Agribusiness & Applied Economics Report 728 **September 2014**

Potential Availability and Cost of Flax Straw for Commercial Applications

Randal C. Coon
Nancy M. Hodur
Dean A. Bangsund

Department of Agribusiness and Applied Economics
Agricultural Experiment Station
North Dakota State University
Fargo, ND 58108-6050

Acknowledgements

Special thanks to the Agriculture Products Utilization Committee (APUC) for financial support.

Thank you to Roger Gussias, a North Dakota flax producer for his insights on issues and considerations from the producer's perspective and Dennis Magotioux a straw purchasing manager for SWM International for his insights on relevant issues from a buyers perspective.

Thank you to Edie Nelson for document preparation.

The author would like to thank Dwight Aakre for his constructive comments.

This publication is available electronically at this web site: http://agecon.lib.umn.edu/. NDSU is an equal opportunity institution.

 Please address your inquiries regarding this publication to: Department of Agribusiness & Applied Economics, P.O. Box 6050, Fargo, ND 58108-6050, Phone: 701-231-7441, Fax: 701-231-7400, Email: ndsu.agribusiness@ndsu.edu.

Table of Contents

List of Tables

List of Figures

List of Appendix Tables

Potential Availability and Cost of Flax Straw for Commercial Applications

Randal C. Coon, Nancy M. Hodur and Dean A. Bangsund

Executive Summary

The concept of turning biomass into a useable product has long been a goal of value-added agriculture. Flax fiber which is two to three times stronger than cotton fiber and superior weight to strength ratio characteristics has been identified as a potential feedstock for an intermediate product used to make innovative biopolymer composite materials.

This study has two objectives: 1) to explore the feasibility of replacing the glass fibers in plastic components with flax fibers and 2) estimate the availability and cost of procuring flax straw for use in commercial applications. Findings related to physical and mechanical properties will be reported as findings to the Agriculture Products Utilization Committee (APUC). This report will examine the second objective and estimate potential flax straw supply based on flax production and estimate the cost to procure flax straw in North Dakota. The study will also examine current flax straw markets and discuss baseline economic conditions required for commercialization.

North Dakota is the nation's leading flax producing state. In the past 10 years, North Dakota has accounted for 95 percent of total flax production in the United States (NASS various years 2004 to 2013). In 2012, the three top flax producing counties were Ward County (50,982 acres), McLean County (36,023 acres), and Mountrail County (31,799 acres). Four other counties, Sheridan, Bottineau, McHenry, and Renville, had planted acreages exceeding 13,000 acres. Flax production is concentrated in northwestern North Dakota in the Northwest Crop Reporting District with substantial production in four counties contiguous to the Northwest Crop Reporting District.

Flax yields can be used to estimate the amount of straw produced. Previous research has used the Harvest Index, which is the ratio of grain weight to the total plant weight to estimate the weight of straw produced, see Coon and Leistritz (2005) and Coon and Leistritz (2010). NASS Crop Reporting District data were used to estimate total flax straw production for each crop reporting district. Average yields multiplied by harvested acres and the ratio of recoverable straw were used to estimate total flax straw produced.

The price of flax straw was based on the nutrient value of the straw, the cost of baling, collection and transportation, and a producer incentive payment. All costs were estimated on a per-acre and per-ton basis. Total cost of flax straw was estimated to be $57.05 per ton based on recent yield and price data. These costs represent a value of $28.05 per acre.

Markets for flax straw in North Dakota are limited but with amply supply there is market potential. In order to gain some industry perspective, a flax producer/straw seller and a flax industry straw buyer were interviewed. Industry representatives, both buyers and sellers,

suggested that a flax processing plant located in the flax producing area of North Dakota could have potential economic benefits. Transportation costs for flax straw buyers could be minimized, and producers would have an additional market for their biomass.

Estimating available raw material and potential acquisition costs are good first steps in evaluating the market viability of flax fibers as inputs for various manufacturing processes. A number of factors may reduce the effective amount of flax straw available for processing, such as weather, producers' willingness to sell, isolated or logistically expensive production, or straw that may already be used for other purposes may reduce the effective amount of flax straw available for production. Even though those factors were not addressed in this project, a considerable tonnage of flax straw would likely be available for processing in the Northwest region of North Dakota. Several additional factors must be evaluated to better define and understand the market for flax fibers. It remains unclear how much demand there may be for flax fibers as research efforts to understand the physical and mechanical properties of biopolymer composites are ongoing.

Introduction

The concept of turning biomass into a useable product has long been a goal of value-added agriculture. Wheat straw has been considered for use in building materials, as a biorefinery feedstock, and for producing ethanol (Leistritz et al. 2006; Brockema 2009). Currently, wheat straw and corn stover are being analyzed for use as a pelleted cattle feed using an ammonia fiber explosion treatment (MBI 2014). Flax straw is also being studied as a feedstock for an intermediate product used to manufacture plastics.

This study has two objectives: 1) to explore the feasibility of replacing the glass fibers in plastic components with flax fibers and 2) Flax fiber is two to three times stronger than cotton fiber and has superior weight to strength ratio characteristics to estimate the availability and cost of procuring flax straw for use in commercial applications. Engineers in the Department of Agricultural and Biosystems Engineering will engineer and manufacture test components with flax fiber and analyze physical and mechanical properties will be reported as findings to APUC. This report will examine potential flax straw supply based on flax production and estimate the cost to procure flax straw in North Dakota. The report will also examine current flax straw markets and discuss baseline economic conditions required for commercialization.

North Dakota Flax Production

North Dakota is the nation's leading flax producing state. In the past 10 years, North Dakota has accounted for 95 percent of total flax production in the United States (NASS various years 2004 to 2013). While North Dakota had over 300,000 acres of flax in 2012 (North Dakota Farm Service Agency 2012), production was far less than all wheat (7.6 million acres), soybeans (4.7 million acres), and corn for grain (3.4 million acres). Figure 1 presents flax acreage by county for 2012. (See Appendix Table 1 for flax acreage in North Dakota, by county, for 1998-2012.) In 2012, the top three flax producing counties were Ward County (50,982 acres), McLean County (36,023 acres), and Mountrail County (31,799 acres). Four other counties, Sheridan, Bottineau, McHenry, and Renville, had planted acreages exceeding 13,000 acres. Flax production is concentrated in northwestern North Dakota in the Northwest Crop Reporting District (Figure 2) with substantial production in four counties contiguous to the Northwest Crop Reporting District.

Flax yields for the three counties with the largest acreages in 2012, Ward, McLean, and Mountrail Counties had yields of 19.1, 19.1, and 17.6 bushels per acre, respectively. These yields were higher than the state average, but below Walsh County (22.7 bushels per acre) which had the highest average yields in the state that year (Figure 3). (See Appendix Table 2 for yields, by county, and the state for 1998-2012). The state average yield peaked in 2009 and 2010 with a 24.0 bushel per acre average.

Flax prices have been more stable than and have not experience large price swings like other commodities in North Dakota. During the period 1998- 2012, flax prices in nominal dollars were at their lowest in 1998 at $3.31 per bushel, increasing to $8.05 in 2004 (Table 1). Prices dropped to just under $6.00 in 2005 and 2006 and then increased to $13.00 and $12.70 in

2007 and 2008, respectively. Prices dropped again in 2009 to $8.15 before increasing to $12.20 in 2010, $13.90 in 2011, and $13.80 in 2012. Flax is considered to be a specialty crop and not as susceptible to the world supply and demand fluctuations like corn and soybeans.

