calf	$619	$529	85%	$59
Dairy heifers	$652	$618	95%	$32
Grass-fed beef	$602	$581	97%	$23

Table 6. Enterprises sorted by cost percent of gross revenue, current prices and costs

	Gross revenue/ acre	Nonland cost/ acre	Nonland cost % of gross	Return to land/acre @ 81 CPI
Current crop mix, surrounding counties	$532	$402	75%	$131
Alternative enterprises, non-livestock				
Switchgrass	$162	$107	66%	$55
Pennycress	$500	$350	70%	$151
Camelina Corn-Wht-Soy	$500	$350	70%	$151
Camelina Corn-Soy	$556	$403	72%	$153
Covercrop Sm Grain	$521	$387	74%	$134
Kernza	$206	$159	77%	$47
Covercrop Corn Soy	$548	$453	83%	$95
Alfalfa hay for sale	$381	$363	95%	$18
Miscanthus	$284	$304	107%	-$20
Livestock enterprises				
Beef cow-calf	$550	$425	77%	$36
Grass-fed beef	$481	$455	95%	$26
Grazing dairy (organic)	$1,585	$1,667	105%	$-82
Dairy heifers	$611	$588	96%	$22

Subsidy comparisons

Given the two soil categories (entire watershed and land capability classes 3-8) and two price scenarios (current and 2012-16 average), there are four comparisons that can be made. Tables 7-10 show the subsidy levels suggested by the budgets. The watersheds are sorted by CPI in these tables. Negative numbers mean that the alternative crop appears to be more profitable than the current crop mix in the watershed. The previous section's discussion might suggest that the subsidies would vary in direct proportion to the differences in CPI from one watershed to the next. They do not follow that pattern exactly, probably because the percentages of the current crops vary from one watershed to the next so that the land return for the current crop mix is not the same. Watson Creek shows larger subsidies because it has more corn and less soybeans than the other watersheds, and corn is less profitable than soybeans in the budgets. Whiskey Creek has wheat and sugar beets, which have been less profitable than soybeans and corn recently. Notice in Table 7 that alfalfa hay, pennycress, camelina, and cover crops following a small grain all provide land returns higher than the current crop mix at the baseline 81 CPI. Table 8 shows that at current prices and costs, one difference is that the revenue-cost margin is much tighter for alfalfa hay because of its lower price. Grazing dairy (organic) also shows a steep increase in the amount of subsidy required.

The bolded numbers in Table 7 indicate enterprises that the project team thought might provide for a desirable distribution of enterprises across the six watersheds, also considering the current agricultural infrastructure:

Table 7. Amount of subsidy, if any, required for net returns to land comparable to current crops on ALL land with 2012-16 prices and costs

	Freeborn Lake-Cobb R	Rogers Creek	Shakopee Creek	Watson Creek	Getchell Cr/Co. Ditch 9	Whiskey Cr, part L & U	Surrounding counties
Crop productivity index	91	87	82	80	79	71	81
Subsidy required, $/A							
Land retirement	311	248	245	266	261	146	243
Switchgrass	208	162	161	174	**172**	87	158
Miscanthus	269	236	237	244	244	145	233
Kernza	210	169	**169**	180	179	**102**	165
Covercrop Sm Grain	8	1	0	-1	2	-18	-4
Covercrop Corn Soy	**34**	36	36	**36**	35	14	30
Camelina Corn-Soy	-30	**-26**	**-20**	-35	-24	-21	-29
Camelina Corn-Wht-Soy	11	4	4	1	5	-11	-1
Pennycress	11	4	4	1	5	-11	-1
Grass-fed beef	246	193	192	211	208	**107**	190
Beef cow-calf	201	156	157	172	171	84	154
Grazing dairy (organic)	-80	-89	-79	**-73**	-69	-95	-81
Dairy heifers	232	183	183	200	198	103	180
Alfalfa hay for sale	**-109**	**-101**	-96	-107	-100	-90	-101

Table 8. Amount of subsidy, if any, required for net returns to land comparable to current crops on ALL land with current prices and costs

	Freeborn Lake-Cobb R	Rogers Creek	Shakopee Creek	Watson Creek	Getchell Cr/Co. Ditch 9	Whiskey Cr, part L & U	Surrounding counties
Crop productivity index	91	87	82	80	79	71	81
Subsidy required, $/A							
Land retirement	217	165	162	178	176	81	161
Switchgrass	114	79	78	87	87	21	76
Miscanthus	176	153	154	157	160	79	151
Kernza	117	86	86	92	94	36	83
Covercrop Sm Grain	4	-3	-4	-5	-1	-6	-4
Covercrop Corn Soy	39	39	39	39	39	24	35
Camelina Corn-Soy	-23	-21	-16	-30	-18	-17	-22
Camelina Corn-Wht-Soy	-10	-16	-16	-19	-14	-27	-20
Pennycress	-10	-16	-16	-19	-14	-27	-20
Grass-fed beef	148	106	106	120	120	39	105
Beef cow-calf	134	97	97	108	109	36	95
Grazing dairy (organic)	266	219	215	228	227	138	213
Dairy heifers	151	111	111	124	124	46	109
Alfalfa hay for sale	127	114	116	114	119	93	113

Table 9. Amount of subsidy, if any, required for net returns to land comparable to current crops on MARGINAL land with 2012-16 prices and costs

	Freeborn Lake-Cobb R	Shakopee Creek	Watson Creek	Rogers Creek	Whiskey Cr, part L & U	Getchell Cr/Co. Ditch 9	Surrounding counties
Crop productivity index	72	57	54	48	45	27	81
Subsidy required, $/A							
Land retirement	203	169	96	22	-9	-123	243
Switchgrass	129	50	103	-5	-29	-110	158
Miscanthus	201	94	168	20	-11	-124	233
Kernza	139	68	115	19	-3	-76	165
Covercrop Sm Grain	0	-11	-12	-20	-14	-28	-4
Covercrop Corn Soy	35	37	37	39	18	40	30
Camelina Corn-Soy	-24	-20	-32	-15	-33	-7	-29
Camelina Corn-Wht-Soy	2	-10	-9	-17	-39	-26	-1
Pennycress	2	-10	-9	-17	-39	-26	-1
Grass-fed beef	156	64	129	-2	-30	-133	190
Beef cow-calf	126	46	102	-11	-36	-130	154
Grazing dairy (organic)	-85	-84	-100	-119	-128	-164	-81
Dairy heifers	149	62	123	-1	-28	-129	180
Alfalfa hay for sale	-97	-86	-99	-78	-78	-60	-101

Table 7. Amount of subsidy, if any, required for net returns to land comparable to current crops on MARGINAL land with current prices and costs

	Freeborn Lake-Cobb R	Shakopee Creek	Watson Creek	Rogers Creek	Whiskey Cr, part L & U	Getchell Cr/Co. Ditch 9	Surrounding counties
Crop productivity index	72	57	54	48	45	27	81
Subsidy required, $/A							
Land retirement	129	100	41	-20	-45	-137	161
Switchgrass	55	-5	33	-46	-64	-124	76
Miscanthus	127	39	98	-21	-47	-139	151
Kernza	65	13	46	-23	-39	-90	83
Covercrop Sm Grain	-2	-12	-12	-18	-4	-22	-4
Covercrop Corn Soy	39	39	39	39	24	39	35
Camelina Corn-Soy	-18	-15	-26	-10	-24	-2	-22
Camelina Corn-Wht-Soy	-15	-23	-25	-28	-46	-32	-20
Pennycress	-15	-23	-25	-28	-46	-32	-20
Grass-fed beef	80	7	57	-44	-66	-147	105
Beef cow-calf	73	8	52	-39	-60	-136	95
Grazing dairy (organic)	184	153	98	39	12	-91	213
Dairy heifers	85	15	63	-36	-58	-139	109
Alfalfa hay for sale	106	84	95	69	61	44	113

The enterprises requiring the lowest subsidies appear to be as follows:

Crops requiring the lowest subsidy, 2012-16 average prices and costs

Average of all cropland in the entire watershed					
Freeborn Lake-Cobb R	Rogers Creek	Shakopee Creek	Watson Creek	Getchell Cr/Co. Ditch 9	Whiskey Cr, part L & U
91	87	82	80	79	71
Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Grazing dairy (organic)
Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Alfalfa hay for sale
Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy

Severely erosive or poorly drained cropland (Capability class 3+)

Freeborn Lake-Cobb R	Shakopee Creek	Watson Creek	Rogers Creek	Whiskey Cr, part L & U	Getchell Cr/Co. Ditch 9
77	68	63	55	50	31
Alfalfa hay for sale	Alfalfa hay for sale	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)
Grazing dairy (organic)	Grazing dairy (organic)	Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Grass-fed beef
Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Switchgrass	Switchgrass	Beef cow-calf

Crops requiring the lowest subsidy, current prices and costs

Average of all cropland in the entire watershed					
Freeborn Lake-Cobb R	Rogers Creek	Shakopee Creek	Watson Creek	Getchell Cr/Co. Ditch 9	Whiskey Cr, part L & U
91	87	82	80	79	71
Camelina Corn-Soy	Camelina Corn-Soy	Pennycress	Camelina Corn-Soy	Camelina Corn-Soy	Pennycress
Pennycress	Pennycress	Camelina Corn-Wht-Soy	Pennycress	Pennycress	Camelina Corn-Wht-Soy
Camelina Corn-Wht-Soy	Camelina Corn-Wht-Soy	Camelina Corn-Soy	Camelina Corn-Wht-Soy	Camelina Corn-Wht-Soy	Camelina Corn-Soy

Severely erosive or poorly drained cropland (Capability class 3+)

Freeborn Lake-Cobb R	Shakopee Creek	Watson Creek	Rogers Creek	Whiskey Cr, part L & U	Getchell Cr/Co. Ditch 9
77	68	63	55	50	31
Camelina Corn-Soy	Pennycress	Camelina Corn-Soy	Grazing dairy (organic)	Grazing dairy (organic)	Grass-fed beef
Pennycress	Camelina Corn-Wht-Soy	Pennycress	Switchgrass	Grass-fed beef	Dairy heifers
Camelina Corn-Wht-Soy	Grazing dairy (organic)	Camelina Corn-Wht-Soy	Grass-fed beef	Switchgrass	Land retirement

Comparing 2012-16 average prices and costs versus current prices and costs, all cropland in the watershed:

2012-16 average prices and costs					
Freeborn Lake-Cobb R	Rogers Creek	Shakopee Creek	Watson Creek	Getchell Cr/Co. Ditch 9	Whiskey Cr, part L & U
91	87	82	80	79	71
Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Grazing dairy (organic)
Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Alfalfa hay for sale
Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy
Current prices and costs					
Camelina Corn-Soy	Camelina Corn-Soy	Pennycress	Camelina Corn-Soy	Camelina Corn-Soy	Pennycress
Pennycress	Pennycress	Camelina Corn-Wht-Soy	Pennycress	Pennycress	Camelina Corn-Wht-Soy
Camelina Corn-Wht-Soy	Camelina Corn-Wht-Soy	Camelina Corn-Soy	Camelina Corn-Wht-Soy	Camelina Corn-Wht-Soy	Camelina Corn-Soy

Comparing 2012-16 average prices and costs versus current prices and costs, severely erosive or poorly drained cropland (Capability class 3+):

2012-16 average prices and costs					
Freeborn Lake-Cobb R	Shakopee Creek	Watson Creek	Rogers Creek	Whiskey Cr, part L & U	Getchell Cr/Co. Ditch 9
77	68	63	55	50	31
Alfalfa hay for sale	Alfalfa hay for sale	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)	Grazing dairy (organic)
Grazing dairy (organic)	Grazing dairy (organic)	Alfalfa hay for sale	Alfalfa hay for sale	Alfalfa hay for sale	Grass-fed beef
Camelina Corn-Soy	Camelina Corn-Soy	Camelina Corn-Soy	Switchgrass	Switchgrass	Beef cow-calf
Current prices and costs					
Camelina Corn-Soy	Camelina Corn-Soy	Pennycress	Switchgrass	Grass-fed beef	Grass-fed beef
Pennycress	Pennycress	Camelina Corn-Wht-Soy	Grass-fed beef	Switchgrass	dairy heifers
Camelina Corn-Wht-Soy	Camelina Corn-Wht-Soy	Camelina Corn-Soy	Beef cow-calf	Beef cow-calf	Land retirement

Using the budgets to evaluate the impact of a new processing plant

One way in which the budgets could be useful is in evaluating the impact that might result from a processing plant in the state. The switchgrass budget results shown above in Table 7 are based on a $40/ton price, based on limited information about its potential use as poultry barn bedding. In the Whiskey Creek watershed, for example, under 2012-16 prices, a typical producer with soils with a CPI of 71 would require a subsidy of $87/acre/year to switch from the current crops to switchgrass. But, since in reality there is no market at all for switchgrass in the near term, the subsidy in that watershed would actually need to be $223/acre/year. If a processing plant were built so that a market existed for switchgrass, a price of $65/ton would provide returns to land similar to the current crop mix at 2012-16 average prices.

Table 8 shows that at the current depressed crop prices, the subsidy for switchgrass in Whiskey Creek is only $21/acre at a price of $40/ton. It is $158/acre at a zero price. A $47/ton price would be enough to eliminate the need for the subsidy under the current prices.

Spreadsheet organization

The budgets for the current annual crops are included in a single sheet labeled “Annual_crop_budgets”. The budgets for the perennial crops and cover crops are in individual sheets because the line items and year-to-year patterns of revenues and expenses are somewhat different from one to the next.