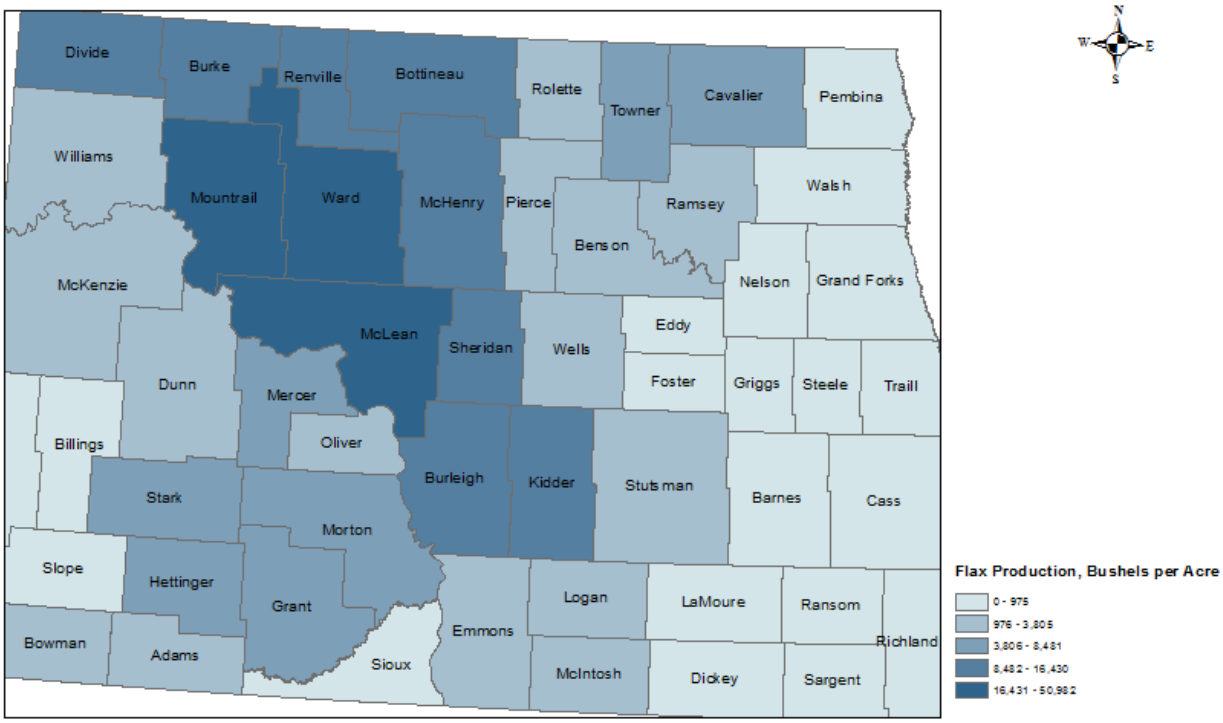

Figure 1. North Dakota Flax Production, Bushels per Acre, by County, 2012

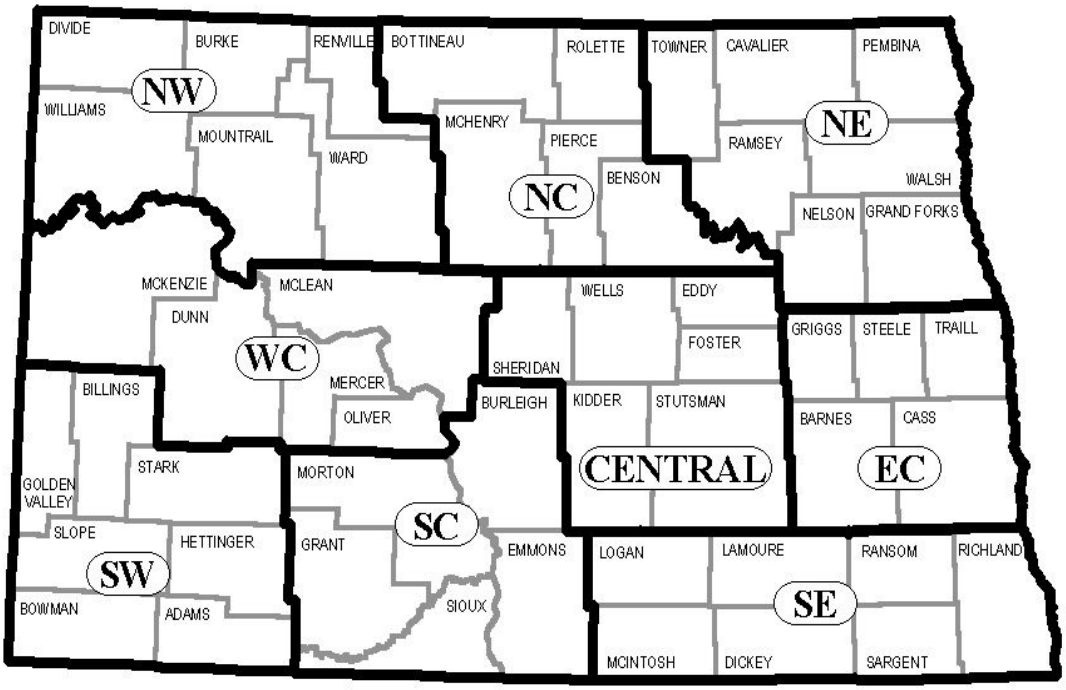

Figure 2. North Dakota Crop Reporting Districts

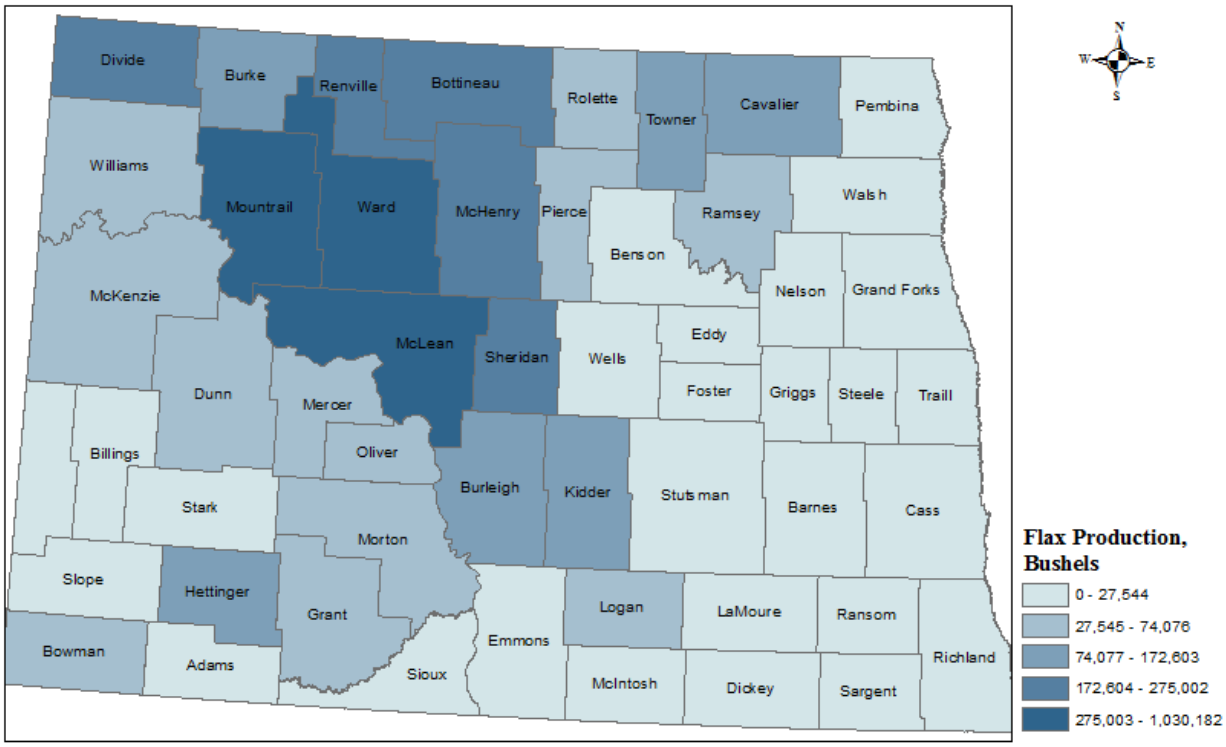

Figure 3. North Dakota Flax Production by County, 2012

Table 1. Flax Prices for North Dakota, 1998 – 2012 (Nominal Dollars)	
Year	Flax Price Per Bushel
	----------$----------
1998	5.05
1999	3.79
2000	3.31
2001	4.29
2002	5.77
2003	5.88
2004	8.05
2005	5.94
2006	5.8
2007	13.00
2008	12.70
2009	8.15
2010	12.20
2011	13.90
2012	13.80
Source: National Agricultural Statistics Service (2014).	

Total flax production for North Dakota and each county for the 1998-2012 period is presented in Table 2. Flax production in the three counties with the largest acreages in 2012 were 1,030,182 bushels in Ward County, 670,768 bushels in McLean County, and 573,544 bushels in Mountrail County. North Dakota's flax production during the 1998-2012 period peaked in 2001 at 10.9 million bushels. For some reporting periods and some counties flax production was not reported due to potential disclosure issues. In instances where an insufficient number of observations were reported, National Agricultural Statistical Agency (NASS) does not report on a per county basis. For this reason the Crop Reporting Districts provide a more complete data set for minor crops produced in the state. Flax production data for North Dakota (Table 3) and the nine Crop Reporting Districts (Tables 4-12) show multi-county flax production. Even though production data were consolidated from county level to crop reporting districts for some reporting periods, disclosure issues prevented reporting for some crop reporting districts. The Northwest District, with two of the largest flax producing counties, produced the most flax in 2012, 2.4 million bushels. Flax production in the North Central Crop Reporting District was the second largest with 600,000 bushels in 2012, or about a quarter of the production in the Northwest District.

Table 2. North Dakota Flax Production, by County, 1998-2012

COUNTY	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
	bushels														
Adams	28,800	35,700	23,100	24,400	0	0	0	0	0	0	0	17,511	19,296	37,216	27,544
Barnes	92,000	96,900	147,500	85,000	70,000	36,000	33,000	46,000	0	0	0	0	0	0	731
Benson	114,300	129,400	256,300	183,000	148,000	158,000	102,000	322,000	164,000	28,000	55,000	35,000	100,973	16,749	20,046
Billings	0	7,700	0	0	0	0	0	0	0	0	0	7,546	5,387	0	641
Bottineau	548,400	222,100	634,000	689,000	1,083,000	674,000	514,000	1,187,000	767,000	338,000	300,000	432,000	530,578	32,748	249,529
Bowman	0	16,700	0	0	11,300	9,000	16,000	47,000	41,000	0	0	43,857	28,680	34,966	35,818
Burke	44,400	99,100	181,100	404,000	728,000	449,000	315,000	846,000	610,000	438,000	292,000	359,000	423,087	68,470	163,817
Burleigh	66,800	86,700	158,700	197,000	141,000	154,000	258,000	475,000	134,000	156,000	176,000	0	375,152	187,920	172,603
Cass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cavalier	479,400	728,700	803,700	639,000	860,000	729,000	476,000	777,000	549,000	144,000	174,000	98,000	304,379	96,094	139,326
Dickey	45,700	79,900	63,800	56,000	13,800	0	27,000	33,000	9,000	0	0	0	0	0	0
Divide	21,500	75,600	154,100	476,000	315,000	108,000	177,000	391,000	305,000	143,000	168,000	176,000	158,916	8,490	198,407
Dunn	21,100	15,600	17,000	20,000	21,000	35,000	37,000	61,000	37,000	46,000	0	74,146	47,954	17,264	40,133
Eddy	69,500	95,800	148,800	83,000	68,000	140,000	102,000	219,000	120,000	0	46,000	15,000	22,433	4,996	8,048
Emmons	64,400	125,200	225,300	182,000	63,000	72,000	36,000	122,000	11,000	24,000	0	0	46,050	25,678	16,200
Foster	221,800	234,100	367,800	179,000	74,000	83,000	88,000	257,000	102,000	0	26,000	12,912	30,249	2,438	4,371
Golden Valley	59,600	57,100	35,000	24,000	22,200	40,000	5,000	32,000	19,000	0	3,000	26,289	16,734	0	7,710
Grand Forks	38,800	44,000	38,100	21,000	11,000	55,000	0	39,000	0	0	0	4,976	2,945	0	1,967
Grant	9,400	35,400	23,700	0	0	14,500	14,000	0	14,000	0	0	0	83,906	84,341	68,750
Griggs	37,300	35,500	47,900	34,000	15,700	7,000	0	17,000	16,000	0	0	0	0	0	0
Hettinger	241,300	353,100	403,400	230,000	109,000	66,000	75,000	349,000	130,000	119,000	41,000	176,000	142,862	83,374	102,199
Kidder	115,400	182,500	265,500	238,000	83,000	195,000	292,000	393,000	72,000	162,000	238,000	330,000	343,972	168,017	137,909
LaMoure	92,100	91,700	142,000	117,000	26,000	44,000	44,000	61,000	0	0	0	0	101	0	0
Logan	93,500	124,600	220,700	162,000	95,000	135,000	123,000	175,000	62,000	0	0	0	51,965	21,721	37,470
McHenry	132,300	104,000	172,200	234,000	323,000	360,000	497,000	667,000	401,000	224,000	292,000	284,000	399,804	76,723	268,805
McIntosh	185,000	260,900	338,300	228,000	48,000	56,000	89,000	122,000	32,000	0	0	0	45,016	11,390	4,776
McKenzie	0	17,800	7,600	50,000	37,000	17,000	26,000	101,000	38,000	0	0	14,855	25,514	9,025	35,801
McLean	198,000	324,600	392,200	794,000	1,012,0	1,003,000	1,161,000	1,568,000	1,165,000	625,000	687,000	1,125,000	1,234,713	1,535,405	670,768
Mercer	0	20,000	27,400	46,000	85,000	58,000	85,000	186,000	73,000	41,000	30,000	72,000	114,476	28,522	74,076
Morton	9,400	11,500	27,000	23,400	22,000	0	0	37,000	0	0	7,000	0	56,004	52,894	71,746
Mountrail	74,000	89,700	279,900	731,000	1,111,000	752,000	750,000	1,472,000	736,000	454,000	297,000	579,312	676,732	152,813	573,544
Nelson	163,700	192,600	189,500	146,000	143,000	127,000	102,000	215,000	90,000	54,000	42,000	19,085	15,048	4,250	4,022

Table 2 (cont.) North Dakota Flax Production, by County, 1998-2012															
Oliver	16,300	16,000	21,800	34,000	25,000	22,000	51,000	94,000	37,000	0	10,000	43,999	58,409	17,221	33,399
Pembina	72,500	110,800	48,300	10,000	15,000	21,000	0	29,000	0	0	0	0	0	0	0
Pierce	137,800	144,200	208,300	158,000	216,000	193,000	198,000	381,000	242,000	133,000	91,000	88,000	97,200	31,954	63,540
Ramsey	251,500	267,300	361,800	371,000	478,000	238,000	164,000	291,000	290,000	64,000	59,000	48,666	125,708	23,588	30,388
Ransom	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Renville	275,100	178,200	262,500	441,000	755,000	527,000	425,000	1,133,000	672,000	337,000	342,000	241,359	390,538	0	254,754
Richland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	125
Rolette	70,200	76,300	180,200	226,000	230,000	185,000	129,000	228,000	186,000	92,000	97,000	47,000	96,908	32,776	57,238
Sargent	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
Sheridan	111,200	184,000	214,900	289,000	428,000	470,000	750,000	882,000	301,000	294,000	325,000	355,000	579,027	216,522	275,002
Sioux	0	7,200	10,300	0	0	0	0	0	0	0	0	0	14,784	5,670	8,031
Slope	25,800	41,900	64,500	69,000	19,500	14,000	17,000	38,000	26,000	0	5,000	156,941	15,684	12,600	9,783
Stark	50,300	81,800	80,500	67,000	40,000	27,000	40,000	88,000	33,000	20,000	0	55,302	37,463	39,096	4,069
Steele	58,200	90,200	72,000	47,000	43,500	44,000	36,000	29,000	0	0	0	0	0	14,598	256
Stutsman	388,800	476,500	655,900	512,000	244,000	270,000	214,000	442,000	181,000	43,000	70,000	88,088	113,142	42,520	22,161
Towner	387,400	464,400	684,200	404,000	489,000	394,000	374,000	639,000	426,000	162,000	209,000	162,000	266,499	0	102,341
Traill	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Walsh	139,700	136,200	114,400	86,000	109,000	121,000	88,000	170,000	125,000	47,000	55,000	31,273	85,501	21,565	19,651
Ward	429,700	428,900	950,200	1,585,000	1,968,000	1,360,000	1,611,000	2,545,000	1,718,000	944,000	1,056,000	1,227,000	1,503,838	206,825	1,030,182
Wells	77,300	114,100	168,100	95,000	178,000	207,000	219,000	472,000	154,000	65,000	82,000	39,000	75,597	34,288	23,620
Williams	14,300	22,500	43,200	153,000	223,000	179,000	122,000	403,000	167,000	73,000	25,000	47,328	69,897	5,411	70,048
ND	5,817,000	6,867,000	9,975,000	10,900,000	12,240,000	9,900,000	9,943,000	18,165,000	10,368,000	5,548,000	5,491,000	7,032,000	8,536,000	2,426,000	5,478,000
Source: National Agricultural Statistics Service (2014); Risk Management Agency (2010 to 2012).															

Table 3. Flax Acres Harvested, Production, and Yield Per Acre for North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	277,000	5,817,000	21.0
1999	327,000	6,867,000	21.0
2000	475,000	9,975,000	21.0
2001	545,000	10,900,000	20.0
2002	680,000	11,560,000	17.0
2003	555,000	9,990,000	18.0
2004	480,000	9,840,000	20.5
2005	865,000	18,165,000	21.0
2006	715,000	10,368,000	14.5
2007	317,000	5,548,000	17.5
2008	323,000	5,491,000	17.0
2009	293,000	7,032,000	24.0
2010	388,000	8,536,000	22.0
2011	147,000	2,426,000	16.5
2012	310,000	5,425,000	17.5
Source: National Agricultural Statistics Service (2014).			

Table 4. Flax Acres Harvested, Production, and Yield Per Acre for Central Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	49,500	987,000	19.9
1999	63,700	1,287,000	20.2
2000	89,400	1,821,000	20.4
2001	81,800	1,396,000	17.1
2002	68,500	1,050,000	15.3
2003	73,800	1,370,000	18.6
2004	79,300	1,655,000	20.9
2005	129,700	2,665,000	20.5
2006	80,000	930,000	11.6
2007	42,100	625,000	14.8
2008	47,200	787,000	16.5
2009	45,200	840,000	18.5
2010	60,500	1,200,000	19.8
2011	33,300	524,000	15.7
2012	33,900	501,000	14.8
Source: National Agricultural Statistics Service (2014).			

Table 5. Flax Acres Harvested, Production, and Yield Per Acre for the East Central Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	9,400	201,000	21.4
1999	11,900	241,000	20.3
2000	13,900	281,000	20.7
2001	8,400	172,000	20.5
2002	6,500	174,000	19.1
2003	4,900	95,000	19.4
2004	3,900	75,000	19.2
2005	4,600	100,000	21.7
2006	3,900	59,000	15.1
2007	(D)	(D)	(D)
2008	(D)	(D)	(D)
2009	(D)	(D)	(D)
2010	550	9,000	16.4
2011	(D)	(D)	(D)
2012	(D)	(D)	(D)
(D): Data not reported to avoid disclosure problems. Source: National Agricultural Statistics Service (2014).			

Table 6. Flax Acres Harvested, Production, and Yield Per Acre for the North Central Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
	-------number-----	------bushels------	----bushels per acre---
1998	47,200	1,003,000	21.3
1999	34,500	676,000	19.6
2000	66,700	1,451,000	21.8
2001	69,700	1,490,000	21.4
2002	106,000	1,825,000	17.2
2003	76,700	1,585,000	20.7
2004	67,700	1,430,000	21.1
2005	134,500	2,785,000	20.7
2006	115,700	1,760,000	15.2
2007	37,800	730,000	19.3
2008	43,200	835,000	19.5
2009	35,700	886,000	25.0
2010	51,400	1,202,000	23.4
2011	11,300	189,000	16.7
2012	39,800	603,000	15.2
Source: National Agricultural Statistics Service (2014).			

Table 7. Flax Acres Harvested, Production, and Yield Per Acre for the Northeast Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
	----------number---------	------bushels------	----bushels per acre----
1998	66,000	1,533,000	23.2
1999	79,700	1,944,000	24.4
2000	102,400	2,240,000	21.9
2001	80,500	1,677,000	20.8
2002	95,000	1,935,000	20.4
2003	71,800	1,705,000	23.7
2004	55,100	1,210,000	22.0
2005	111,100	2,160,000	19.4
2006	76,700	1,508,000	19.7
2007	22,200	495,000	22.3
2008	25,100	550,000	22.0
2009	14,500	364,000	25.0
2010	28,300	708,000	25.0
2011	8,600	180,000	20.9
2012	(D)	(D)	(D)
(D): Data not reported to avoid disclosure problems. Source: National Agricultural Statistics Service (2014).			

Table 8. Flax Acres Harvested, Production, and Yield Per Acre for the Northwest Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	39,500	859,000	21.7
1999	38,800	894,000	23.0
2000	86,100	1,871,000	21.7
2001	177,500	3,790,000	21.4
2002	284,000	4,950,000	17.4
2003	214,000	3,405,000	15.9
2004	158,500	3,351,000	21.1
2005	307,000	6,790,000	22.1
2006	283,500	4,208,000	14.8
2007	133,500	2,460,000	18.4
2008	123,000	2,180,000	17.5
2009	106,800	2,630,000	24.5
2010	134,700	2,896,000	21.5
2011	29,300	449,000	15.3
2012	127,600	2,438,000	19.1
Source: National Agricultural Statistics Service (2014).			

Table 9. Flax Acres Harvested, Production, and Yield Per Acre for the South Central Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	9,000	150,000	16.7
1999	14,900	266,000	17.9
2000	20,000	445,000	22.3
2001	22,500	426,000	18.9
2002	17,500	202,000	11.5
2003	19,000	260,000	13.7
2004	21,500	319,000	14.8
2005	33,900	685,000	20.2
2006	24,500	166,000	6.8
2007	17,200	240,000	14.0
2008	17,800	220,000	12.5
2009	(D)	(D)	(D)
2010	29,000	653,000	22.5
2011	23,800	399,000	16.8
2012	23,400	405,000	17.3
(D): Data not reported to avoid disclosure problems. Source: National Agricultural Statistics Service (2014).			