The key summary values are transferred over to the “Returns_by_CPI” sheet. These key values include total revenue, nonland costs, and net return to land from all of the current and alternative crop budgets, along with the crop prices. That sheet also contains two Excel data tables that iteratively recalculate the budgets for a range of Crop Productivity Index values. The bottom data table provides the data for the graphs.

The data tables are a convenient Excel feature, but they complicate the spreadsheet design slightly because their row and column input cells must be in the same sheet as the table. The crop yields entered in the other sheets are linked to the CPI value in cell A20 of the “Returns_by_CPI” sheet in order to make the net returns to land and the other results calculate properly in the data tables.

The “Watershed List” sheet lists the overall HUC8 watersheds under consideration in the overall BWSR project along with the smaller HUC10 or HUC12 watersheds included in this spreadsheet. Also included in this sheet are:

- Total acres in each watershed
- Acres of corn and soybeans in each watershed, plus acres of spring wheat and sugar beets in the Whiskey Creek watershed
- Acres of those crops on land classified in the USDA-NRCS soil survey as Land Capability Class 3 with slopes of 6 percent or greater, and in classes 4-8 (abbreviated as “LCC 3+” in this document).
- Percentages of the four crops on the LCC 3+ land in each watershed
- Average Crop Productivity Index (CPI) for:
    - the LCC 3+ land in the four crops,
    - all watershed land in the four crops, and
    - all land in the surrounding counties in those four crops.

- Crop yield per point of CPI based on 2016 USDA-NASS yields for the counties surrounding each of the watersheds
- Net return per acre under the four current crops, by default at the LCC 3+ crop yields or optionally at the average crop yields for the entire watersheds (the crop yields vary proportionately with the CPI).

The crop yields for the current annual crops and the alternative perennial crops and cover crops vary with the CPI values. The budgets display the costs and returns that result at the average CPI for the LCC 3+ acres in each watershed. As the user switches the view from one watershed to another, the yield variation makes it difficult to compare the budgets against the original sources referenced in the literature review. To make such comparisons easier, a "State benchmark" or "State" scenario has been added below the list of watersheds. Selecting that State scenario sets all of the yields at the averages for the surrounding counties, and the related cost and return results are set to match the original sources. The LCC 3+ land tends to have CPI values that are quite a bit lower than those overall county averages. As a result, the costs and returns vary noticeably when switching from one watershed to another.

The "CPI_by_watershed_LLC" and "CPI_by_watershed_all" sheets contain the acres by CPI for each watershed addressed in the model. The "CPI_by_watershed_LLC" sheet acreages are only cropland in Land Capability Classes of 3 with slopes of 6 percent or greater, and in classes 4-8. The "CPI_by_watershed_all" sheet contains land in all capability classes. The Watershed List sheet contains the names of those watersheds. The first table in the "CPI_by_watershed..." sheets contains acres for every increment of the CPI. The acres based on the CPI values less than 60 are aggregated by increments of five in the second table in this sheet In order to reduce the dimensions of the data tables in the "Returns_by_CPI" sheet and to speed up recalculation.

The CPIs and associated crop yields displayed throughout the spreadsheet are set at levels based on the LCC 3+ land when the spreadsheet is first loaded, but the user can toggle the dropdown menus at the top of the "CPI chart" sheet or the "Returns_by_CPI" sheet.

In the "Watershed List2" sheet, starting at A34, is a summary comparison of the net returns per acre for all of the watersheds and all of the current and alternative crops. The returns for the LCC 3+ land are shown first, and then the returns for the entire watersheds are shown starting in A65. These values are just numbers. They are not connected to the budgets in the rest of the spreadsheet. If you change any of the parameters in the rest of the spreadsheet, you will need to update these tables by clicking the grey button in row 34. This button runs an Excel macro that iterates through all of the watersheds and copies the values over to this table.

The average CPI for each watershed is shown in cell A20 of this sheet. The crop yields entered in the budget sheets are adjusted up or down in the budget calculations as the data table varies the CPI above or below this default.

The "Supply curve chart" sheet and the "Returns_by_CPI" sheet contain menus at the top to select one of the watersheds to use in the calculations and to select one of the alternative crop scenarios to apply to that watershed. Changing the alternative crop in those menus will change the one assigned to that watershed in column L of the "Watershed List" sheet. Column M in that sheet contains a list of default crop assignments for each watershed. To return to the default crop assignments, click the button next to the menu.

Concerns have been expressed that spreadsheet users in specific watersheds might question the credibility of the calculations if they are presented with a list of alternative crops that may be suitable for other watersheds but not for that one. To avoid such credibility questions, the "Dropdowns" sheet contains separate crop lists for each watershed. Crops can be added or deleted for the different watersheds later to make sure that only suitable crops are listed for each watershed.

The sheet names and descriptions are as follows:

Sheet name	Description of the contents
Intro	
CPI chart	Graph showing how much of each watershed contains soils below a given soil productivity index
LCC chart	Graph comparing the cumulative distribution of CPI values for the selected watershed based on the Land Capability Classes of 3-8 vs. all land in the selected annual crops.
Supply curve chart	Graph showing how much of the selected watershed would convert from annual crops to the selected alternative perennial crop or cover crop
Watershed list	List of the HUC8 watersheds in the study, the HUC10 or HUC12 watersheds in each for which the CPI values were summarized, and related information
Watershed list2	The top of this sheet is a transposed in Watershed List. Starting in row 40 is the calculation of the required subsidies for each alternative crop based on the differences in returns/acre compared to the current crops.
CPI_by_watershed	Acres by CPI for each watershed addressed in the model, counting only land in LCC 3 with slopes of 6% and greater, and in LCC 4-8.
CPI_by_watershed_all	Acres by CPI for each watershed addressed in the model, counting all land in the selected annual crops.
Chat_acres_by_CPI	Graphs of cropland acres by crop productivity index for all cropland, marginal (LCC3) cropland, and non-marginal cropland in the selected watershed
Returns_by_CPI	Key summary values of total revenue, nonland costs, and net return to land from all of the current and alternative crop budgets
Prices	List of the current and 2012-16 prices used throughout the budgets
Returns_export	While the rest of the spreadsheet shows results for only one watershed at a time, the current crop net returns/acre for all six watersheds and the state (surrounding counties) are shown in columns B-H. The returns for the alternative crops are the same across watersheds, and are shown in columns I-V. As the name suggests, this sheet provides a summary that can be copied over to a different spreadsheet for further analysis.
Annual_crop_budgets	Corn, soybeans, spring wheat, and sugar beets
FINBIN_summaries (hidden)	The 2016 FINBIN summaries (on rented land) for corn, soybeans, and spring wheat. Not used directly in the analysis. Included here for comparison with the budgets, as discussed in the paper.

Land retirement ..... Alfalfa	Separate sheets for each alternative perennial or cover crop. The grass-fed beef scenario requires six different sheets.
Beef returns chart	Chart with 20-year series of net returns/head of beef finishing, nominal and deflated to 2016 dollars
Beef-corn returns chart	Similar chart comparing beef and corn, 20-year series of net returns, deflated to 2016 dollars
Input prices	Data from the Farmfutures weekly fertilizer price review and from Brad Kincaid in the U of MN Agronomy Department, referenced by the other sheets containing the budgets themselves
Machinery costs	Data from the MACHDATA.XLSM machinery cost spreadsheet that contains the per-acre costs included in the crop enterprise budgets
Input prices	Prices of fertilizer ingredients and chemicals used in the budgets.
Yld_per_CPI	Corn grain, soybeans, spring wheat, and sugar beet 2016 harvested acres, 2012-16 average yields, CPIs, and yields/CPI point by county, used to convert different CPI values to crop yields
Dropdowns	The overall list of perennial crops and cover crops is shown in column A. Columns B:H contain the crops that are considered realistic for each watershed, and are the lists that show up in the dropdown menus in the Watershed List, LCC Chart, and Returns by CPI sheet, so users are not presented with alternatives that may not look credible.

Macro to jump quickly between sheets

There are quite a few sheets in this spreadsheet, so scrolling across the tabs at the bottom to find the one you want is time-consuming. To jump quickly to any given sheet, hold the "Ctrl" key down and press the "D" key. This will bring up a box showing all of the sheet names. You can jump quickly to any given sheet by clicking its name in the list.

Current annual crops – acreages and yields

The USDA National Agricultural Statistics Service (USDA-NASS) reports acreages and yields at the county level for seven crops in Minnesota: corn grain, soybeans, spring wheat excluding durum, barley, oats, sugar beets, and dry edible beans. The "Yld_by_CPI" sheet shows data for the 13 counties that contain the pilot watersheds. This calculation was done before the final decisions were made about two of the watersheds, so the counties were selected based on the HUC8 Le Sueur River watershed rather than the Freeborn Lake-Cobb River one, and for the entire Sauk River HUC8 rather than for Getchell Creek/Co. Ditch 9.

"Current annual crops" are defined for the purpose of this analysis as those crops for which USDA-NASS reports county-level yields and which make up at least 90 percent of the acreage of all of those USDA-NASS crops in a given watershed. Only corn grain and soybeans met that criterion in all of the watersheds except for Whiskey Creek, where wheat and sugar beets are also included along with corn and soybeans.

The "Yld_by_CPI" sheet is organized with the harvested acres by county and crop at the top. Next is the 2012-16 yields. The yields for the corn grain, soybeans, spring wheat, and sugar beets are 2012-16 county averages from USDA-NASS and are shown in the “Yld_by_CPI” sheet. The range of 2012-16 was chosen in order to reduce the influence of yearly weather-related yield fluctuations without going so far back in time that a trend adjustment would be necessary. Those averages are adjusted up or down as the CPI varies.

The third area has CPI values for each county and crop. These values are derived from the NRCS SSURGO soil survey database merged with the 2016 USDA Cropscape cropland data layer database for each county. This merged data allowed the CPI values to be calculated on acres planted to that particular crop, for better accuracy than would be possible by averaging just the soil survey CPI values for the entire county (USDA Natural Resources Conservation Service , USDA NASS 2014). The CPI values can vary from 0 to 100 for individual soils. We found that the average CPI for these 13 counties and these crops is 81.

The fourth area in this sheet has the 2012-16 average yields divided by the CPIs. These ratios are used in the crop enterprise budgets to arrive at crop yields on cropland with varying CPIs, as discussed further below. The corn yields averaged 2.12 bushels per CPI point, while the soybean yields averaged 0.58 bushels per point. The wheat yields averaged 0.78 bushels per point while sugar beets averaged 0.35 tons per point. Those ratios varied slightly by county.

Crop enterprise budgets for the current annual crops are contained in the “Annual_crop_budgets” sheet. The annual crop budgets are based generally on the Cropbud.xsm spreadsheet available for extension use on the website http://wlazarus.cfans.umn.edu/william-f-lazarus-crop-economics. Those budgets are based loosely on the 2016 FINBIN crop enterprise summary reports. The crop prices in those extension budgets were updated on May 26, 2017. The main adjustments were in:

- crop prices, updated to reflect best estimates for the 2017 crop year,
- machinery costs, and
- fertilizer prices (see below for details).

The machinery costs are based on estimated costs for individual field operations from a 2016 extension publication (Lazarus 2016). The other main difference between these crop budgets and the FINBIN summaries is that we break out per-acre quantities and per-unit prices for the seed, fertilizer, and chemicals.

The crop yields are assumed to vary linearly with the CPI on a given soil. The yield adjustments for a given CPI in a given watershed are made in rows 4:12 of the “Annual_crop_budgets” sheet. The all-counties, all-crops average CPI is shown first. The average CPI for the selected watershed and for the four individual crops is shown next. The actual 2012-16 crop yields are then calculated at both the overall average CPI and the individual watershed and crops.

The crop yields are adjusted further in the Revenue section of the budgets, in rows 57:58. The purpose of this further adjustment is to tie the crop net returns to the frequency distribution of CPI values that is contained in the “Returns_by_CPI” sheet starting in row 27.

Seeding rates and seed prices

The corn seeding rate is 34,000 kernels/acre (Hoverstad 2009) at a corn yield of 173 bushels/acre (the 2012-16 state average). The soybean seeding rate is 160,000 seeds/acre (Quiring 2009), which is around one 60-pound bushel. The wheat seeding rate is 117 pounds/acre (Anderson, Wiersma et al. 2017). The seeding rates for all of the crops vary in proportion to the yields above or below the state average. The per-acre average costs from FINBIN are divided by the seeding rate/acre to arrive at per-unit prices. A Roundup-Ready® fee that is assumed to be $10/acre is netted out of the FINBIN per-acre costs for corn and soybeans. The sugar beet seed cost/acre is not broken out into a rate and a price due to lack of information.

Fertilizer rates and prices

Fertilizer prices declined 15 percent between the 2016 crop and the 2017 one, based on Illinois prices (Schnitkey 2017). Fertilizer expenses on corn averaged $129 per acre on Minnesota farms in FINBIN, as shown in columns B and C of the "FINBIN summaries" sheet. A 15 percent reduction would bring that expense down to $110.