Table 10. Flax Acres Harvested, Production, and Yield Per Acre for the Southeast Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	22,300	422,000	18.9
1999	32,300	571,000	17.7
2000	41,100	770,000	18.7
2001	34,800	570,000	16.4
2002	17,000	172,000	10.1
2003	18,000	255,000	14.2
2004	16,200	295,000	18.2
2005	24,100	400,000	16.6
2006	13,300	124,000	9.3
2007	(D)	(D)	(D)
2008	(D)	(D)	(D)
2009	(D)	(D)	(D)
2010	5,750	106,000	18.4
2011	(D)	(D)	(D)
2012	(D)	(D)	(D)
(D): Data not reported to avoid disclosure problems. Source: National Agricultural Statistics Service (2014).			

Table 11. Flax Acres Harvested, Production, and Yield Per Acre for the Southwest Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	20,600	418,000	20.3
1999	29,800	594,000	19.9
2000	26,600	630,000	23.7
2001	19,400	435,000	22.4
2002	20,000	212,000	10.6
2003	12,800	170,000	13.3
2004	11,100	150,000	13.5
2005	26,600	570,000	21.4
2006	28,600	263,000	9.2
2007	11,400	170,000	14.9
2008	7,700	77,000	10.0
2009	12,100	350,000	29.0
2010	11,600	292,000	25.2
2011	11,300	230,000	20.4
2012	17,800	312,000	17.5
Source: National Agricultural Statistics Service (2014).			

Table 12. Flax Acres Harvested, Production, and Yield Per Acre for the West Central Crop Reporting District, North Dakota, 1998-2012			
Year	Acres Harvested	Production	Yield
		------bushels------	----bushels per acre----
1998	13,500	244,000	18.1
1999	21,400	394,000	18.4
2000	29,100	466,000	16.0
2001	50,400	944,000	18.7
2002	65,500	1,090,000	16.6
2003	64,000	1,145,000	17.9
2004	66,700	1,355,000	20.3
2005	93,500	2,010,000	21.5
2006	88,800	1,350,000	15.2
2007	46,700	755,000	16.2
2008	53,300	742,000	14.0
2009	53,600	1,330,000	25.0
2010	66,200	1,470,000	22.2
2011	26,000	415,000	16.0
2012	48,900	874,000	17.9
Source: National Agricultural Statistics Service (2014).			

Estimating Flax Straw Production

Flax yields can be used to estimate the amount of straw produced. Previous research has used the Harvest Index, which is the ratio of grain weight to the total plant weight to estimate the weight of straw produced, see Coon and Leistritz (2005) and Coon and Leistritz (2010). Each grain crop has its own Harvest Index with flax having a 0.31 ratio of grain weight to total plant weight (Gailans 2010). For example, the Harvest Index for wheat is 0.38 (Ottman et al. 2000) and corn is 0.50 (Pennington 2013).

Flax yield per acre is the key variable used to estimate the amount of straw produced. Flax yield for Ward County, the largest flax producing county in North Dakota in 2012, was 19.1 bushels per acre in 2012. Using the flax Harvest Index of 0.31, the amount of straw produced was determined as follows:

Harvest Index	=	$\frac{\text{dry grain weight}}{\text{total plant dry weight}}$
Harvest Index	=	0.31
19.1 bu/acre	=	1,146 pounds of flax based on a 60 pound test weight Rowlett (2001) and a 10 percent moisture content Tames (2013)
1,146 pounds at 10 % moisture	=	1,031.4 pounds at 0 percent moisture
0.31	=	$\frac{\text{1,031.4 pounds of grain}}{\text{1,031.4 pounds of grain + x (where x is straw weight)}}$
1,031.4	=	0.31 (1,031.4) + 0.31 (x)
1,031.4	=	319.7 + 0.31 (x)
711.7	=	0.31 (x)
x	=	2,295.8
Flax straw production	=	2,295.8 pounds of straw per acre.

Crop Reporting District data presented for each of the nine Districts (Tables 4-12) were used to estimate total flax straw production for each crop reporting district. Average yield multiplied by harvested acres were used to estimate total flax straw produced. Because there is no data to suggest potential demand for flax straw for commercial uses, the Northwest Crop Reporting District (the district with the largest flax production) will be presented as an example. For the 1998-2012 period, the Northwest Crop Reporting district produced a low of 26,941 tons of flax straw in 2011, a high of 487,427 tons in 2005 and 146,466 tons in 2012. Ward County straw production was estimated to be 2,295.8 pounds per acre. Total Ward County production was estimated to be 58,521 tons of flax straw in 2012 (50,931 acres x 2,295.8 pounds/acre =117,042,180 pounds, or 58,521 tons).

Not all straw produced can be recovered by harvesting and baling operations. Recoverable straw was estimated to be 43 percent for grain crops (Lundstrom 1994). Applying this ratio to the total flax straw produced resulted in an estimate of recoverable (useable for processing) flax straw for the Northwest Crop Reporting District (Table 13). Recoverable straw in that district during the 1998-2012 period ranged from 11,585 tons in 2011 to 209,594 tons in 2005. Because there is no pre-determined feedstock requirements, estimates of recoverable straw were not done for the other crop reporting districts at this time. Similar calculations could be performed for the other eight Crop Reporting Districts to determine total recoverable flax straw.

Table 13. Total Flax Straw Production and Recoverable Flax Straw, Northwest Crop Reporting District, North Dakota, 1998-2012

Year	Flax Straw Production	Flax Straw Recoverable
	----------tons----------	
1998	51,512.0	22,150.2
1999	53,630.4	23,061.1
2000	112,283.0	48,281.7
2001	288,277.6	123,959.4
2002	296,974.2	127,698.9
2003	204,485.3	87,928.7
2004	200,984.6	86,419.1
2005	487,426.9	209,593.6
2006	252,154.0	108,426.2
2007	147,621.7	63,477.3
2008	129,358.3	55,581.1
2009	157,249.2	67,617.2
2010	174,043.3	74,838.6
2011	26,940.8	11,584.5
2012	146,465.5	62,980.2

Cost of Procuring Flax Straw

The price of flax straw was estimated based on the sum of the nutrient value the straw, the cost of baling, and collection and transportation. A producer incentive payment was included in flax straw cost estimates. It is possible an additional incentive payment would be required before producers would be willing to supply flax straw in quantities necessary to operate a processing plant.

Nutrient Value of Flax Straw

Flax straw has nutrient value. Removing the straw would require replacing the nitrogen, phosphates, and potash in the straw with commercial fertilizers. Flax straw produced per acre depends on the yield per acre. The Harvest Index for flax is 0.31, meaning that the ratio of dry grain weight to total plant dry weight is 0.31. As previously illustrated, North Dakota's 2012 average flax yield of 19.1 bushels per acre, would produce 2,295.8 pounds of straw per acre.

Flax straw contains levels of key nutrients including nitrogen (N), phosphate (P_20_5), and potash (K_20). Heard et al. (2006) reported 2,000 pounds of flax straw would have the following nutrient value:

2,000 pounds of flax straw:	28 pounds of N
	3.2 pounds of (P_20_5)
	5.6 pounds of (K_20)

Converting this to a percentage basis, the pounds of nutrients would be:

N	=	1.4 percent of straw weight
(P_20_5)	=	0.16 percent of straw weight
(K_20)	=	0.28 percent of straw weight

The 2012 flax yield of 19.1 bushels per acre would produce 2,295.8 pounds of straw per acre. This straw would have the following nutrient value:

N	=	2,295.8 pounds of straw x .014	=	32.1 pounds of N
(P_20_5)	=	2,295.8 pounds of straw x .0016	=	3.7 pounds of (P_20_5)
(K_20)	=	2,295.8 pounds of straw x .0028	=	6.4 pounds of (K_20)

Fertilizer prices have been significantly higher in past years. In 2013, fertilizer prices moderated making predicting future fertilizer prices difficult. Lacking any insight into future prices, fall 2013 prices will be used for this analysis (Perry 2013). While changes in flax yield would not affect economic analysis, increased fertilizer prices would. Typically, straw would be purchased by the bale (weight). If yields declined there would be less straw and fewer bales per acre but the nutrient value per unit of straw weight would be the same. However, if fertilizer prices were to rise, the value of the straw to the farmer would increase accordingly.

Fall 2013 fertilizer prices were as follows:

Nitrogen:	NH_3 (82-0-0)	=	$640/ton ($0.390/pound of N)
	Urea (46-0-0)	=	$415/ton ($0.451/pound of N)
Phosphorus:	P_20_5 (11-52-0)	=	$495/ton ($0.476/pound of P_20_5)
Potash:	K_20 (0-0-60)	=	$430/ton ($0.358/pound of K_20)

Using the above prices (anhydrous ammonia for N) for fertilizer, the per acre straw value for a 19.1 bushels per acre flax crop would be calculated as follows:

N	=	32.1 pounds/acre	x	$0.390	=	$12.52
P_20_5	=	3.7 pounds/acre	x	$0.476	=	1.76
K_20	=	6.4 pounds/acre	x	$0.358	=	2.29
Flax Straw Nutrient Value per Acre					=	$16.57

The flax straw nutrient value per acre ($16.57) represents the total amount of straw produced per acre. If the flax straw were to be baled, the recovery rate of 43 percent would apply (i.e., 43 percent of the 2,295.8 pounds of flax straw would be removed). Thus 43 percent of the total nutrient value ($16.57) per acre, or $7.12 worth of nutrients would be removed with the recoverable straw.

Nutrient value of all flax straw produced per acre ($16.57) and recoverable straw ($7.12) provide per acre values useful to the farmer. However, in all likelihood, a commercial flax straw processing facility would want to purchase the straw on a dollar-per-ton basis. This is likely because the types of bales (i.e., square or round) could be different, flax yield could change, recovery rates may vary by operator, and fertilizer prices typically change quite often. Converting the nutrient value to a per ton of flax straw basis provides a uniform method for pricing. The nutrient value of an acre of flax based on a yield of 19.1 bushels per acre was $16.57. This acre produced 2,295.8 pounds of straw, or 1.1479 tons. Converting this to a per ton basis, $16.57 per acre divided by 1.479 tons per acre equals $14.44 per ton. A $14.44 per ton value for nutrients removed would provide an equitable price for a ton of straw removed based on a yield of 19.1 bushels per acre and current fertilizer prices.

Farmer Incentives

Nutrient value of flax straw removed was used to establish a proxy value for flax producers. However, it is unlikely that many farmers would sell straw at a “break even” price. Cenusa Bioenergy (2012) estimated delivered costs for switchgrass. Cost of production less transportation yielded a $4 to $6 per ton producer incentive. A similar incentive of $5 per per ton was used for this analysis. Based on a 2012 yield of 19.1 bushels of flax per acre, 2,295.8 pounds of straw were produced, or 987.2 pounds of recoverable straw. This equals 0.494 tons per acre of flax straw removed, which amounts to ($5.00 per ton x 0.494 tons per acre = $2.47 per acre) $2.47 on a per acre basis. The incentive would be added to the nutrient value of the flax straw to obtain the total returns to the farmer.

Flax Straw Baling Costs

Previous studies have reported producers have little interest or ability to harvest, store or transport biomass concluding these operations would typically be hired out or done by custom workers (GRE 2009). Cost of baling flax straw would likely be similar to reported custom rates in North Dakota (Aakre 2014). The flax straw would need to be dropped into windrows by the combine during harvest. Once in windrows, custom handlers can bale, gather and transport the flax straw.

North Dakota custom baling rates for three types of bales are as follows:

Type of Bale	Rate	Most Frequent Response	Average Rate
	----------$ per bale ----------		
Large square bale (700#)	3.00 - 20.00	n/a	9.64
Round bales (1,500# or less)	3.00 - 30.00	10.00	9.47
Round bales (over 1,500#)	2.50 - 22.00	10.00	10.53

The most common types of custom bales are the 700 pound square bale and the 1,000 pound round bale. Average custom baling rates for the 700 pound square bales and the 1,000 pound round bales were $9.64 and $9.47, respectively.

It takes 2.86 square bales weighing 700 pounds to equal one ton, and 2 round bales weighing 1,000 pounds to make a ton. The average per ton cost of baling was calculated as follows:

Cost per ton for square bale (700#) = $\frac{2{,}000 \text{ pounds}}{700 \text{ pounds}}$ x $9.64 per bale

Cost per ton for square bale (700#) = 2.86 bales/ton x $9.64 per bale

Cost per ton for square bale (700#) = $27.57

Cost per ton for round bale (1,000#) = $\frac{2{,}000 \text{ pounds}}{1{,}000 \text{ pounds}}$ x $9.47/bale

Cost per ton for round bale (1,000#) = 2 bales/ton x $9.47/bale

Cost per ton for round bale (1,000#) = $18.94

Average cost per ton = ($27.57 + $18.94) / 2

Average cost per ton = $23.26 per ton

Based on custom farm work rates, the charge for baling flax was estimated to be $23.26 per ton.

Using the 2012 per acre flax yield of 19.1 bushels per acre, 2,295.8 pounds of straw would be produced. Recoverable straw for this yield would be:

Recoverable straw (pounds) = total straw (pounds) x recovery rate (percent)

Recoverable straw (pounds) = 2,295.8 x 0.43

Recoverable straw (pounds) = 987.2 pounds

For 700# bales = 987.2 pounds straw ÷ 700 pounds = 1.4 bales/acre
For 1000# bales = 987.2 pounds straw ÷ 1,000 pounds =0.99 bales/acre

Per acre square baling cost = 1.4 square bales x $9.64 = $13.50
Per acre round baling cost = 0.99 round bales x $9.47 = $9.38

Average per acre cost = ($13.50 + $9.38) ÷2 = $11.44

An $11.44 cost per acre charge was used in this analysis for baling flax straw.

Bale Collection and Loading

After the baling operation is completed, most farmers want to start their fall tillage, so the bales will need to be moved to a convenient location for loading and transportation. These operations require a tractor loader and their costs will be based on custom work rates (Aakre 2014). Bale collection costs for this analysis were determined using the following assumptions:

- tractor loader work charged at $60 per hour (Aakre 2014)
- tractor loader could haul 2 bales at a time
- average round trip to haul bales to a storage location was one-half mile
- tractor loader could travel at 6 miles per hour (12 trips per hour, or 24 bales per hour)
- cost per bale collected would be $2.50($60/hour ÷ 24 bales per hour = $2.50)
- 700 pound square and 1,000 pound round bales are the most popular sizes, so an average bale weight is 850 pounds

For flax straw, the 2012 yield of 19.1 bushels per acre would yield 2,295.8 pounds of biomass, or 987.2 pounds recoverable straw. The cost per ton for collecting flax straw was:

$$\text{Cost per ton for collecting flax straw} = \frac{2{,}000 \text{ pounds}}{850 \text{ pounds}} \times \$2.50 \text{ per bale}$$

Cost per ton for collecting flax straw = 2.35 ton x $2.50

Cost per ton for collecting flax straw = $5.88 per ton

The calculation for the per acre cost of collecting flax straw bales was:

$$\text{Bales per acre} = \frac{\text{Recoverable Flax in Pounds}}{\text{bale size in pounds}}$$

$$\text{Bales per acre} = \frac{987.2 \text{ pounds}}{850 \text{ pounds}}$$

Bales per acre = 1.16 bales per acre

Cost per Acre = 1.16 bale/acre x $2.50/bale

Cost per Acre = $2.90 per acre

Bales would need to be loaded onto a semi-truck flatbed trailer for transport to a processing or storage facility. This also would require a tractor loader. Using the same custom rate as for collection ($60.00 per hour), a per bale charge of $1.00 per bale was estimated. A semi could haul 54 square bales weighing 700 pounds, or 30 round bales weighing 1,000 pounds. The average number of bales was 42 per load (54 + 30) = 84 ÷ 2 = 42). A semi load of square bales was 18.9 tons (54 bales x 700 pounds = 37,800, or 18.9 tons) and a load of round bales was 15 tons (30 bales x 1,000 pounds = 30,000 pounds, or 15 tons). The average load was 16.95 tons (18.9 tons + 15 tons ÷ 2 = 16.95 tons). Cost per ton for loading flax straw was:

$$\text{Cost per ton} = \frac{\$42.00/\text{truckload}}{16.95 \text{ tons per load}}$$

Cost per ton = $2.47

Per acre cost of loading flax straw bales was based on 2012 yields. These calculations were as follows:

$$\text{Bales loading per acre cost for flax straw} = \frac{\text{Recoverable Biomass in Pounds}}{\text{bale size in pounds}} \times \text{loading cost}$$

$$\text{Bale loading cost per acre for flax straw} = \frac{987.2 \text{ pounds}}{850 \text{ pounds}} \times \$1.00 \text{ per bale}$$

= 1.16 bales per acre x $1.00 per bale

Bale loading per acre cost for flax straw = $1.16 per acre

Transportation Costs

Flax straw will have to be transported from the fields to a processing center regardless of where it is located. The two most common types of bales, the 700 pound square bales and the 1,000 pound round bales, will be used to estimate the transportation costs. The cost for hauling straw with a semi-truck and flatbed trailer was estimated to be $4.00 per loaded mile (Aakre 2014). The average cost per ton per loaded mile was calculated as follows:

A semi loaded with large round bales could haul 30 bales, or 15 tons
(30 - 1,000 pound bales is 30,000 pounds or 15 tons)

A semi loaded with large square bales could haul 54 bales, or 18.9 tons
(54 - 700 pound bales is 37,800 pounds or 18.9 tons)

Cost per loaded mile for large round bales =
$4.00/mile ÷ 15 tons = $0.27 per ton per loaded mile

Cost per loaded mile for large square bales =
$4.00/mile ÷ 18.9 tons =$0.21 per ton per loaded mile

Average cost per ton loaded mile	=	$0.27/ton/loaded mile
	+	0.21/ton/loaded mile
		$0.48 ÷ 2 = $0.24
Average cost per ton per loaded mile	=	$0.24

It is difficult to estimate the average loaded mile trip to haul flax straw to a processing center without knowing the feedstock requirements. At this stage of the engineering analysis, a plant size has not yet been determined. Combined acreage of flax for Ward, McLean, and Mountrail Counties represented 4.6 percent of those counties total planted crop acres in 2012 (North Dakota Farm Service Agency 2012). These three counties traditionally have the largest number of flax acres of any in the state. With only 4.6 percent of those counties crop acres in flax, procuring enough flax straw to operate a conversion facility may require long travel distances. A previous study (Coon and Leistritz 2005) estimated a 50-mile radius for wheat straw procurement to operate a biorefinery. This resulted in an average loaded haul distance of 25 miles. Based on a 25-mile average loaded mile haul to a processing plant would, the delivered cost per ton for flax straw would be:

Cost per ton for transportation = 25.0 loaded miles x $0.24/ton/loaded mile

Cost per ton for transportation = $6.00 per ton

Using the 2012 North Dakota flax yield of 19.1 bushels per acre, 2,295.8 pounds of straw was produced. This resulted in 987.2 pounds of recoverable straw. Cost per acre for transporting the flax straw was calculated as follows:

Cost per acre for transportation = 987.2 pounds per acre ÷ 2000 pounds/ton x $6.00/ton

Cost per acre for transportation = 0.4936 tons x $6.00 per ton

Cost per acre for transportation = $2.96 per acre

As the physical properties and processes of substituting flax straw for glass fibers are better understood, procurement costs can be refined. Once the amount of flax straw that is needed to supply commercial applications, feedstock supply areas and associated costs of transportation can be refined.

Total Costs

Total costs to obtain, bale, collect, load and transport flax straw to a processing facility are presented in Table 14. Costs include a nutrient value for flax straw, an incentive to the farmer, baling costs, charges for collecting the bales and loading them on semi-trucks, and a transportation cost to the processing facility. All costs were estimated in a per acre and per ton basis. Total costs to purchase flax straw were $57.05 per ton based on the most recent yield and price data available. These costs represent a value of $28.05 per acre. Per acre costs were less than per ton because average production was slightly less than one-half ton of recoverable straw per acre. Purchasing biomass on a per ton basis clearly has advantages due to differences in yield, type and size of bales, custom work rates, and straw recovery rates. These cost estimates provide a good indicator of the cost structure a flax processing facility will encounter.