Fertilizer prices are based on prices collected by the USDA Agricultural Marketing Service and reported by Farmfutures in their Weekly Fertilizer Review (Farmfutures 2013). That publication typically reports prices in several locations such as at the Gulf of Mexico and in the Midwest, and they are often reported as ranges, so some interpretation is needed to arrive at prices that may be applicable to Minnesota. The product prices are rounded and then inserted into the "Fertilizer Price" sheet in the manurwkst.xlsm spreadsheet where they are converted to prices per pound of active ingredient. Phosphorus is purchased together with N in the form of diammonium phosphate or monoammonium phosphate, so the P2O5 price is calculated by netting out the N value as either NH3 or as urea. The prices as of 5/26/17 are calculated to:

N (as NH3) - $0.29 per pound (rounded off to $0.30)

N (as urea) - $0.35 per pound

N (unspecified) - $0.35 per pound

P2O5 (with N netted out as NH3) - $0.35 per pound

K2O - $0.27 (rounded off to $0.30) per pound

The fertilizer application costs of $10 per acre are from information reported by a farm supply cooperative.

Nitrogen fertilizer rates on corn in Minnesota averaged 147 pounds per acre in 2012 (Minnesota Department of Agriculture and USDA National Agricultural Statistics Service Minnesota Field Office 2014). Average or typical rates for P2O5 and K2O are not readily available, but rates of 50 pounds of each, along with 150 pounds of N at the urea price and two applicator trips, add up to a cost of $108, which is close to the 2017 estimate of $110 based on FINBIN.

The fertilizer rates for soybeans, wheat, and sugar beets are similarly set at levels consistent with the estimated 2017 FINBIN expenses, with the relative amounts of N, P2O5, and K20 based on University of Minnesota (UMN) recommendations (Kaiser, Lamb et al. 2011). The UMN recommended rates themselves tend to cost less than the FINBIN expenses, depending on soil test levels of P and K. One reason for the difference is that producers may also apply lime, sulfur, or micronutrients not included in the budgets.

Nitrogen fertilizer rates for switchgrass are set at one percent of the dry matter yield/year (Schaeffer 2009). That translates to a rate of 80 pounds for a yield of 4 tons. He also recommended nine pounds of P and 46 pounds of K based on his research, limited to a maximum of the recommended rate for corn.

Chemicals

One source of cost data on chemicals is the 2016 FINBIN reports. It is assumed that most producers include chemical application costs with their machinery costs rather than in the FINBIN chemical cost line item, so application costs are included separately here. The chemical application cost per pass is based on data from Jeff Gunsolus and his staff in the Agronomy Department who do economic comparisons of the effectiveness versus cost on corn and soybeans for a number of herbicide mixes at Lamberton, Rochester, and Waseca every year (Gunsolus 2017a, Gunsolus 2017b). They obtain the prices for the herbicides included in that trial from the manufacturers or dealers.

Chemical costs on corn and soybeans are expected to increase in 2017 and future years, however, due to the spread of herbicide-resistant weeds, which will require more passes over the field, and/or chemical formulations that are more costly than the glyphosate that has been the mainstay in recent years. The costs of the chemical mixes in the 2016 corn trials ranged from $45 to $87 per acre compared with $49 in FINBIN. For soybeans, the costs in the trials ranged from $49 to $90 compared with $52 in FINBIN. The chemical costs included here are based on the midpoints of the ranges from the trials - $66 per acre for corn and $70 per acre for soybeans. The trial costs include the cost of the chemicals, adjuvants, technical fees, and application costs. Here the technical fee (Roundup Ready® fee) is included with the seed cost, so is netted out of the trial costs, since many of the formulations include Roundup®. That is an increase of $6-7 per acre compared with the FINBIN numbers.

The fertilizer and chemical prices are listed in the "Input prices" sheet. Those prices are referenced from formulas in the other sheets so they can be updated in one place later on when that becomes necessary.

The chemical application costs per acre are from Dr. Gunsolus' herbicide economics trials.

Crop insurance

Crop insurance premiums are omitted from expenses and crop insurance indemnities are omitted from revenues because the budgets are intended to reflect a long-term profitability perspective when indemnities and premiums should balance out. While they are omitted from the budgets, it is recognized that crop insurance protection can be very important for individual farms in years when adverse weather occurs. The lack of crop insurance for recently-developed alternative crops may hamper their adoption, a policy issue that is beyond the scope of this analysis.

Labor expenses

Labor for machinery operations is based on calculations in the "Machinery Cost Estimates" extension publication (Lazarus 2017). A copy of the data from that publication is contained in the "Machinery Costs" sheet. Two different labor cost rates are assigned to the different operations depending on their skill levels. Unskilled labor is valued at $18/hour including fringe benefits, based on the October, 2016 rates for the Lake States (USDA National Agricultural Statistics Service 2017). Those reported rates do not include fringe benefits, so 30 percent was added for fringe benefit costs. Skilled labor is valued at $25/hour, based on FINBIN summaries for Minnesota crop farms in 2016. Their average value of labor and management per year is divided by hours of unpaid labor to arrive at an hourly rate.

Machinery operating labor for crop operations is typically only a small portion of the total labor required to operate a crop farm. The FINBIN crop enterprise summaries include estimates of labor hours per acre that is a labor calculation based on taking the farms' total work force and allocating its time to the individual enterprises. The crop enterprise budgets for the annual crops here include a line item for "labor (non-machinery) and management". Those expense amounts reflect the difference between the FINBIN labor hours per acre, and the machinery operating time that is included with the machinery cost line item.

Crop prices for the current annual crops

The crop prices are for planning purposes. The general approach has been to use expected cash prices for the next harvest, because next harvest is the earliest time frame affected by today's decisions. The harvest-time cash prices are estimated as the harvest-time futures prices minus an estimated basis. The harvest-time futures contract expiration dates are December for corn grain, November for soybeans, and July for wheat. The prices have been low for several years. Drought concerns in mid-summer 2017 have caused sharp increases in the wheat price. Soybean prices also appear to be increasing somewhat. Wheat price information is difficult to interpret because of the large number of protein levels. The basis also varies somewhat seasonally and spatially among elevators, so is a bit difficult to nail down. USDA-AMS publishes a daily basis report for Minnesota, which is useful for estimating the basis for each crop.

Some of the scenarios being considered in this project involve introducing more small grains such as wheat into watersheds that are almost exclusively corn and soybeans presently. Before estimating wheat profitability estimates based on recent prices, we review the relationship between corn, soybean, and spring wheat prices over the past 20 years in order to gauge whether last year's cash prices and next year's harvest-time futures prices are consistent with historical patterns. The table below shows that the wheat price in the most recent marketing year, 2016-17, was low compared to corn while the soybean price was high relative to the 20-year averages. It appears that $3.50 per bushel for corn, $9.00 for soybeans, and $5.50 for wheat are reasonable planning prices to use for this study.

Minnesota average prices reported by USDA-NASS, and planning prices assumed here	2016 marketing year	20 year average, 1997-201	Planning price assumed here
corn grain	$3.30	$3.21	$3.50
soybeans	$9.25	$8.12	$9.00
spring wheat (excluding durum)	$4.40	$4.85	$5.50
wheat - percent of corn	133%	151%	157%
wheat - percent of soy	48%	60%	61%
soy - percent of corn	280%	253%	257%

Miscellaneous income, expenses for drying and hauling, and interest on operating expenses

The FINBIN crop enterprise summaries generally include a small amount of miscellaneous income from various sources. Those average amounts are included here. Drying expenses from FINBIN are included for corn grain. Expenses for hauling crops to market are also from FINBIN. Interest on operating expenses is calculated for six months at 5 percent per year.

Gross revenues, total nonland costs, and net returns compared with FINBIN

Gross revenues, total nonland costs, and net returns are shown in rows 62-82 of the "Annual_crop_returns" sheet along with the input category totals. Yields and these items will vary slightly from one watershed to another because the yields displayed in this sheet are based on the average CPI for the watershed. The approach used in these budgets for application rates and prices of specific fertilizer ingredients, chemicals, and machinery operations has pros and cons compared with using the FINBIN income and expenses for the most recent year or for an average of some recent years. An advantage of this approach is that prices can be based on more recent history or projections for the future, and in this case are based on prices in early 2017, whereas the most recent FINBIN summaries represent inputs typically purchased in early 2016 or late 2015. A disadvantage of the approach is that it is not known how typical the rates and prices really are, since they are based mainly on information from extension staff about what they recommend or from anecdotal information about what they think producers are doing.

The 2016 FINBIN summaries for corn grain, soybeans, and spring wheat on rented land are shown in the "FINBIN_summaries" sheet for comparison. Rows 63-64 show total nonland costs and net returns over nonland costs calculated in the same format as in the budgets in the Annual_crop_returns sheet. Nonland costs in the budgets are lower than the FINBIN averages for corn grain and soybeans, partly due to fertilizer differences as discussed above. The spring wheat nonland costs are higher than in FINBIN.

Perennial crop stand life

The stand lives of the perennial crops are assumed to be as follows:

Switchgrass – 10 years including an establishment year with a reduced yield, first year after establishment with a reduced yield, and 8 years of a mature stand with a full yield

Miscanthus – 20 years including an establishment year with no yield, first year after establishment with a reduced yield, and 18 years of a mature stand with a full yield

Kernza – 4 years including an establishment year with a full yield and three years with a reduced yield

General information for the perennial crops and cover crops under consideration

The individual perennial crops and cover crops vary enough that a separate sheet is devoted to each one, starting with the "Switchgrass" sheet and continuing through the "Alfalfa hay" sheet. The CPI-based yield adjustments are made by starting with the average of all of the counties listed in the "Yld_per_CPI" sheet (labelled "State" in the watershed lists). That average CPI is displayed near the top of each sheet. The yields shown first are those that are expected on soils with that average CPI. Then, further down in the Revenue section of each sheet, those yields are adjusted as the CPI is varied in the table in the "Returns_by_CPI" sheet.

Switchgrass

Yields

A long-term perennial plant trial over the six years 2007-13 at eight Minnesota locations showed that switchgrass averaged 3.0 tons per acre when fertilized with 53 pounds of N fertilizer per year. The switchgrass yielded more on average than a 4-species grass mix, a grass/legume mix, a 12-species mix, and a 24-species mix. The location CPIs varied from 39 at Becker to 98 at Lamberton. The switchgrass varied with CPI at:

Yield, tons/A = 0.10 + 0.036 CPI.

Thus, at least in this trial the switchgrass yielded relatively better on the poorer soil than annual crops would, based on the CPI being an estimate of annual crop yield. Graphs in the article show that switchgrass yields trended upward over the six years of the trial (Jungers, Clark et al. 2015).

A separate two-year trial in 2008-9 at three locations, evaluated five N rates. The average yield over both years and all locations was 2.7 tons per acre at the 50 pounds per acre N rate. The yields appeared to vary proportionally with location CPIs which varied from 75 to 86 (Jungers, Sheaffer et al. 2015).

Liberty is a new switchgrass variety bred for high biomass energy yields in the Midwest and Great Plains. The three-year average yield over 2009-11 for Liberty switchgrass at three Wisconsin locations was 4.6 tons/A with 100 pounds of N per acre (Vogel, Mitchell et al. 2014). The article also includes yields for Nebraska and Illinois, which were higher than in Wisconsin, but the Wisconsin data is discussed here because its climate is more similar to Minnesota. Recent plant breeding programs have increased biomass yields of upland switchgrass varieties of 0.71 Mg/ha, and 0.89 Mg/ha for lowland varieties (Casler and Vogel 2015).

Switchgrass yields in eastern and southwestern Ontario are currently estimated at 4 to 5 tonnes/acre (4.4 to 5.5 tons) on class 1 and 2 lands, and 3 to 3.5 tonnes (3.3 to 3.85 tons) on class 3 marginal lands (Todd 2017).

Research in South Dakota suggests that the switchgrass yield in the planting year is expected to be half of the yield of a mature stand, which will be achieved by year two (Jordan 2017).

For the planning purposes of this study, we assume yields that are higher than those of Jungers' 2007-13 studies and in line with the Liberty variety results. This is consistent with an expectation of some genetic improvement over time. The Shakopee Creek watershed is one where switchgrass may be suited, and has an average CPI of 90 on the land in corn and soybeans. Taking that watershed as an example, at a CPI of 90 we will assume mature stand yield of 4 tons per acre, half as much in year 1 for 2 tons, and 75 percent as much in year 2 for 3 tons, which calculates to a ten-year stand-life average of 3.7 tons/acre. We will reduce those yields proportionally for CPIs of less than 90. An example yield for an 80 CPI would be 1.8 tons in year 1, 2.7 tons in year 2, and 3.6 tons in later years, for a stand life average of 3.3 tons.

Prices

For livestock bedding, switchgrass would compete mainly with small grain straw. A total of nine lots of small grain straw sold at the Sauk Centre, Minnesota hay auction on August 3, 2017 (Mid-American Auction Company 2016). Two of the lots were priced at $75/ton and $110/ton. The other seven lots were priced as bales that are 3 feet by 3 feet by 8 feet, for an average of $34/bale. The exact bale weights are not listed, but a reasonable estimate is 1,000 pounds per bale, which would translate to a price of $68/ton.

A group of producers in Ontario is experimenting with growing switchgrass for use as livestock bedding or for use at construction sites (Carter 2016). The group had planted 2,000 acres as of 2016 and were planning on selling it for at least seven cents per pound in the near term. At an exchange rate of $0.82 US/$1 Canadian, that translates to a U.S. price of $0.574/lb or $115/ton. So, their expected price was somewhat higher than the current Minnesota prices for straw. Proximity to urban markets for horse bedding or construction uses could have a large impact on the price, as could the packaging method. Smaller bales of around 14 inches by 18 inches by 4 feet would likely bring a higher price than the larger bales sold at Sauk Centre, but would be more expensive to bale and transport.

It may be difficult, at least in the short run, to sell switchgrass for livestock bedding at the same price as small grain straw because of concerns about whether it would absorb moisture as well (Endres 2017). For that reason and because the bedding market is small, a market price of $40/dry ton (which is less than small grain straw is currently selling for) is included in the budget as a placeholder until more information becomes available about the future market potential for this crop. (See also the note about miscanthus for bedding use in the next section.)

Miscanthus

The miscanthus budget is adapted from one developed for Iowa, with formatting changes to be consistent with the other budgets developed for this project (Hoque, Artz et al. 2014).

Since miscanthus is a sterile hybrid, the crop cannot be planted from seeds, but instead must be established with vegetative materials such as rhizomes or plugs. The price of $.09/rhizome from the Iowa budget is used here, although it appears speculative because no suppliers are currently marketing miscanthus rhizomes for biomass plantings Several suppliers who undertook to produce them have discontinued due to the lack of demand (Lee 2017).

The Iowa budget is for a miscanthus planting following pasture or hay, and includes a site preparation year of a herbicide tolerant crop to control weeds. The miscanthus or other perennial crops would follow an annual crop in this project, we assume that the previous annual crop is herbicide tolerant and serves that purpose but is budgeted separately. Consequently, that site prep year is omitted here.

The cover crop of oats in the Iowa budget is included here, however. The cover crop seed cost and associated tillage is included in the planting year in the spreadsheet rather than as a separate site prep year as in the Iowa budget, because the cover crop is planted only a half-year before the miscanthus is planted (in the fall). The net return per acre is expressed as an annualized net present value of the discounted cash flows from the planting year, the next year of reduced yields, and the remaining years of mature stand.

A tandem disking and a trip with a field cultivator is included before the cover crop is seeded, with two diskings and two cultivations in the spring before miscanthus planting. The Iowa budget included two diskings and two cultivations in the site prep year for a total of four tillage operations, so we are assuming less tillage before the cover crop than they did because of the difference in the previous crop.

The phosphorus and potash fertilizer rates after the planting year vary with yield, as in the other budgets. Unlike the other budgets, the nitrogen fertilizer rate and the raking and baling costs for miscanthus are also varied with yield, following the Iowa budget. The rationale for varying the raking and baling costs with yield is that the miscanthus yield is much larger than other crops such as alfalfa, so that the acres raked or baled per hour are likely to be limited mainly by tonnage rather than by the roughness of the terrain as is the case with second or third crop alfalfa.

The burndown herbicide before miscanthus planting in the Iowa budget is omitted here. It is not clear why that would be needed after two diskings and two cultivations.

Yields

The yields in the Iowa budget appeared to be expressed in as-harvested terms rather than in tons of dry matter used in the switchgrass. Hay is typically around 20 percent moisture at harvest, so the Iowa yields were multiplied by 0.8 to convert them to a dry matter basis. The miscanthus stand life is assumed to be 20 years rather than the 10 years assumed for switchgrass.

Prices

Professor Sally Noll in the Department of Animal Science at the University of Minnesota is currently working on a project with Mike Hulet at Pennsylvania State University on the feasibility of using miscanthus as bedding for turkey hens (Noll 2017). Preliminary results showed no negative impact on weight gain, feed conversion, or mortality, but there was greater severity and prevalence of foot pad dermatitis although the scores on average would be considered acceptable. For miscanthus to be an acceptable substitute for wood shavings as bedding, considerations include:

- bulkiness (relative to transport, storage space, and amount used in a barn in comparison to wood shavings),
- transport costs,
- storage conditions and space,
- handling costs,
- chopping costs,
- how to distribute in the barn,
- how many cycles would it last under re-use conditions,
- any quality concerns such as mold,
- impact of harvest time and conditions, and
- impact on barn air quality.

A market price of $40/dry ton is included in the budget as a placeholder until more information becomes available about the future market potential for this crop.

Kernza

A USDA-funded research project on intermediate wheatgrass (Kernza) was carried out several years ago under the leadership of Professor Don Wyse with participation by Dr. Lee DeHaan of the Land Institute.

One output of that project was a crop enterprise budget developed by Dr. Jacob Jungers (now research assistant professor in the Department of Agronomy and Plant Genetics) and Dr. William Lazarus (Department of Applied Economics). For the purposes of this project, Dr. Jungers has provided additional unpublished Kernza data from six Minnesota locations from a legume experiment and a nitrogen fertilizer rate trial. Dr. DeHaan also provided planning data in a personal communication with Mr. Brendan Jordan on expected Kernza grain and forage yields based on his research at the Land Institute. The information from those three sources is summarized in the following table:

Source	Stand life	Grain yield	Forage yield
(Jungers 2017a)	4	planting year – 400 lb/ A with 50 lb of N	All years – 5 tons
		years 2-4 – 200 lb with 70 lb of N	
(Jungers 2017b)	at least 3	planting year (2013) avg. 848 lb, ranging from 610 at St. Paul to 954 at Lamberton with 71 lb of N fertilizer	
		year 2 (2014) avg. 283 lb. with 71-107 lb of N fertilizer	year 2 avg. 4.9 tons/A
		year 3 (2015) avg. 202 lb. with 71-107 lb of N fertilizer	year 3 avg. 4.3 tons/A
(Jordan 2017)		planting year grain yields 900 kg/ha (801 lb/A), 300 kg/ha (267 lb/A) after 2-3 years	planting year 10 T/HA (3.7 tons/A), later years 7 T/HA (2.6 tons/A)
(Solberg 2017b)		Commercial producers reported grain yields as low as 20 lb/A on commercial farms in 2016	
Use in these budgets	4	planting year 600 lb with 70 lb of N, years 2-4 - 150 lb with 100 lb N, 271 lb/A annualized	planting year 5 tons, years 2-4 – 4 tons/A

Linear regressions show that the first year Kernza grain yields from Dr. Jungers' trials vary in proportion to the crop productivity indices at the six locations (Jungers 2017b). The yields from years 2 and 3 were not analyzed due to missing observations at Morris and St. Paul.

Anecdotal information suggests that Kernza yields on commercial farms fell far short of the research results shown above, however, with some organic producers struggling to harvest 20 pounds per acre (Solberg 2017b). So, it is difficult to know what to plan for in our analysis. The spreadsheet currently has a planting year yield of 600 pounds/acre and a year 2-4 yield of 150 pounds for an annualized stand life average of 271 pounds. This is a discount of around 30 percent compared with the research yields.

Prices

The Kernza grain price currently in the budget is $0.75 per pound, based on the budget that Dr. Jungers developed previously as discussed above. There has been little commercial production and sale of Kernza so far on which to establish an estimate of a market price that is likely to prevail if and when economically significant acreages are grown in the future. Prices as high as $1.00 to $2.00 per pound are currently being mentioned. However, recall that the price of the normal annual wheat in these budgets is $5.50 per bushel. Wheat weighs 60 pounds per bushel, so that translates to a price of only nine cents per bushel for normal wheat. So, the Kernza prices being discussed are ten or more times the current price of normal wheat. It is not obvious why Kernza is likely to command a price ten times the price of normal wheat over the long run. Therefore, even the $0.75 per pound in the current Kernza budget may be high.

Cover crops – General comments

Cover crops play a role in nine of the scenarios:

1) Non-legume cover crop between soybeans and corn
2) Legume Cover Crop between a small grain and corn
3) Camelina cover crop interseeded into corn
4) Camelina cover crop between a small grain and soybeans
5) Pennycress between a small grain and soybeans
6) Grass-fed beef finishing (with some of the grazing supplied by a cover crop)
7) Beef cow-calf production
8) Organic dairy
9) Dairy heifers

This section contains general comments that apply to all of those scenarios.

Cover crops are a topic of keen interest by policymakers for their potential to improve water quality. Producers are interested in cover crops both for water quality and for their potential to maintain and improve soil health and productivity as well as to reduce costs, but are also concerned about the cost and time required to seed and terminate cover crops. The literature on the agronomic aspects of cover crops is too voluminous to describe in its entirety here. This review is an economist's perspective focused on information that relates most directly to the economics of cover crops.

The Midwest Cover Crop Council (MCCC) website serves as a clearinghouse of information relevant to Minnesota and the rest of the Midwest (Midwest Cover Crops Council undated). One feature of their website is a selector tool that suggests different cover crop species and mixes based on the user's location, main crop, planting and harvest dates, and other information. Their list of potential cover crop species includes 16 grains and other nonlegumes, four brassicas, and 11 legumes along with six mixes.

Winter cereal rye is often suggested as the easiest and most foolproof species for producers who are planting a cover crop for the first time, although some agronomists recommend starting with a mix to increase the likelihood of at least one species becoming established successfully. An exception to this suggestion is that when interseeding (discussed below), annual ryegrass seems to perform better than cereal rye.

Benefits of cover crops to the individual crop producer

Some producers are already adopting cover crops because they perceive the benefits to their own operations to be greater than the costs. Other producers have not adopted them because they see the costs as outweighing the benefits. Still, cover crops may provide some benefits to those nonadopting producers, and those benefits may reduce the compensation they might require before adopting them.

Grazing a cover crop or harvesting it for forage offers clear economic benefits. Some commentators would refer to such a crop as a "forage crop" rather than a "cover crop", but we will not dwell on that distinction. Herbicide residues are a concern if grazing or harvesting, and are discussed below. The beef scenario discussion below includes more detail on the economics of grazing cover crops.

A number of potential economic benefits of cover crops have been identified in the literature. A legume cover crop species can provide nitrogen. For the nitrogen to be of benefit, the following crop would need to be one such as corn that needs nitrogen. A 1991 study in southwestern Ontario found that a red clover cover crop following barley or wheat increased the yield of the following corn crop by 23 to 27 percent on average over two locations and three years (1991, 1994, and 1995) (Vyn, Janovicek et al. 1999), table 6. The yield increases may have been exaggerated due to the fact that the corn was not fertilized with N, but rather depended on residual N from fertilizer applied to the small grain at rates of 40, 80, or 160 pounds per acre.

An on-farm trial in Iowa in 2015 and 2016 showed that a cover crop of red clover and sweet clover increased the following corn yield by 12 percent in 2015 and 18 percent in 2016 compared with a cover crop mix of oats, sorghum-sudangrass, peas, and rapeseed (OSPR) (Gailans 2017). The clover was interseeded with cereal rye in April while the OSPR mix was drilled in August. The corn was fertilized with 100 pounds of N per acre in this trial. The peas in that trial may have also provided some N and the trial did not include a check treatment with no cover crop, so it is unknown how the legume would have compared with no cover crop.

A recent meta-analysis of 65 studies of cover crop studies found little evidence of cover crops increasing corn yields in the North Central U.S. at least in the short term (Marcillo and Miguez 2017). The results were more positive in the Northeast and the Southeast. Three North Central studies that were included covered between two and four years. It may be that it takes longer than two to four years for improvement to be observable in outcomes such as increased soil organic matter.

Another potential benefit is increased soil organic matter, which can improve soil water-holding capacity and can provide extra nitrogen to later crops as it mineralizes. The increase in organic matter is slow, however. Anecdotal evidence from a farm in Southeastern Minnesota suggests that the default estimate of an 0.1 percent change per year provided in an NRCS spreadsheet is reasonable (Cartwright and Kerwin undated). Their supporting information suggests that a one percent increase in soil organic matter will provide 20 pounds of N, so a 0.1 percent increase would provide 2 pounds. That is an economic value of $0.70 per acre at the current N fertilizer price of $0.35 per pound.

Cartwright and Kerwin also provide an estimate of the value of the increased water holding capacity, but the economic valuation is complicated. They assume that a 1 percent increase in organic matter will provide an acre-foot of additional water to the crop. In dryland agriculture, one way to value an extra acre-foot of water is to base it on the yield reduction that would occur in a drought year. Such an estimate would require analysis of the frequency distribution of drought vs. normal years, and estimating crop response to extra water in those year types. Another question would be how long the extra organic matter would remain in the soil and providing that extra water before mineralizing entirely and falling back to the original percentage. In theory, such an analysis could be done, but it has not been done in the current version of the analysis.

Cover crops can reduce soil erosion, which can help to avoid future crop yield declines if the land is sloping and if the crops are planted with conventional tillage. It may be possible to arrive at an approximate estimate of soil erosion on the soils in the pilot watersheds based on slope and other information in the soil survey, although those estimates would not be totally accurate without information on the tillage and other cropping practices currently in use on those farms.

Cover crops can mitigate soil compaction, especially when the mix includes radish. Several journal articles contain estimates of corn yield losses from compaction: a cover crop of forage radish or cereal rye on compacted soil increased corn silage yield by 21-37 percent in Maryland (Chen and Weil 2011). Compaction reduced corn grain yields by 33 percent in Ontario (Gregorich, D. R. Lapena et al. 2011), and by 14-27 percent in Jordan (Abu-Hamdeh 2003).

A number of other potential benefits can be identified, but they appear to be too site-specific to generalize them to an entire watershed as would be needed for this analysis. They are listed here but not included in the budgets in the current version:

- Reduced weed pressure, which may make it possible to reduce herbicide applications
- Reduced crop disease, especially in the case of sclerotia or white mold in soybeans
- Increased water infiltration and reduced runoff, which can increase the water available to the crop as well as reducing flooding
- Better support for farm equipment when the soil is wet, allowing more working days

Planting method and timing

Planting method and timing is another main consideration. Planting methods include:

- Ground equipment such as drills or row planters used after the main crop is harvested
- Aerial application with a helicopter or fixed-wing airplane, into a standing crop such as corn grain or soybeans
- Broadcasting after harvest followed by a light incorporation with secondary tillage equipment
- Interseeding into standing corn or soybeans with ground equipment
- Frost-seeding

Ground equipment

Ground equipment choices include presswheel drills, notill drills, prairie grass drills, and row planters. Drills have planting units spaced as close as seven inches. Conventional row planters designed for corn commonly have planting units spaced 30 inches apart, which is too wide for satisfactory cover crop planting. The row planters that producers are using for cover crops have been modified with a second row of planting units bringing the row spacing down to 15 inches.