Table 14. Costs Associated with Purchase of Flax Straw for Processing, Based on 2012 Flax Yields and 2013 Production Costs

Item	Cost Per Acre	Cost Per Ton
	----------$----------	
Nutrient Value	7.12	14.44
Farmer Incentive	2.47	5.00
Baling	11.44	23.26
Bale Collection	2.90	5.88
Bale Loading	1.16	2.47
Transportation	2.96	6.00
Total	28.05	57.05

Flax Industry Perspective

There are limited markets for flax straw in North Dakota but with amply supply there is potential for the market to grow. In order to gain some industry perspective, a flax producer/straw seller and a flax industry straw buyer were interviewed.

One of the biggest concerns as a farmer is getting the flax straw off of the fields so that tillage can be started. Most farmers have trouble dealing with the flax straw and would welcome a market for it and are eager to remove the straw as soon as possible so field work can begin. Flax straw is sold by the ton, and shipped all over the United States and into Canada. One of the larger markets is Bast Labs in Nebraska however transportation costs ($3.00 - $4.00 per loaded mile) are very high. The Nebraska plant, which makes linen for clothing and paper, has considered moving to North Dakota to be closer to the flax producing areas. Most flax straw harvesting (baling, collecting, stacking, and loading) was custom hired at a cost of $15.00 to $20.00 per bale. Most farmers producing flax did not own a baler or equipment so custom hire was the popular alternative. Flax farmers would welcome more alternatives for their flax straw (Gussias, 2014).

The flax straw buyer's perspective was obtained from a straw buyer with Magotioux (Magotioux 2014) who buys straw for an international corporation. The corporation buys flax straw primarily in Canada, but annually purchases about 20 percent in North Dakota. Again, transportation costs are a substantial consideration with as much flax straw as possible purchased locally. Flax straw purchased in North Dakota is generally from the Minot area and southward. Transportation distance is 300 plus miles, with a typical freight rate of $0.26/ton/loaded mile. All trucking was hired as the corporation owned no semi-tractors for over-the-road hauling, and most flax was purchased locally. The flax straw is converted into 3'x3'x6' bales of flax fiber that are shipped by rail (box cars) to Richmond, VT where the flax fibers are converted into cigarette paper.

$26.25/ton is allowed for baling, collection, and bale loading. (Although this corporation is located in Canada, they use American units of measure such as tons, feet, and miles.) The company collects the straw as soon as they can and stores it at their production facilities. Because they are very concerned with the quality of the straw (and the resulting paper product) the flax straw bales are covered with tarps until they are used. Tarps are less expensive than buildings, but still add to their raw product costs. The straw buyer stressed that the industry only had one chance a year to obtain enough flax straw bales, so it was critical that they buy enough for a year's production. With that requirement, they buy the flax straw they will need from North Dakota to supplement what is available locally in Manitoba. The freight for getting flax straw bales from the Minot area to the Manitoba production facility increases the input costs significantly for SWM International.

Industry officials, both buyers and sellers interviewed for this report, suggest that a flax processing plant, such as the one analyzed in this study, located in the flax producing area of North Dakota could have potential economic benefits. Transportation costs for flax straw buyers could be minimized, and producers would have an additional market for their biomass.

Market Viability

This study addressed the first steps in determining the viability of using flax fibers for inputs into various manufacturing processes by assessing the availability and cost of acquiring flax straw. A number of factors are likely to reduce the effective amount of flax straw available for processing, such as weather, producers' willingness to sell, isolated or logistically expensive production, or straw that may already be used for other purposes. Even though those factors were not addressed in this project, a considerable tonnage of flax straw would likely be available for processing in the Northwest region of North Dakota. Also, this project provided a baseline for estimating the acquisition cost of flax straw.

Estimating potentially available raw material and potential cost to acquire are good first steps in evaluating the market viability of flax fibers for inputs into various manufacturing processes. However, several additional factors must be evaluated to better define and understand the market for flax fibers. Another element in the value chain that remains uncertain is the intermediate processing cost to convert the raw flax straw for various applications.

The engineering processes would need to be well understood, along with scale and other factors to estimate the costs associated with intermediate processing. Combining those costs with the acquisition costs of the straw would help an end user to better understand how flax fibers may compete with other manufacturing inputs. Understanding the processing steps and final cost of the processed flax fibers will be a necessary next step to better define the market potential for flax straw.

Market potential must also consider demand and how much an end user would be willing to pay for processed flax fibers, and quantities required to meet their needs. It remains unclear how much demand may exist for flax fibers as engineering processes, material characteristics, and applications are not well understood at this time. Therefore, it remains speculative what the processed flax fiber might cost an end user.

If the value of the processed flax fiber to an end user is less than the cost to acquire the flax straw, process it, and ship it to the user, it would be unlikely a market would develop. However, if the price an end user is willing to pay for the flax fibers covers the cost of the straw, the cost of intermediate processing, and provides for a return on investment, then the conditions would seem favorable for commercialization. It also is entirely possible that the potential end user(s) may need a quantity of flax fiber that exceeds the region's ability to supply. In that case, available product volumes may limit manufactures ability to use flax fibers because product volumes are too low to entice them to switch from other inputs.

Additional work to define the demand for processed flax straw is needed. Unfortunately, those questions were beyond the scope of work in this project. Further, additional analysis would be required to model the value-added processing costs. Combining both the costs of supplying the processed flax fibers with anticipated demand would be required to draw conclusions on economic viability of large-scale flax straw processing activities.

Conclusions

North Dakota is the nation's leading flax producing state. In the past 10 years, North Dakota has produced 95 percent of the flax grown in the United States (NASS various years 2004 to 2013). Flax production is concentrated in northwestern North Dakota with substantial production in four counties contiguous to the Northwest Crop Reporting District.

NASS Crop Reporting District data were used to estimate total flax straw production for each crop reporting district in North Dakota. Average yield multiplied by harvested acres were used to estimate total flax straw produced. Because there is no data to suggest potential demand for flax straw for commercial uses, the Northwest Crop Reporting District (the district with the largest flax production) was used as an example of potential production volumes.

From 1998-2012 in the Northwest Crop Reporting district, production ranged from a low 26,941 tons of flax straw in 2011, to a high of 487,427 tons with production of 146,466 tons in 2012. Flax straw production was estimated to be 2,295.8 pounds per acre in Ward County. Total flax straw production in Ward County was estimated to be 58,521 tons in 2012.

Estimated cost to acquire flax straw was based on the nutrient value of the straw, baling costs, bale collection and loading, transportation costs, and a producer incentive payment. Costs were estimated on a per ton and per acre basis because industry buyers purchase straw by the ton, but farmers relate costs and returns on a per acre basis. The estimated cost per ton of $57.05 and per acre cost of $28.05 was based on the 2012 flax yields and 2013 straw collection rates. These costs are closely aligned with current flax straw prices.

There are limited markets for flax straw in North Dakota but with amply supply there is potential for the market growth. Industry officials, both buyers and sellers interviewed for this report, suggests that a flax processing plant, located in the flax producing area of North Dakota could have potential economic benefits. If a flax straw processing plant were to be built in North Dakota, a location in the Ward, McLean, and Mountrail County area would seem to be the logical choice.

Additional analysis would be required to model value-added processing costs. An assessment of both the cost of flax straw fibers, processing costs and potential demand for the final project would be required to draw conclusions on the economic viability of large-scale flax straw processing activities.

References

Aakre, Dwight. 2014. Custom Farm Work Rates in North Dakota Farms, 2013 by North Dakota Farming Regions. Fargo: North Dakota State University. Extension Service, Farm Management Economist.

Brockema, Sandra. 2009. *Feasibility Study of a biomass Supply for the Spiritwood Industrial Park.* NDIC Contrast No. R001-003. Submitted by Great River Energy, Great Plains Institute, ND Association of Rural Electric Cooperatives, ND Department of Agriculture, ND Farmers Union, and ND Natural Resources Trust.

Coon, Randal C., and F. Larry Leistritz. 2005. A Potential Role for Wheat Straw in Value-added Agriculture. Unpublished Report. Fargo: North Dakota State University, Department of Agribusiness and Applied Economics.

Coon, Randal C., and F. Larry Leistritz. 2010. Nutrient Value of Wheat Straw. Unpublished Report. Fargo: North Dakota State University, Department of Agribusiness and Applied Economics.

Cenusa Bioenergy. 2012. "Sustainable Production and Distribution of Bioenergy for the Central USA. A report to USDA-NIFA AFRI CAP, Grant no. 2011-68005-30411

Gailans, Stefans R. 2010. The Agronomic and Economic Performance of Flax in Iowa. Master of Science Thesis. Ames: Iowa State University, Agronomy Department.

Gussias, Roger. 2014. Personal Communication - Telephone Interview. Carrington, ND.

GRE. 2009. Feasibility Study of a Biomass Supply for the Spiritwood Industiral Park. NDIC Contract No. R001-003. http://www.nd.gov/ndic/renew/projects/r-001-003fr.pdf, viewed February 13, 2014.

Heard, John, Curtis Cavers, and Greg Adrian. 2006. *Up In Smoke - Nutrient Loss With Straw Burning. Better Crops* (Volume 90: No. 3, pp 10-11. Norcross, Georgia: International Plant Nutrition Institute.

Leistritz, F. Larry, Donald M. Senechel, Mark D. Stowers, William F. McDonald, Chris M. Saffron, and Nancy M. Hodur. 2006. *Preliminary Feasibility Analysis for an Integrated Biomaterials and Ethanol* Biorefinery *Using Wheat Straw Feedstock.* AAE Report No. 590. Fargo: North Dakota State University, Department of Agribusiness and Applied Economics.

Lundstrom, Darnell. 1994. Response to Steele County Job Development Authority on Straw Board Growers Questions. Fargo: North Dakota State University, Extension Service. Agriculture and Natural Resources.

Magotioux, Dennis. 2014. Personal Communication - Telephone Interview. Winkler, Manitoba = Straw Purchase Manager, SWM International.

MBI. 2014. Developing a Biomaterials Industry in North Dakota. Final report - MBI Project No. 1655001. Lansing, Michigan.

National Agricultural Statistics Service. 2004. North Dakota Agriculture. Ag Statistics No. 73. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2005. North Dakota Agriculture. Ag Statistics No. 74. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2006. North Dakota Agriculture. Ag Statistics No. 75. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2007. North Dakota Agriculture. Ag Statistics No. 76. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2008. North Dakota Agriculture. Ag Statistics No. 77. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2009. North Dakota Agriculture. Ag Statistics No. 78. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2010. North Dakota Agriculture. Ag Statistics No. 79. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2011. North Dakota Agriculture. Ag Statistics No. 80. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2012. North Dakota Agriculture. Ag Statistics No. 81. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2013. North Dakota Agriculture. Ag Statistics No. 82. Fargo: North Dakota State University, ND Department of Agriculture and US Department of Agriculture, cooperatively.

National Agricultural Statistics Service. 2014. North Dakota Interactive Data Tables. Quick Stats 2.0 Internet Website: http://quickstats.nass.usda.gov/results .Washington, D.C.: US Department of Agriculture.

North Dakota Farm Service Agency. 1998-2012. Annual Average Summary Report - North Dakota. Unpublished Data. Fargo: North Dakota State Farm Services Agency Office.

Ottman, Michael J., Thomas A. Dorge, and Edward C. Martin. 2000. *Durum Grain Quality as Affected by Nitrogen Fertilization Near Anthesis and Irrigation During Grain Fill*. Agronomy Journal 92: 1035 - 1041.

Pennington, Dennis. 2013. Harvest Index: A Predictor of Corn Stover Yield. Internet Website: http://msue.anr.msu.edu/news/harvest_index_a_predictor_of_corn_yield. East Lansing: Michigan State University, Extension Service.

Perry, Steve. 2013. Fall 2013 Fertilizer Price Quotes. Personal Communication. Buffalo, ND: the Arthur Companies Station Manager.

Rawlett, Russ. 2001. U.S. Commercial Bushel Sizes: a Dictionary of Units of Measure. Internet Website: http://www.unc.edu/~rowlett/units/scales/bushels.html. Chapel Hill: University of North Carolina.

Risk Management Agency. 2010-2012. North Dakota Flax Yield Per Acre by County. Unpublished Data. Billings, Montana: U.S. Department of Agriculture, Regional Office.

Tames, Stacey. 2013. Cereal Grain Drying and Storage. Internet Website: http://www/.agric.gov.ab.ca/$department/deptdocs.nsf/all/crop1204. Alberta: Canada, Ag-Info Centre.

Appendix A

Appendix Table 1. Flax Acreage Planted in North Dakota, by County, 1998 - 2012

	YEAR														
COUNTY	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Adams	1,663.2	2,166.3	1,583.3	1,346.9	1,060.6	208.3	398.0	1,218.7	1,574.5	111.9	498.8	644.0	746.3	1,898.1	1,944.4
Barnes	4,766.2	4,928.0	6,650.0	3,439.0	3,433.0	1,922.9	1,272.5	2,092.5	1,141.2	71.8	44.2		138.7	28.2	0.0
Benson	5,173.7	7,068.3	11,762.1	9,584.0	9,408.3	7,147.6	4,654.0	16,441.5	10,525.0	1,343.7	3,685.9	1,389.8	4,064.9	1,015.7	2,482.0
Billings	352.0	451.5	110.1	40.0	458.4	236.3	358.5	130.2	360.0	582.5	133.8	277.5	267.7	135.6	186.8
Bottineau	25,617.0	10,336.0	26,964.9	28,865.9	59,736.7	34,023.8	26,267.2	58,747.4	47,453.9	14,416.0	15,559.0	16,818.9	21,674.7	2,245.7	15,552.2
Bowman	210.2	817.3	1,035.5	838.2	1,319.9	790.3	966.5	2,999.4	3,282.0	1,565.4	1,126.0	1,612.9	1,339.0	1,425.6	2,085.7
Burke	2,616.7	3,862.2	9,103.5	20,002.6	38,419.6	33,085.1	17,809.8	40,983.1	42,261.5	20,234.8	15,977.0	14,656.2	18,698.6	3,620.3	11,157.8
Burleigh	3,876.0	4,373.8	6,533.6	10,191.7	12,762.9	11,763.4	14,127.3	21,591.6	22,486.3	11,266.2	13,682.8	13,884.1	17,989.5	13,536.7	11,940.2
Cass	337.7	543.5	464.3	170.4	92.7	191.1		298.3		8.4		5.0	4.0	5.3	0.5
Cavalier	21,144.4	28,025.9	34,580.1	28,329.5	36,898.9	28,365.2	22,234.5	42,710.2	24,616.6	6,505.1	8,503.5	3,540.1	10,963.2	3,889.0	8,481.2
Dickey	2,638.9	4,046.5	3,758.4	3,537.5	2,095.6	1,588.2	1,929.1	2,405.8	1,231.4	372.4	457.9	365.7	172.6		
Divide	1,045.9	2,623.9	6,309.7	23,522.3	23,044.1	8,913.9	10,258.5	21,379.4	26,176.7	9,988.9	11,033.1	7,558.2	7,264.0	792.7	11,043.3
Dunn	835.5	594.8	1,138.1	1,285.3	1,839.0	2,017.9	2,956.2	2,622.4	3,735.8	3,045.8	1,983.1	2,873.1	2,235.2	890.0	2,624.1
Eddy	4,276.5	4,314.9	8,733.5	5,336.8	4,230.3	5,550.6	4,464.4	8,975.4	7,606.4	1,771.9	2,780.9	792.5	787.4	593.3	974.7
Emmons	3,768.3	7,216.2	9,497.3	9,409.7	9,928.2	5,507.1	4,271.2	7,286.2	5,122.3	1,751.5	1,562.6	1,954.6	2,813.5	1,580.3	1,642.5
Foster	10,219.4	10,438.0	18,610.3	10,929.2	5,283.8	4,048.0	4,331.8	10,978.0	7,089.0	1,711.1	1,501.8	757.3	650.7	316.6	330.6
Golden Valley	3,493.3	3,462.0	2,214.1	1,990.8	2,335.2	2,619.2	617.0	1,810.3	1,441.3	397.6	654.9	966.8	759.9		396.8
Grand Forks	1,468.1	2,137.5	1,948.8	1,311.2	734.1	1,741.8	756.4	2,090.7	1,086.5	406.1	352.4	193.6	137.3	232.9	445.5
Grant	588.6	1,705.3	1,256.8	831.8	2,260.6	1,221.9	2,522.9	3,281.0	4,425.2	2,629.7	1,606.0	2,000.2	4,845.8	4,642.7	5,237.8
Griggs	1,837.1	2,016.7	2,645.0	2,019.5	814.5	477.5	298.4	815.5	1,064.7			147.6	131.3	19.1	73.0
Hettinger	11,174.0	14,466.7	14,722.0	9,591.3	11,162.0	5,404.2	4,647.3	15,083.3	16,626.9	6,373.3	3,898.0	5,278.9	5,976.1	4,993.4	8,130.7
Kidder	7,956.4	11,214.2	13,122.0	14,895.5	13,690.4	14,680.4	16,591.0	21,587.0	16,928.2	11,926.1	15,879.2	19,220.3	23,161.5	14,291.4	11,636.6
LaMoure	4,594.6	4,995.7	7,029.5	6,263.6	3,651.8	2,358.7	2,311.3	3,774.9	1,954.8	294.6	327.8	212.9	100.0		219.0
Logan	5,310.4	7,652.5	10,819.3	10,086.0	10,332.5	7,542.3	6,310.8	10,627.5	8,455.0	2,608.1	2,116.2	2,418.7	2,651.8	1,461.5	2,990.2
McHenry	6,855.7	6,667.3	10,486.2	11,997.9	20,960.9	16,615.6	21,322.6	31,051.5	29,053.7	12,110.6	16,043.6	11,360.5	15,383.0	4,844.5	14,670.5
McIntosh	9,628.2	14,154.8	19,022.4	14,424.9	8,237.0	5,849.1	4,846.9	6,760.9	5,433.1	2,097.9	2,190.4	2,311.3	2,308.5	1,974.5	1,582.1
McKenzie	64.9	700.1	482.1	2,513.8	2,048.6	1,066.4	1,994.9	5,547.7	4,889.0	1,194.7	916.6	575.6	805.0	414.5	1,688.1
McLean	11,034.7	17,617.7	25,376.6	42,895.7	57,955.6	54,610.3	53,652.7	73,591.5	70,777.7	38,358.5	48,226.0	43,401.9	53,781.9	21,071.0	36,022.6
Mercer	232.6	1,007.8	1,612.4	2,006.8	4,988.2	3,800.5	5,697.9	8,603.5	7,447.1	2,345.8	2,919.1	3,564.9	5,595.0	2,082.1	4,931.7
Morton	506.3	727.2	1,306.4	1,294.5	2,450.7	838.1	433.8	1,691.6	2,196.3	1,144.7	936.9	912.3	2,195.3	3,450.7	4,170.5
Mountrail	3,638.1	4,744.0	13,356.3	34,908.7	64,481.1	47,390.6	42,288.4	73,311.9	61,166.0	32,881.9	26,214.2	23,803.8	31,229.5	9,430.8	31,799.1
Nelson	7,048.6	9,203.7	9,913.6	8,645.3	8,010.4	5,060.6	4,683.4	9,556.7	7,498.7	2,500.2	1,964.2	742.5	870.7	334.5	345.1
Oliver	952.3	991.7	989.2	1,579.2	1,885.4	1,661.8	1,829.0	3,521.5	3,457.5	1,531.4	1,629.7	1,704.9	3,107.8	1,332.2	1,607.6
Pembina	3,135.1	4,144.9	1,849.6	613.5	767.0	874.9	479.1	2,521.8	548.5	299.7	40.0		281.5		
Pierce	6,932.9	7,668.8	10,908.3	9,278.6	14,322.9	10,802.7	10,226.0	19,506.9	18,964.7	5,686.4	5,486.1	3,798.5	5,154.4	2,023.2	3,572.0
Ramsey	12,134.0	11,378.7	16,261.1	18,196.4	23,727.0	11,958.5	7,579.6	16,464.9	17,909.9	3,203.0	2,950.3	1,893.4	3,341.7	1,082.4	1,384.1
Ransom	138.0	144.8	227.0	78.0		72.3	56.0	249.0				18.2			

—continued----

TABLE 1 Cont.