The choice of planting method involves a tradeoff between seed cost versus time availability and convenience. Advantages of ground equipment are that it provides good seed-to-soil contact so that a dense, even stand can be attained with less seed than is required with aerial application. For example, the MCCC recommends a cereal rye seeding rate of 55-100 pounds per acre when drilling but 96-175 pounds for aerial application. At a typical price of $13/bushel or $0.23/pound, 78 pounds drilled would cost $18/acre while 135 pounds aerially-applied would cost $31/acre. The equipment and labor costs for drilling with the producer's own equipment has recently been similar to the cost of hiring a contractor for aerial application. A drawback of using ground equipment after corn grain or soybean harvest is that the weather may be too wet to get into the field early enough so that the cover crop can become established well enough to survive the winter. The fall of 2016 was warm enough and dry enough that ground equipment worked well for fields in Southeastern Minnesota that were planted as part of the Southeastern Minnesota Cover Crop Initiative. USDA's Crop Progress August, 2017 report showed that cool weather delayed the corn and soybean crops slightly compared to previous years. Data is not yet available on whether the success of cover crop plantings will be affected as a result of the delays.

Planting a cover crop with ground equipment after a small grain, a canning crop such as peas, or corn silage would typically take place in August and would not pose the weather risks that planting after corn grain or soybeans poses.

Aerial application

Aerial application has the advantage that large acreages can be applied quickly despite wet weather, but a rain within a few days of application is needed to provide the moisture needed for germination (Wilson 2012b). Cover crop seed lying on the soil surface is often eaten by birds before it can germinate. It is also more difficult for an aerial applicator to achieve even coverage of the entire field, especially when obstacles such as fencerow trees or power lines are nearby. Estimates are that only 20 to 25 percent of aerially-seeded cover crop acres can be expected to become established well enough to provide measurable water quality benefits in a given year (Strock, Porter et al. 2004, Wilson 2012a).

Interseeding

Interseeding of cover crops into standing corn is being explored due to the drawbacks of the two previous methods. The idea is that the cover crop will germinate and grow slowly without competing significantly with the main crop until harvest, at which time the cover crop growth will accelerate sufficiently to accomplish its purpose. Equipment for interseeding includes highboy sprayers, drills with some of the planting units removed over the crop rows, and tillage toolbars fitted with seed boxes and row openers. Use of the drills and toolbars is limited to corn that is around two to three feet tall, while highboy sprayers can reportedly get through corn up to 12 feet tall without significant stalk breakage (Big Tractor Power). Highboy sprayers typically either just blow the seed down from above the sprayers using pneumatic distribution tubes, or use drop tubes to place the seed below most of the corn leaves to avoid seed getting caught in the whorls of the plants. Either way, the seed is not incorporated mechanically but interseeding is still thought to provide more even coverage and better seed-to-soil contact and more reliable establishment than with aerial application.

A drill and a tillage toolbar were demonstrated at a field day held by the Cannon River Watershed Partnership on June 20, 2017. They were both fitted with equipment that incorporated the cover crop seed for improved seed-to-soil contact. Reports later in the summer were that the interseeded cover crops were doing well, although it was recognized that 2017 had been a very wet year. Concerns remain that in a dry year interseeded cover crops may compete for moisture and could reduce yield of the main crop.

Herbicide rotation restrictions

Herbicides applied to previous crops can interfere with the establishment and growth of cover crops (Stahl 2016). The main situation encountered recently in southeastern Minnesota was that producers were interested in planting a mix of cover crop species after soybeans but were limited to cereal rye because they had applied Flexstar to the soybeans (Thomas 2016). If the cover crop will be grazed or harvested for feed, the herbicide label specifies the length of time until a crop can be planted in the same field after application. Some authors refer to a cover crop that will be grazed or harvested for feed as a "forage crop", and use the term "cover crop" for crops that will not be harvested or grazed (Bosak and Davis 2014). Several soybean herbicides require as long as 30 to 40 months delay before planting a forage crop. A number of corn herbicides require 18 months while one requires 26 months. At least one Midwestern dairy farm was prevented from selling milk for several months after feeding a cover crop that contained a herbicide residue (Thomas 2016).

Economic value assumed as a benefit of cover crops to the following main crop

It is difficult to generalize based on all of the considerations listed above, but one overall measure of benefit is listed in the 2016-17 cover crop survey by the Conservation Technology Information Center (Conservation Technology Information Center 2017). The national average yield difference was 2.3 bushels for corn and 2.1 bushels for soybeans based on 1,365 responses. The Minnesota respondents reported an average six-bushel increase in corn yields and a 0.6 bushel soybean yield increase. There were between 13 and 20 responses from Minnesota. These are farmer-reported yields, and the survey report does not delve into how they were calculated by the producers. An economic benefit of $15/acre is included in the spreadsheet to reflect these yield reports together with the other benefits listed.

Camelina

Camelina can be planted in either the fall or the spring. This analysis is based on fall seeding, for the erosion benefit. Most of the information below on camelina is from a 2016 review article which discussed both winter (fall-seeded) and spring camelina results from a number of U.S. states and other countries (Berti, Gesch et al. 2016), two follow-up phone calls with one of the co-authors (Gesch 2017b), and a follow-up email (Gesch 2017a).

Two camelina scenarios are included in the spreadsheet. The winter camelina currently grown at Morris is integrated into a three-year rotation of corn grain, spring wheat and soybeans that is typical of western Minnesota (Wells 2017). The camelina is planted after spring wheat harvest using a prairie grass drill. Soybeans is planted the next spring into the camelina in 30 inch rows. The camelina is harvested using a combine over the tops of the young soybean plants. That scenario is contained in the "Camelina_CWS" sheet.

The other camelina scenario assumes that it is interseeded into standing corn in a corn grain-soybeans rotation. That scenario is included in the "Camelina_CS" sheet. It is included because the WLWRP partners have expressed concerns that the corn-spring wheat-camelina-soybean rotation may not be appealing to producers currently following a corn-soybean rotation because wheat is less profitable than corn and soybeans in our budgets. Dr. Gesch states that it is too early to draw conclusions about the feasibility of such interseeding because the corn or camelina yield may be reduced (Gesch 2017a). This scenario assumes a 10 percent corn yield reduction, but it should be regarded as speculative given Dr. Gesch's comment.

Seeding rate

The Camelina seeding rate commonly varies between 4 and 6 kg ha-1 (Berti, Gesch et al. 2016). A 5 kg ha-1 is equivalent to 4.5 lb/A. Winter camelina is seeded at a higher rate than spring camelina; 6 lb/A and 4 lb/A respectively (Gesch 2017b). In University of Minnesota studies, the most effective planting method involved no-till drilling the camelina in mid to late September following spring wheat.

Fertilizer

60-80 kg N ha-1 in eastern Canada and the Pacific Northwest (Berti, Gesch et al. 2016). In optimum conditions, seed yield increases at rates up to 200 kg N ha-1., 70 kg ha-1 is equivalent to 60 lb/A. Fertilizer is broadcasted on in the spring after thawing (Gesch 2017b). No response to P has been observed.

Chemicals

Sethoxydim is the only herbicide currently registered for use on camelina in the U.S., at rates between 0.21 and 0.54 kg of active ingredient per ha (Berti, Gesch et al. 2016). Trade Names: Poast®, Torpedo®, Ultima®, Vantage®, Conclude®, and Rezult® (Tu, Hurd et al. 2001). Researchers at the University of Minnesota have been successful in applying glyphosate at one qt/A prior to drilling the winter camelina and avoiding any other chemical applications prior to the plant's termination because the camelina suppresses the weeds (Gesch 2017b).

Yields

Camelina seed yield 743-2,300 kg ha-1 in MN and ND (Berti, Gesch et al. 2016), table 6, based on Gesch et al. (2015) and Berti et al. (2015), the only reference that included a winter type cultivar. The midpoint is 1521 kg ha-1, equivalent to 1,360 lb/A. Winter camelina yields are lower than those of spring camelina; 1300-1400 lb/A and 1600-1700 lb/A respectively, but winter camelina has a higher oil content making it ideal for oil products (Gesch 2017b). Unlike its spring counterpart, winter camelina is winter hardy, making it a viable option for most northern climates.

The yield of soybeans grown after camelina was 82 percent of monocropped yield (Berti, Gesch et al. 2016). Yield of wheat following camelina was 72 percent of monocropped wheat. However, Dr. Gesch says in a follow-up email (Gesch 2017a) that the soybean yield loss can be reduced to 5 to 10 percent, so 7.5 percent is assumed in the spreadsheet.

Again, as in the case of Kernza, the camelina yields discussed above and the pennycress yields discussed next are from research trials. Whether they will be achievable on commercial farms over the next few years remains to be seen. We have discounted the Kernza research yields by 30 percent based on anecdotal 2016 results from a few commercial producers. To be consistent, we discount the camelina and pennycress research yields by the same percentage.

Pennycress

Compared with camelina, pennycress has the drawback that its oil is nonedible although it is cost-effective for making advanced biofuels (Wyse undated). Professor Scotty Wells says that pennycress has the advantage that it can be harvested earlier than camelina, so that when followed by soybeans it may be possible to plant the soybeans early enough that its yield will be comparable to soybeans planted alone (Wells 2017). He goes on to say that pennycress as a crop has been developed from the weed referred to as "field pennycress", which contains a chemical that can give milk a garlicky taste if grazed by dairy cows. He says that that chemical has now been bred out of the crop version of pennycress so that it is now safe to graze, but that many dairy farmers are still leery of it based on that history and so it is not likely to be acceptable as a crop in dairy areas of the state.

Pennycress and camelina were grown in rotation with soybeans in field experiments at Rosemount, St. Paul, and Waseca in 2014 and 2015 (Johnson, Wells et al. 2017). Two planting arrangements were compared: "relay planting" of the soybeans into the standing pennycress or camelina before those crops are harvested, and "doublecropping" where the soybeans are not planted until after that harvest. That research showed that both the pennycress and the camelina reduced the soybean yield at one of the three sites in 2014 and at all three sites in 2015, in contrast to Professor Wells' assertion that it might be possible to grow soybeans after pennycress without a yield penalty. The pennycress did not reduce the soybean yield as much as camelina did when using the relay system.

The article does not include tables with the camelina and pennycress yields, but its graphs suggest that pennycress yielded around 30 percent more than the camelina when averaged over both years and all three sites. However, in a follow-up email Dr. Gesch states that the pennycress and camelina in that article were hand-harvested so that those results may not reflect what can be expected in a commercial farm situation (Gesch 2017a). He suggests setting the pennycress "closer to" that of camelina. Given this uncertainty, the pennycress yield is set to be the same as the camelina in the present version of the spreadsheet. His work shows that camelina yields tend to be higher than pennycress in central Minnesota, but that the reverse has been typical in southern Minnesota.

Based on that, the pennycress budget in the spreadsheet is a copy of the camelina analysis. The market price for pennycress is the same as for camelina, at 15 cents per pound (which is based in turn on the soybean price) despite the fact that the camelina is edible and the pennycress is not, due to the lack of more detailed information about how much that fact might affect the price. The per-acre net returns in the pennycress and camelina are identical based on those assumptions. Both budgets are included in the spreadsheet in case information becomes available on a price or yield difference.

Legume cover crop between a small grain and corn

An alternative to camelina as a cover crop is to plant a legume that will not provide a product for sale but rather would provide nitrogen to the following crop. This scenario is portrayed in the "Covercrop_wheat" sheet. The preceding small grain crop is assumed to be wheat in this scenario, which is similar to Vyn, et al. but different from Gailans. There is no planting equipment cost for the cover crop because it is seeded in the spring with the wheat. The producer discussed by Gailans applied an herbicide mix in the spring to terminate the cover crop. The corn herbicide is assumed to accomplish the cover crop termination in this scenario, so a separate termination cost is not included in the cover crop column.

Non-legume cover crop between corn grain and soybeans

Wheat has been less profitable in recent years, however, so the difference in net returns of the preceding crop detracts from whatever other benefits that the camelina or legume provides. A less dramatic change in the current crop mix is to plant a cover crop that can be planted later in the year between corn and soybeans, without altering the acreages of either of those crops. That scenario is portrayed in the "Covercrop_CS" sheet.

The only change from the current crop mix in both of these scenarios compared with the "Annual_crop_budgets" sheet is to add a cover crop seed cost of $36 per acre and to add $17 per acre for planting, for a total addition of $53 per acre for the cover crop. The cover crop seed cost is based on aerial seeding of cereal rye into the standing corn or soybeans in September, which is a conservative budgeting assumption. Planting the cover crop with a drill or row planter after the corn or soybean harvest would cut the seed cost because a lower seeding rate would be required. Ground equipment worked well in southeastern Minnesota in the fall of 2016. It may not work as well in 2017, however, because harvest was delayed due to cool summer temperatures that have slowed crop maturation. In addition, freezing temperatures usually arrive much earlier than they did in 2016 and may prevent late-planted cover crops from becoming established well enough to survive the winter.

This nonlegume scenario is included here partly to facilitate calculation of environmental benefits that are being modeled separately.

Grass-fed beef finishing

This scenario is intended to reflect the grazing of a cover crop or other use of cropland primarily dedicated to some conservation use. However, a cover crop would only provide grazing for a few weeks in the spring and possibly in the fall, so other pasture or hay acreage would be needed for the rest of the growing season, not to mention over the winter months.

The current version of the model's grass-fed beef scenario calculations draw on reports from the FINBIN farm business summary database (Center for Farm Financial Management 2017). The FINBIN data was provided by farm management education programs in a number of states. The Minnesota data is from the Minnesota State Colleges and Universities Farm Business Management Education program and the Southwest Minnesota Farm Management Association. Importantly, the farms represented in the database participate voluntarily and pay a fee for the service. It is not a statistically representative sample of all farms in a given region, but the number of farms is large enough that it is believed to be the best source of information available for analyses of the type discussed here.

There are too few Minnesota farms with grass-fed beef enterprises to provide a report (at least five are required), so data from the North Dakota Farm Business Management Education program is used, as discussed in more detail below. FINBIN provides whole-farm reports and reports for individual crop and livestock enterprises. Crop enterprise reports for pasture and grass hay along with livestock enterprise reports for grazed beef (assumed here to be synonymous with grass-fed beef) and beef finishing that does not include grazing.

The grass-fed beef scenario here is assumed to consist of four separate enterprises as characterized in the FINBIN data: 1) pasture, 2) grazed cover crop planted to corn and soybeans, 3) grass hay, and 4) grazed beef or beef finishing. The beef enterprise reports include expense line items for several different feeds. The list of feeds varies from one livestock species to another and from one region to another depending on practices of the farms included. The feeds are valued at market prices. The enterprise reports for livestock such as beef include expenses incurred for specific feeds per head or per hundred pounds of production, but they do not include feed quantities.

The pasture enterprise reports include yields per acre that are expressed in animal unit months (AUMs) that reflect the amount of forage that would support a 1,000 pound animal such as a beef cow or a finishing steer or heifer that is about halfway to market weight. One AUM is equivalent to around 800 pounds of biomass dry matter weight (Rasby 2013). That output is valued at what is intended to represent a market price for that forage. The crop producers with pasture enterprises might actually sell that forage to other producers with beef enterprises who transport the animals to the pasture for the duration of the grazing period. However, it is more likely that the same producer operates both the pasture enterprise and the beef enterprise, so that the price per AUM represents an internal transfer price between the two enterprises.

The output of hay enterprises in FINBIN is measured in tons. There is more of a cash market for hay than for pasture, but most hay is still fed on the farm where it is produced. The beef enterprise is the one that generates the revenue on most farm operations. The purpose of this part of the analysis is to estimate the revenue potential of converting marginal cropland to a combination of pasture and hay that supports the right number of finishing beef animals such that the pasture and hay makes up as much of the total diet as possible but is supplemented with other feeds for a cost-effective total diet.

A research report from Michigan State University provides another perspective on the potential for finishing steers on pasture, although the difference in format makes comparisons difficult (Rowntree, Carmichael et al. Undated). The Michigan trial compared two systems: 1) intensive grazing between May 15 and November 15, 2013, with irrigation and hay supplementation at 1.2 steers/acre, and 2) a leader-follow system without irrigation where the steers move in synchrony with a beef herd moving three times daily. I assume that the steers in the irrigated system were also moved three times/day, but that is not stated. The steers were slightly heavier than in the ND data when placed on pasture, at 750-800 pounds compared with 610 pounds. The Michigan steers on the irrigated system were slaughtered at a carcass weight of 660 pounds with a 54 percent dressing percentage, for a live weight of 1,222 pounds compared with 803 pounds average in the ND data. The Michigan steers gained an average of 2.4 pounds/day with irrigation and the hay supplementation compared with 0.97 pounds/day in the ND data. The net income/head for the Michigan steers on irrigation was $75/head compared with $109/head in the ND data. The Michigan report does not provide an economic analysis of the leader-follow system. Those two net return results should be interpreted with caution because of differences in accounting formats and because the ND records are not broken out by year within the 2012-16 period.

Pasture and hay costs and returns

The pasture enterprise reports include yields per acre that are expressed in animal unit months (AUMs) that reflect the amount of forage that would support a 1,000 pound animal such as a beef cow or a finishing steer or heifer that is about halfway to market weight. An AUM is assumed to represent around 1,000 pounds of forage dry matter. The yield estimate is based on three sources: 1) FINBIN summaries for intensively-managed pasture, 2) input from Kent Solberg, livestock and grazing specialist with the Sustainable Farming Association, and 3) input from George Boody, science and special projects lead with the Land Stewardship Project. Pasture is a highly variable land use, so it is not surprising that the yield estimates vary.

Our definition of an AUM may be generous because others have defined an AUM as around 800 pounds of forage biomass dry matter weight (Rasby 2013). The AUMs are valued at what is intended to represent a market price for that forage. The crop producers with pasture enterprises might actually sell that forage to other producers with beef enterprises who transport the animals to the pasture for the duration of the grazing period. However, it is more likely that the same producer operates both the pasture enterprise and the beef enterprise, so that the price per AUM represents an internal transfer price between the enterprises.

The pasture land for the grass-fed beef enterprise is assumed to be managed intensively since it is converted from cropland that by definition would have been managed more intensively than pasture land is usually managed. The "Pasture" sheet of the spreadsheet contains a copy of the FINBIN enterprise report for 15 farms with intensively-managed pasture on rented acres, in columns A and B. Columns E and F show the same report for 25 farms with pasture on owned acres. Columns I and J show an average for the 40 farms shown in those two reports, weighted by the number of farms in each. The key numbers from the 40 farms are summarized in columns A3:C15 of the Grass-fed Beef sheet. They averaged 4.2 animal unit months (AUMs)/acre, valued at $26/AUM. An AUM is generally defined as a 1,000 pound animal. The net return over all costs including labor and management was a negative $6.19/acre. A net return of $16.48 per acre of land is calculated by adding back the land costs, including land rent for the rented land and interest and real estate taxes on the owned land.

Kent Solberg has found that with careful management pasture yields of 11.5 AUM/acre are attainable (Solberg 2017a). This higher yield will probably require intensive management practices such as daily rotation of paddocks, which may require more labor than is reflected in the FINBIN labor and management charge, but that cost was not adjusted due to a lack of information on the amount of the increased requirement.

George Boody suggests 5.9 AUM/acre for the budgets based on extension publications from Iowa and Montana (USDA Natural Resources Conservation Service 2008, Anonymous 2015, Boody 2017).

Those three estimates average 7.2 AUMs/acre. The estimate was rounded down to 7.0 AUMs for use in the pasture budget.

	AUMs/acre of pasture
FINBIN	4.2
Boody	5.9
Solberg	11.5
Average	7.2
Used in budget	7.0

A total of 274 farms reported pasture enterprises in FINBIN that were not managed intensively. While not used in this analysis, the report for those pasture enterprises is shown starting in column Q of the Pasture sheet. The yield is only half the yield on the intensive pasture, and it is valued at only half the value per AUM.

Similar calculations for grass hay and alfalfa hay are located in the sheets named after them. The organic dairy enterprise draws on the organic grass hay and alfalfa hay costs.

A Michigan State University report showed that an improved pasture on a four-day grazing rotation had a higher cost per acre at $202 than did a native pasture on a 14-day rotation at $87/acre (Lindquist Undated). Despite the higher cost/acre, the improved pasture provided a lower cost/ton of dry matter at $78 compared to $95/ton with the native pasture. Differences in the accounting format make it difficult to compare these costs with the FINBIN pasture data, but the FINBIN data appears to show a higher cost/animal unit month with the intensively-managed pasture ($28.32/AUM, in cell J60 of the Pasture sheet) than with pasture that was not intensively managed ($17.88/AUM, in cell R58) on average between 2012 and 2016.

Cover crop costs and returns

Columns L:O of the Pasture sheet show calculations for corn and soybean acres planted to a cover crop and grazed in the spring before planting the next crop. The corn and soybean enterprise budgets from the current annual crops are summarized first. The ratio of corn acres to soybean acres is assumed to be the same as at present. The return to land for the mix of corn and soybeans before considering a cover crop is shown in O6.

The costs to add a cover crop are for seed and planting equipment. Seed costs vary widely depending on the species mix, time of purchase, seeding rate, and other factors, so the $25/acre assumed here is based on only limited information. The cost is $38/acre when the cost of planting equipment and labor is added.

The model includes a benefit of $15 per acre, which is attributed to reduced soil erosion. That value is based loosely on an estimated three-ton/acre reduction calculated using the RUSLE2 soil erosion prediction software for two farms in southeastern Minnesota where conventionally-tilled peas were grown in a rotation with no-till corn grain and soybeans, on soils with slopes of over 8 percent (Renard, Foster et al. 1997). The reduced erosion is valued at $5 per ton, which would be consistent with a corn yield reduction of 8 bushels per acre for each 1 inch of soil loss.

The information in the model on the amount of grazing likely to be provided by a cover crop planted after harvest of corn grain or soybeans is based largely on results from two farms in southeastern Minnesota where a cover crop seeded in the fall of 2016 was grazed. Neither situation is totally satisfactory for this model, however. The first situation involved a cover crop planted in early August after a pea harvest. Because of the early planting date and ample precipitation, the cover crop had produced lush growth estimated at around 3,000 pounds of dry matter/acre by the time of a field day held on the farm on September 27, 2016. The producer reported later that it had been grazed for 6 weeks at a stocking rate of 2.1 head/acre, equivalent to 3.2 AUM/acre. It was not grazed in the spring of 2017.

The other producer planted a cover crop after corn grain harvest, planning to have stocker cattle graze it in the spring. However, it became over-mature before he got the animals onto the field in the spring, so they refused to eat very much of it. It thus did not provide any significant grazing.

The current version of the model contains a beef stocking rate of one animal per acre for a 1-month grazing period (one AUM/acre) as an estimate of spring grazing that is likely if planted after grain harvest and then grazed at optimal maturity based on those two data points. Obviously, more experience is necessary before that estimate can be considered reliable. That one AUM/acre is valued at $26/acre based on the value/AUM from the FINBIN intensive pasture enterprises. Together with the $15/acre soil erosion reduction, the cover crop adds $41 in benefits compared to $40 in planting costs, making it slightly better than a breakeven proposition.

The total grazing period is assumed to extend from May 1 through October 30 for six months of time. Thus, the one month of cover crop grazing amounts to 17 percent of the total grazing period.

Beef finishing costs and returns

Beef finishing tends to be a risky enterprise, as shown by the 20-year series of per-head returns in the "Beef returns chart" sheet. The past few years have been particularly volatile, with returns reaching $356/head in 2014 and then falling to a minus $331 in 2015, in 2016 dollar terms. Average returns were slightly negative over the period, at a minus $6.93/head.

The FINBIN livestock enterprise summary for 16 North Dakota operations that reported grazed beef enterprises between 2012 and 2016 is shown in the "Beef_grazed_ND" sheet. Despite the small number of farms and the location outside Minnesota, that report is included here to show the breakdown of individual feeds fed in a grazing situation (see rows 15-20 compared to the total feed cost per head in row 61). Note that the pasture cost made up 46 percent of the total feed cost while grass hay made up another 25 percent, so that a total of 71 percent of the feed was from a perennial grass crop. While the enterprise is called "grazed beef" in FINBIN, others might call it a stocker enterprise based on the average purchase weight of 610 pounds and the average weight sold per head of 803 pounds, for an average gain of 193 pounds per head.

Another data source is a spreadsheet decision tool and documentation from Winrock International (Williams 2013). Its documentation states that "the model includes actual input costs and performance data from grass-finishing operations in the Upper Midwest." but specifics such as state and management level are not stated. The spreadsheet includes calculations for both a stocker enterprise and a finishing enterprise. The stocker enterprise starts with a calf weight of 400 pounds with a finish weight of 750 pounds for a 350-pound gain, while the finishing enterprise starts at 700 pounds with a finish weight of 1,200 pounds for a 500-pound gain.

Comparing the ND FINBIN grazed beef and pasture summaries against the Williams calculator's stocker calculations is complicated by the fact that the FINBIN pasture summary expresses output in AUMs while Williams expresses the output of both the pasture and the harvested forage (hay) as tons of dry matter (DM). Williams assumes a pasture yield of 3 tons DM/acre while the FINBIN average for owned and rented, intensive pasture is 4.2 AUM/acre, which is 1.7 tons DM/acre at the Rasby conversion of 800 pounds DM/AUM (Rasby 2013). The FINBIN gain and feed numbers work out to 12.6 pounds of pasture, hay, and cover crop per pound of gain, plus $33/head for protein, barley, corn and other feedstuffs for a total feed cost of $113/head or $0.58/lb of gain at 193 pounds. The Williams calculations work out to be 8.8 pounds of pasture and harvested forage per pound of gain, plus purchased feed of $120/head for a total feed cost of $214/head or $0.61/lb of gain at 350 pounds so the feed cost/lb of gain is similar between the two sources. The FINBIN numbers are currently used in this analysis.

The FINBIN beef report does not show the values per AUM or per ton that these producers placed on that pasture and hay, but the grazing was valued at $26/AUM on the intensive pasture enterprises while the hay was valued at $91/ton on the grass hay enterprises. If these beef producers placed similar values on their feeds, that works out at 2.01 AUM of pasture and 0.31 ton of grass hay/head. Furthermore, the 2.01 AUM of pasture breaks down to 0.33 AUM of grazed cover crop and 1.67 AUM of intensive pasture based on the cover crop supplying 17 percent of the seasonal grazing supply (see the "Grass-fed sheet, rows 30:46).

At the yields reported for the pasture and grass hay, and the two head/acre stocking rate assumed for the cover crop, 1.04 acre is required to supply the grazing and hay for an average animal based on the feed costs shown in the ND report. This is considered the stocking rate at the all-counties CPI of 81. At other CPI values, the pasture and hay yields adjust while the stocking rate also adjusts to maintain the same quantity of feed per head.

The ND grazed beef report shows a net return over labor and management of $109/head. However, that value is not used in this analysis because that report is for the five-year period of 2012-16 and it is not known which years in that period these reports are from, and given the price volatility of that period and the small number of farms. Instead, the net return is taken from the non-grazed Minnesota beef enterprises shown in the "Beef_notgrazed_MN" sheet. The number of farms with that enterprise ranged from 61 in 2015 to 136 in 1999. The implicit assumption is that the total feed costs and the other costs and revenues will be similar over the long run between grass-fed beef and other beef enterprises.

The acres/head for the three crop enterprises is used to convert their per-acre costs and returns to a per-head basis, in G30:J41 of the Grass-fed Beef sheet. The number of head/acre of pasture, cover crop, and hay combined, is then used to convert the per-head net return back to a net return per acre in J43 which is used in the comparison with the other alternative crops in the "Returns_by_CPI" sheet.

Beef cow-calf production

The Beef cow-calf sheet layout is similar to that of the Grass-fed Beef sheet. The cow-calf calculations include gross returns, total cost, and net returns for the beef herd itself, which are based on the inflation-adjusted 1997-2016 FINBIN enterprise information in the Cowcalf_MN sheet. There were 115 beef cow-calf enterprises in the Minnesota FINBIN data in 2016 compared to the 16 grazed beef enterprise reports between 2012 and 2016 that provide information on grass-fed beef finishing that was discussed above. So, the cow-calf feed cost data is probably more reliable but it is also compared to the cow-calf feed costs in the Winrock grazing calculator (Williams 2013). The 2016 FINBIN average feed costs were less than the defaults in the calculator. The FINBIN pasture expenses averaged $53/cow while the grazing calculator default is $93. The FINBIN cost for harvested forage was $250 compared to $259. Adding in feed purchase, the FINBIN total feed cost was $412/cow compared with $475 in the grazing calculator. The weaning percentages are nearly the same in FINBIN (89 percent) and in the calculator (90 percent). The calculator assumes a much higher calf sale price ($2.63 per pound) than the FINBIN 2016 average ($1.56 per pound). Consequently, the calculator shows a much greater net return per head than does FINBIN. The FINBIN value is used in this analysis.

The Minnesota beef cow-calf enterprises in FINBIN incurred feed expenses for alfalfa hay along with grass hay and pasture. So, the calculations in the Beef cow-calf sheet are tied to costs and returns for the alfalfa acres that would be required to supply that alfalfa along with the grass hay and pasture acres.

Dairy production, organic and/or grazing

FINBIN dairy enterprise summaries are shown in the "Dairy FINBIN" sheet. Summaries for the five years 2012-16 are included to reflect recent volatility in dairy markets. FINBIN has the capability of including or excluding operations based on various criteria, which include rotational grazing, organic, and organic transition. There were between 376 and 416 non-grazing dairy operations in FINBIN over that period. They are shown in columns AD:AJ. Between 15 and 25 organic dairy operations are summarized in columns J:P. Fifteen operations were in transition to organic in total over the five years, with only 2012 having enough to summarize by year (minimum required is five in a given year). The fifteen average to three per year.

Business summaries are also available for 15 organic dairy operations in Eastern Iowa and nine in Southwest Wisconsin, as well as seven in North Carolina, Virginia, and West Virginia, for 2014 (Tranel 2015). The text of the Tranel report suggests that the farms in that report sold their milk through the CROPP Cooperative/Organic Valley. Below is a comparison of a few key factors for 2014 for the Minnesota, Iowa, and Wisconsin operations:

	Minnesota (2014)	Eastern Iowa	Southwest Wisconsin
Average number of cows	86	73	65
Milk sales per cow (pounds/year)	13,235	11,658	13,582
Milk price, $/cwt	$27.88	$31.57	$31.28
Net return over direct & overhead costs/cow	$808		
Net farm income/cow		$1,647	$2,108
Net return over labor & management	$484		

Summarizing, the operations in the three states appear to be similar. The Minnesota operations are slightly larger and they receive a lower price for their milk. Costs and profitability are difficult to compare because of differences in the format of the calculations. The Minnesota analysis views the dairy herd as a separate enterprise with its feed valued at market prices. Profit or loss for growing the feed is handled in a separate crop enterprise analysis and is not factored into the Minnesota analysis discussed here. The Iowa and Wisconsin analysis appears to value the feed based on its cost of production, based on the fact that there is a “Fert/Chem/Seed Cost/Crop Acre” expense line item in the table. There are also differences in how capital, labor, and management are valued. The two net return calculations that appear to be most comparable are “Net return over direct & overhead costs/cow” in the Minnesota analysis, and “Net farm income/cow” for Iowa and Wisconsin. Those values suggest that the Minnesota operations were less profitable than those in the other states.

The organic dairy scenario discussed below is based on the Minnesota analysis. The previous discussion was about the 2014 year, since that is the more recent year for which the Iowa and Wisconsin data is available. The organic dairy scenario actually included in the spreadsheet is based on the 2012-16 average costs and returns.

An estimate of the organic price premium is based on the difference between the per-hundredweight price that the organic dairies received and what the conventional dairies received. That difference has been increasing in recent years, from $9.67 in 2012 to $18.53 in 2016 as shown in J89:P89 of the “Dairy FINBIN” sheet. The five-year average is $12.17/hundredweight. However, anecdotal information suggests that the organic premium has declined precipitously in 2017 due to changes in the market and increasing numbers of small dairy operations switching to organic. So, it is difficult to know what organic premium to plan for in the future. The scenario used in this analysis is based on the value entered in cell C6 in the spreadsheet. The default value is set at a premium of $8.00/hundredweight.

The fifteen operations in the organic transition category between 2012 and 2016 are shown in columns F:G. They lost an average of $620/cow in net return over labor and management over those five years, likely due mainly to incurring the higher costs for organic feed and producing less milk/cow without receiving organic premiums for that milk. Any dairy producer making that three-year commitment would expect to continue operating later as an organic operation to make up for the loss. A question that for this analysis must address is how many years of organic production would be typical. Seven years of organic production is assumed in this scenario, for a total planning horizon of ten years when the transition years are added in. That ten-year average is shown in column D of the Dairy FINBIN sheet and is transferred over to row 52 of the Grazing Dairy sheet. With the assumed $8 organic premium and seven year of organic production, the organic operations would have a net loss after labor and management of $104/cow.

The totals from the "Dairy FINBIN" sheet are transferred over to the "Dairy organic" sheet. The format of the calculations in that sheet is similar to those in the "Beef cow-calf" sheet. The pasture, grass hay, alfalfa hay, and cover crop calculations stay the same but are now based on the FINBIN organic enterprises. The livestock enterprise calculations now come from the "Dairy FINBIN" sheet. The combination of the crop and livestock enterprises shows a net return of $73 per acre of pasture and alfalfa hay combined or $83/head.

An organic operation would need to operate as organic for seven years to cover the transition year losses and turn a profit at the $8 premium in the scenario shown. Fewer years would be needed to break even at higher premiums.

Between 9 and 16 operations used rotational grazing, and they are shown in columns V:AB. It appears that many or most of the rotational grazing operations are also organic, based on their high average milk price and the expenses they incurred for organic corn silage, alfalfa hay, and pasture. They received around 40 percent more per hundredweight on average for their milk than did the non-grazers - $27.10 compared with $19.64. The grazing dairies were more profitable on a per-cow basis than were the non-grazers, with a net return over labor and management averaging $400 per cow compared with $240. The grazers had smaller herds, however, at 84 cows compared with 183. As a result, the non-grazers averaged a net return over labor and management of $43,947 total per year for the herd compared with $33,829 per year for the grazers. Note that these are results for the livestock enterprise only, with feed valued at market prices. Profits or losses on crop enterprises are summarized separately in FINBIN.

With that in mind, columns A:B in the "Dairy FINBIN" sheet show how the 2012-16 average rotational dairy results would have turned out if those operations would have received the non-grazers' milk price of $19.64 per hundredweight instead of $27.10. We also assume that they fed non-organic corn silage, alfalfa hay, and pasture in place of the organic types that they actually fed, at half of the prices they actually paid (or at which they valued their own organic crops). Those two changes, other things being equal, would have changed their net return to labor and management from $400 per cow to a negative -$373 per cow.

The University of Minnesota operates an organic dairy herd at the West Central Research and Outreach Center at Morris. One research finding from that operation is that it is most profitable to feed some grain to the herd, but not as much as would be optimal in a non-organic herd. Six pounds of grain per cow per day along with 25 pounds of a total mixed ration was shown to be most profitable during the summer of 2012 (Heins 2014). The feed cost for that group was $4.05/cow/day compared with

$4.68/cow/day average for the 25 herds in FINBIN in 2012. The WCROS herd averaged 37.2 pounds of milk/cow/day compared with 34.8 pounds for the FINBIN herds, so the reduced grain did not appear to adversely affect milk output. Feed prices are not provided in the FINBIN data, so it is impossible to be sure that the difference is in the feed quantity rather than the feed prices.

Another data source on organic and grazing dairy operations is a series of reports authored by Tom Kriegl, farm financial analyst emeritus with the Center for Dairy Profitability at the University of Wisconsin. That work grew out of Mr. Kriegl's discussions with the Great Lakes Grazing Network. A USDA grant allowed the project team to analyze dairy operation records from eight states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin) and Ontario over five years (2000-2005). Since the end of that funding, Mr. Kriegl continued to summarize records for a group of organic and grazing operations in Wisconsin through the 2014 year. He sent me a summary of financial performance for the 16-year period from 1999 to 2014 that does not seem to be on their web page (Kriegl 2015). In that report he lists a number of observations which are reproduced below:

Observations of the Financial Performance of Organic Dairy Farms.

1. Income and costs have increased dramatically for all systems from 1999 to 2014.
2. The increasing advantage that confinement herds have in lbs. milk sold per cow is a threat to the economic competitiveness of grazing and organic systems.
3. Non-organic graziers have fallen behind small confinement herds in NFIFO/cow since 2010, mainly because the small Wisconsin confinement farms were able to offset most of their purchased feed costs with the sale of small amounts of high priced feed that they raised. This peaked in 2012 and is declining with grain prices.
4. Data is scarce from any organic group especially from transitional organic.
5. By most measures, grazing systems had the lowest cost of production per unit followed by confinement herds smaller to larger. The organic cost of production averaged about $5/CWT sold higher than non-organic herds.
6. Organic dairy farms need a price premium of about $5/CWT sold to be economically competitive. The 8-year annual average organic price premium was $5.14 from 1999-2005 and $8.99 from 2006-2014 over the confinement price.
7. Organic price premiums ranged from $2.70 to $13.02 vs. non-organic herds.
8. Organic is most competitive when non-organic price low.
9. Wisconsin graziers usually had the highest NFIFO as a percent of income followed by organic and confinement herds smaller to larger. Organic had higher NFIFO/CWT sold for 13 of 16 years and higher NFIFO/cow 10 of 16 years.
10. Grazing practices appear to enhance profitability more than organic practices.
11. If already practicing organic – go for reward.
12. If far from organic practices, 3-5 year transition challenging.
13. Organic dairy farms appeared to be competitive with non-organic dairy farms in (1990-95) Quebec study.
14. Lbs. of milk sold/cow from organic farms similar from WI to MN to New England to Quebec.
15. In 2004, organic dairy farms in a New England study were not as competitive as
    a) non-organic New England dairy farms
    b) any Wisconsin dairy system
16. Since 2005, New England Organic farms have become more competitive benefitting from increased price premiums.
17. Feed costs were much higher for New England farms – especially for those which are organic.
18. Performance of Minnesota herds was fairly similar to Wisconsin's performance.
19. Be careful about comparing one dairy system in one state to a different dairy system in another state.

Source: Kriegl, 2015

Kriegl's data on non-organic grazing dairies is particularly useful because FINBIN does not separate organic from non-organic operations within the overall group that practice rotational grazing. Kriegl's results for non-organic grazers are that in general, a "grazing system is more economically flexible than a confinement system because of a lower investment requirement. That is, someone who invests in a well planned grazing operation will likely be able to recover most of their investment in assets if a few years later they decide to switch to a confinement system or quit farming entirely. In contrast, if you invest 'from scratch' into a new confinement system and decide to change or quit in a few years, you will be lucky to recover half of what you invested in the confinement system." "Grazing systems may be the only viable (vs. confinement) choice for a beginning farmer starting "from scratch" at herd sizes less than 300 cows" (Kriegl 2015), page 7.

Six of the Wisconsin herds are included in a preliminary 2014-16 summary (Kriegl 2017). The Wisconsin summary includes both the dairy herd and the crop enterprises, so in that regard the format is similar to the reformatted FINBIN data shown starting at cell A119 of the "Dairy organic" sheet, although the FINBIN data is a five-year average for 2012-16. The Wisconsin herds in 2016 were slightly larger at 106 compared with 97 cows/herd for the FINBIN herds in 2016, and gave more milk/cow at 16,155 pounds compared with 15,079 for the FINBIN herds. The milk prices were similar at $35.23 in Wisconsin and $35.02 in FINBIN. The Wisconsin producers spent $1,431/cow on feed purchases in 2016. The FINBIN format does not distinguish between purchased and raised feed, but in 2016 the FINBIN producers spent an average of $1,356 on feeds other than pasture and hay. For the individual crop expense items, the Wisconsin farms had higher expenses for some items and less for others but their total cash expenses appeared to be higher than for the FINBIN farms after subtracting rents and taxes. Income taxes are not included in FINBIN.

Dairy heifer production

Dairy operations have traditionally raised their own replacement heifers. However, many dairy operations purchase a few replacement heifers or cows occasionally, and anecdotal evidence suggests that some have now chosen to purchase all of their heifers or contract with other producers to raise the heifers for them. That suggests that raising dairy heifers may be an attractive enterprise for expansion under this program, because the heifers can graze on pasture or cover crops during the growing season and would utilize hay.

Dairy heifer enterprise data in FINBIN is shown under four categories of interest for this analysis: dairy replacement heifers, dairy heifers (for sale), dairy heifers – contract grower, and dairy heifers (for sale) - contract grower. Those four reports were downloaded from FINBIN and then combined in columns D-O of the "Heifers FINBIN" sheet for the five years of 2012-16. The columns of data from the four reports are as follows (color-coded in the spreadsheet as shown below):

- dairy replacement heifers - white
- dairy heifers for sale - grey
- dairy heifers – contract grower - green
- dairy heifers (for sale) – orange

Row 10 shows the number of operations in each category by year and for 2012-16. The vast majority of the operations still appear to be growing heifers for their own herds, assuming that that is what the "dairy replacement heifers" enterprise represents. That can be seen clearly by comparing the number in that category with the number of milking herds shown in the "Dairy FINBIN" sheet.

The number of records from operations producing dairy heifers for sale or under contract is still relatively small – 48 in all over the five years (adding E10:G10), or an average of less than ten operations per year. FINBIN only generates summaries for categories with at least five operations. Averages for dairy heifers for sale are thus only available for 2012 and 2013. Averages for contract growers are only available for 2012, while those for "dairy heifers (for sale) – contract grower" were not available for any of the five years.

With that caveat, a few observations can be made based on the five-year averages in columns D-G. First, looking at D77, the operations growing heifers for their own herds apparently failed to cover their total costs. The caveat there is that most of their heifers are transferred to the milking herds at values that are imputed rather than from market transactions, so they may have overvalued the transfers in and/or undervalued the transfers out to the milking herd. The operations producing heifers for sale also failed to all costs, but their losses were smaller. The contract growers growing heifers for sale showed a profit, although it is not possible to determine whether they were profitable in all five years or not. The contract growers not producing for sale covered all of their costs except for a few dollars of their unpaid labor and management charges.

The values used in this scenario comparison are a simple average of the values for the heifers for sale enterprise and the two contract grower categories, and NOT from the dairy replacement heifers category not for sale or under contract. In other words, columns E-G are averaged. Column D is not included due to the question about the imputed values on the animals, and because the producers with milking herds may not have managed their heifers as intensively as those specializing in heifer raising.

Another observation is that these operations did barely any grazing of their heifers, or if they did graze they did not place much economic value on that pasture in their accounting records. The only one of the three categories of operations that reported any pasture expenses was the contract growers (for sale), and they only averaged $5.54/head in pasture expenses, so the average over the three categories is only $1.85/head out of a total feed cost of $419/head. The largest feed expense is for corn silage. Of course, if this project encourages more producers to raise dairy heifers in the future, they might make pasture a larger part of the diet than is apparently the case for these existing operations.

A contract dairy heifer raising scenario was added to the spreadsheet based on a simple average of the FINBIN per-head summaries for the heifers for sale, contract heifers, and contract heifers for sale enterprises. The replacement heifer enterprise was NOT included because that category is typically used for operations that also have a milking herd rather than being a standalone enterprise as is assumed here.

There is a question about whether dairy heifers can be raised on pasture and still meet the requirements of current production contracts, since little grazing is currently being done in these enterprises. Heins and Hadrich both thought that the contract terms that are currently typical in the state would need to be renegotiated for such a pasture-based scenario to be feasible because contractors currently specify high rates of daily gain such as 2.5 pounds per day, while the best that can be expected for heifers on pasture is around 2 pounds per day (Hadrich 2017, Heins 2017). However, a study showed that on at least one Minnesota farm, there were no significant differences in average daily gain between a feedlot and pasture (Rudstrom 2004). As long as the pasture is rotated and is supplemented with some grain, Salfer thinks that rates of gain should be similar between the two systems (Salfer 2017).

Given that information, the dairy heifer scenario assumes that 30 percent of the FINBIN expenses for corn silage, alfalfa and grass haylage, and oatlage would be replaced with intensively-managed, non-organic pasture of the same market value. It is also possible that a different measure such as dry matter might be better than market value as the basis for the substitution, but that extra calculation is beyond the scope of this analysis.

Alfalfa for beef cow-calf feed and for sale

Yields and economics

The alfalfa economic information is based largely on the FINBIN enterprise summary displayed in the Alfalfa_hay sheet. Like the other crops, the alfalfa yield is based on the five-year average for 2012-16. The alfalfa hay fed to the cow-calf enterprise is valued at the 2016 FINBIN price of $120 per ton, which is lower than the five-year average of $157. However, it is believed that most of the farms with alfalfa enterprises in FINBIN fed the alfalfa to their own livestock located on that farm. USDA-NASS reports prices actually received by producers for alfalfa that is sold. The average price reported for the 2016-17 marketing year (June 1, 2016 - May 31, 2017) was $81 per ton, or considerably less than the FINBIN price (USDA National Agricultural Statistics Service).

The "alfalfa hay for sale" enterprise included in this analysis would most likely incur a transportation cost to ship the hay to a different livestock operation that may be located some distance away from the crop farm raising the alfalfa. One venue for selling hay is the Sauk Centre Hay Auction (Mid-American Auction Company 2016). Actual shipping distances for hay sold in 2016 is are unknown, but 50 miles might be typical. A scenario is shown starting in row 109 of the Alfalfa Hay sheet based on a one-way distance of 50 miles works out to be $5.63/ton. That and the other assumptions are shown in the yellow cells. The basic transportation model was developed for a 2008 analysis of biomass crops for energy (Lazarus 2008). The truck overhead cost is from a recent New York analysis (Volk 2017). The labor and fuel prices are from a report of farm machinery operation costs in Minnesota (Lazarus 2017). If the hay sellers deduct their transportation costs from the prices they report to USDA-NASS, that would account for some but not all of the $39 per ton difference between that price and the FINBIN price. Perceived feed quality differences may be another factor accounting for the difference. The $81 per ton USDA-NASS price is used for the alfalfa hay-for-sale enterprise in this analysis.

Environmental benefits of the perennial crops and cover crops

The environmental benefits of switchgrass and the other perennial crops under consideration are being calculated by MPCA staff using HSPF rather than in the spreadsheet discussed in the rest of this document. This section discusses the environmental calculations in the NBMP and PBMP spreadsheets for use in the HSPF calculations.

Nitrogen and phosphorus loading from current annual crops

The nitrogen loading coefficients in NBMP and PBMP were developed by Professor David Mulla and Jake Galzki as part of that project, so there is no separate documentation for them.

The "current" loading calculations (as opposed to the loading after BMP implementation, which is calculated in the BMP sheet) are in the Current sheet. Total N loading is divided into amounts in

- tile drainage
- leaching to groundwater (not in tile drainage), and
- in runoff.

Total current N loading per acre by crop is not broken out in the distribution copy of NBMP, but was calculated for this analysis. It varies by watershed, but the statewide amounts are:

Crop	N loading/acre	P loading/acre

Corn grain	14.3	
Soybeans	5.5	
Alfalfa	0.9	
Average for small grains, sugar beet, potato, sweet corn, peas, and dry edible beans	5.7	
All cultivated agricultural land	9.7	
Perennial crops (switchgrass)	1.9	0.36

NBMP is set up to evaluate BMPs that affect the per-acre N loading from corn along with overall watershed loading that would result from converting land from annual crops to other land cover such as buffers. It is NOT set up to evaluate BMPs that change the acres or loading per acre for alfalfa, small grains, sugar beet, potato, or the short-season crops sweet corn, peas, or dry edible beans. The above corn loading rate would be reduced by implementation of the BMPs such as a reduced fertilizer application rate that are built into the spreadsheet.

The P loading calculations in the PBMP spreadsheet are not broken out by crop.

A modified version of NBMP and PBMP is available from the authors for recalculating the above loading amounts for specific HUC8 or HUC10 watersheds.

Switchgrass

The perennial crop represented in NBMP is switchgrass. The switchgrass contributes much less N loading than corn and soybeans, but still contributes some. The switchgrass N loading coefficients are in the “Returns_per_A” sheet, in A77:D79, and are based on a 2010 article based on Illinois research (McIsaac, David et al. 2010). Table 3 in that article shows switchgrass contributing 5.7 kg of total inorganic N ha-1 yr-1. That is an 87 percent reduction from the 43 kg of N contributed by a corn-soybean rotation. That percentage reduction is applied to the corn and soybean N loading in NBMP to arrive at the switchgrass loading.

The P load reduction benefits of switchgrass are calculated in PBMP. Land in corn, soybeans, or small grains can be converted to switchgrass but only on marginal land, defined as land with a CPI of less than 60. The adoption rate from the Main sheet is transferred over to row 82 of the Erosion sheet. The top section of that sheet uses the Universal Soil Loss Equation to calculate erosion under the annual crops based on two values for the C coefficient. The “worst” one is used for conventional tillage and the “best” one for reduced tillage. Those coefficients are in rows 57:58. Conversion to switchgrass reduces the C coefficient to a value of 0.005, in row 103. Those values influence the scores in row 107 and 152. Those values are transferred to the “P_Index_Scores” sheet. The index values are converted to pounds of P loading based on the conversion factor of 50 contained in the Parameters sheet.

Alfalfa

The alfalfa loading coefficients in NBMP and PBMP were developed by Professor David Mulla and Jake Galzki as part of that project, so there is no separate documentation for them.

Alfalfa is included in the N loading calculations in the NBMP spreadsheet. The “current” loading calculations (as opposed to the loading after BMP implementation, which is calculated in the BMP sheet) are in the Current sheet. Total N loading is divided into amounts in tile drainage, amounts leaching to groundwater, and in runoff.

The percent of each agroecoregion that is NOT drained is in row 223. Row 249 shows pounds of N from undrained alfalfa land based on 1.56 lbs/acre of undrained alfalfa. Row 250 shows the pounds of nitrate leaching to groundwater after the percent denitrified in row 246. N from alfalfa to tile lines is shown in row 262. A factor of 12 percent is added to those amounts in row 271 to adjust for TKN (total kjeldahl nitrogen). Alfalfa acres are not included in the runoff calculations.

The pounds of N leaching to groundwater from alfalfa after BMP implementation are in row 353 of the BMP sheet while the N from alfalfa to tile lines is in row 367. However, NBMP is not set up to evaluate BMPs that change the alfalfa acres or loading per acre. Hence, those amounts for alfalfa should match those in the analogous rows of the Current sheet.

Kernza

No data on the N or P loading results have been located so far for Kernza. The Kernza scenario modeled here involves a four-year stand, which is similar to alfalfa hay. So, as a first cut it might be reasonable to use the alfalfa values for Kernza until more data becomes available.

Cover crops

Studies of the potential for cover crops to reduce nitrate loading vary widely. A 2008 interpretative summary reported in the Iowa Nutrient Reduction Strategy literature review found reductions from 13 percent in Minnesota to 94 percent in Kentucky (Iowa State University 2016), p. 59. The Minnesota study showing a 13 percent reduction was (Strock, Porter et al. 2004). In follow-up discussions, Dr. Strock attributed their low percentage to adverse weather conditions that affected establishment. The Iowa researchers chose 31 percent as the planning number to use in their analysis (see Table 2, p. 6). That was rounded off to 30 percent and used as the default number in the Minnesota nitrogen reduction planning spreadsheet (Lazarus, Kramer et al. 2013). That 30 percent estimate is recommended for use in the “cover crop between soybeans and corn” scenario here.

Research at Morris, Minnesota has shown that camelina and pennycress cover crops reduce N in the underlying groundwater by around the same amount as cereal rye (they were not statistically different) (Forcella, Matthees et al. 2017). The results are displayed in a handout from a recent field day. A journal article with the full results is in press. The reductions in soil water N compared to no cover crop shown in the handout are impressive, but in a follow-up conversation, Dr. Gesch pointed out that the graph in the handout shows results from suction cup lysimeters in the plots rather than measurements of actual tile line N. There is no way to translate those lysimeter readings to tile line percentage reductions comparable to those discussed above from the Iowa document or from the Strock et al. article.

For the purpose of this analysis, then, the N loading reduction that would result from adopting the “cover crop between soybeans and corn” scenario on cropland in a 50:50 corn/soybeans rotation can be calculated in a straightforward way by applying the 30 percent reduction estimate to the current corn and soybean loading amounts shown above.

The N loading reductions from adopting the “legume cover crop between a small grain and corn” scenario or the “camelina cover crop between a small grain and soybeans” scenario would be different because one would be replacing the soybeans or the corn in the rotation with the small grain. The initial N load that the cover crop's 30 percent reduction is applied to would be different.

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