	YEAR														
COUNTY	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Renville	12,322.6	7,116.2	13,269.5	20,620.9	50,286.3	33,071.1	15,674.6	46,515.5	47,272.9	16,756.9	16,664.6	9,917.4	16,414.7		13,737.9
Richland	15.0	153.3	14.6		49.1		25.3	67.9	223.3		25.3			22.9	25.3
Rolette	3,074.4	3,502.4	7,878.7	10,276.3	11,065.1	8,184.6	5,726.6	12,500.1	8,929.2	3,683.4	4,968.8	2,635.3	3,818.6	1,290.2	3,100.6
Sargent		354.0	64.1	321.0	77.0		339.5	287.1	1.8	433.8	359.6	1.9	2.2	1.9	1.9
Sheridan	6,209.4	9,624.7	13,739.1	17,961.9	25,623.2	24,835.0	32,610.6	42,223.6	32,069.8	19,002.1	19,100.1	16,515.0	22,996.9	15,063.2	16,429.6
Sioux		492.9	546.8	377.3	344.8	166.4	562.2	695.6	494.9	220.5	778.0	54.6	362.4	479.0	375.4
Slope	1,318.7	2,174.4	2,648.3	2,643.9	2,779.7	1,589.6	1,826.3	2,168.2	2,375.2	678.9	1,429.2	864.1	348.3	846.7	187.7
Stark	2,555.3	4,927.1	3,376.7	3,156.9	4,335.3	2,495.2	3,008.7	3,962.7	3,874.2	1,352.2	1,046.2	2,033.8	2,115.3	2,218.7	4,109.6
Steele	2,005.9	3,754.3	3,601.6	2,585.9	1,865.7	1,856.4	1,818.6	1,567.2	1,464.1		50.0		51.9		64.0
Stutsman	17,062.0	21,290.2	29,825.2	27,442.9	20,512.9	14,552.1	10,446.6	23,394.8	12,280.6	3,502.8	4,624.4	5,166.4	7,089.7	1,751.4	2,076.0
Towner	17,369.4	17,840.8	32,817.7	19,545.2	25,199.5	17,931.2	15,570.2	33,830.3	19,789.2	7,385.3	9,873.5	6,540.9	8,547.0	1,904.2	4,454.9
Traill	116.4	300.3	204.2	117.0	396.3	365.2	49.8	40.0	70.0			129.8			
Walsh	5,871.1	5,213.1	5,388.0	4,112.3	4,535.0	5,045.4	3,696.1	7,570.1	6,022.1	1,826.1	2,092.4	1,216.7	3,314.4	1,088.9	866.2
Ward	19,330.8	18,946.9	40,439.2	70,952.2	106,389.5	77,406.2	65,858.7	107,388.4	90,287.2	47,252.4	53,264.0	44,870.3	58,419.2	15,536.6	50,981.8
Wells	3,468.8	5,646.0	8,860.0	7,052.1	10,658.4	9,547.4	10,549.3	22,775.1	13,572.2	4,455.8	4,614.2	2,514.6	3,793.6	2,126.1	1,885.3
Williams	488.3	950.2	1,841.6	7,487.5	13,129.3	12,253.5	7,034.4	20,661.7	15,970.6	5,069.7	3,244.8	1,944.7	2,612.0	214.3	3,804.8
ND	278,473.6	320,896.0	476,898.6	546,905.2	742,074.9	551,306.3	480,242.4	877,957.9	740,684.7	314,357.6	335,017.1	286,062.0	381,514.2	148,198.6	303,450.0

Source: North Dakota Farm Service Agency (1998 - 2012).

Appendix Table 2. North Dakota Flax yield Per Acre by County, 1998-2012

	YEAR														
COUNTY	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
	bushels														
Adams	16.9	15.5	15.4	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	24.0	17.2	17.4
Barnes	19.2	19.4	22.0	25.0	20.6	18.0	22.0	23.0	0.0	0.0	0.0	0.0	0.0	0.0	17.0
Benson	22.0	18.2	21.9	19.5	18.0	22.3	22.2	19.8	15.3	20.0	16.5	19.5	24.1	18.8	11.7
Billings	0.0	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	13.7	0.0	8.8
Bottineau	21.6	22.0	23.5	23.8	19.4	20.1	19.5	21.3	16.3	23.0	20.5	25.5	22.8	15.4	18.0
Bowman	0.0	18.6	0.0	0.0	10.3	10.0	16.0	16.8	13.2	0.0	0.0	25.0	23.6	24.5	19.3
Burke	16.4	25.4	19.3	20.6	19.5	13.3	17.7	21.9	14.3	21.4	18.5	24.0	20.1	20.6	16.5
Burleigh	17.1	19.7	23.3	18.8	14.2	10.0	17.6	22.2	7.4	13.6	13.5	0.0	21.2	14.7	15.5
Cass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cavalier	23.6	25.7	23.0	22.5	24.2	25.9	21.3	18.5	22.5	22.9	21.0	26.5	26.6	24.8	17.0
Dickey	19.0	20.0	17.7	15.6	9.9	0.0	13.5	15.0	7.5	0.0	0.0	0.0	0.0	0.0	0.0
Divide	21.5	28.0	23.7	20.3	14.4	12.9	17.2	19.2	11.6	14.2	15.5	22.0	17.5	10.6	18.1
Dunn	23.4	26.0	14.2	16.7	13.1	16.7	12.3	22.6	9.7	15.3	0.0	23.5	21.5	19.4	15.3
Eddy	16.2	21.8	19.6	16.9	17.0	25.5	22.7	24.9	16.0	0.0	19.0	19.0	22.3	10.5	10.7
Emmons	16.5	16.9	22.8	19.2	15.0	13.6	8.4	16.9	5.0	14.1	0.0	0.0	16.9	17.8	12.2
Foster	21.8	21.5	20.3	16.7	16.8	20.2	19.6	23.8	15.2	0.0	16.5	17.0	29.8	7.7	13.2
Golden Valley	17.0	15.0	15.2	15.0	12.3	15.4	7.1	16.8	12.7	0.0	4.5	25.0	21.1	0.0	15.0
Grand Forks	25.9	20.0	20.1	16.2	18.3	27.5	0.0	20.5	0.0	0.0	0.0	25.0	15.3	0.0	12.7
Grant	15.7	19.7	18.2	0.0	0.0	12.1	5.4	0.0	0.0	0.0	0.0	0.0	18.7	19.9	15.0
Griggs	19.6	16.9	18.4	16.2	19.6	14.0	0.0	21.3	16.0	0.0	0.0	0.0	0.0	0.0	0.0
Hettinger	22.1	23.7	26.4	24.0	10.9	13.8	16.3	23.0	8.1	18.6	10.5	34.0	24.2	18.5	14.0
Kidder	14.4	16.0	20.0	16.2	9.9	13.1	17.5	18.0	7.4	14.1	16.5	17.0	16.0	12.7	13.1
LaMoure	20.0	18.0	19.7	18.6	14.4	16.9	20.0	16.1	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Logan	17.6	15.8	19.9	15.9	12.0	15.9	18.9	16.2	10.5	0.0	0.0	0.0	15.9	14.5	11.0
McHenry	19.5	17.3	18.3	19.5	17.0	21.8	23.2	21.5	13.0	18.4	19.0	25.0	23.1	17.1	18.2
McIntosh	19.1	18.0	17.9	15.9	8.4	11.2	17.8	17.7	8.2	0.0	0.0	0.0	21.1	8.4	3.8
McKenzie	0.0	22.3	15.2	20.0	18.5	15.5	13.0	18.4	9.5	0.0	0.0	23.5	15.7	27.6	13.6
McLean	17.7	18.1	15.8	18.4	18.2	18.4	21.5	21.4	16.5	16.2	14.5	25.5	23.1	16.2	19.1
Mercer	0.0	18.2	18.3	23.0	19.8	14.5	14.2	22.1	10.3	17.1	11.5	20.0	23.5	14.8	18.4
Morton	15.7	14.4	19.3	18.0	11.0	0.0	0.0	23.1	0.0	0.0	7.0	0.0	22.5	16.3	18.2
Mountrail	20.6	18.7	20.9	20.9	18.2	15.8	17.6	20.2	12.0	13.6	11.5	24.5	21.2	17.0	17.6
Nelson	23.4	20.3	19.3	17.0	20.4	24.9	21.3	22.6	12.3	20.8	21.0	25.0	19.1	17.0	19.1
Oliver	16.3	16.0	21.8	21.3	13.2	12.2	25.5	26.9	11.9	0.0	8.5	23.5	22.7	15.3	17.6
Pembina	25.0	25.8	25.4	16.7	21.4	23.3	0.0	17.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pierce	20.3	18.5	19.5	17.0	17.1	17.9	19.6	19.5	13.1	22.9	17.5	23.0	20.6	16.7	16.2

---- continued ---

TABLE 2 cont.

	YEAR														
COUNTY	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Ramsey	21.1	23.4	22.1	20.5	21.0	20.0	21.6	18.7	16.6	19.4	21.0	25.0	22.5	21.8	17.8
Ransom	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renville	22.4	25.1	19.4	21.1	15.4	16.0	25.4	24.6	14.3	20.3	21.0	24.5	24.0	0.0	22.0
Richland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0
Rolette	23.4	21.8	22.8	22.4	22.3	22.8	22.6	19.0	21.9	24.9	20.5	24.5	28.7	26.4	20.0
Sargent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0
Sheridan	17.7	18.8	17.3	16.3	18.6	18.9	22.7	20.8	9.6	15.3	17.0	21.5	25.0	15.3	18.4
Sioux	0.0	14.4	17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.6	15.0	14.6
Slope	18.4	18.2	23.0	25.6	8.1	10.0	12.1	18.1	11.3	0.0	7.0	25.0	20.9	15.1	12.8
Stark	20.1	16.0	23.0	21.6	10.8	13.5	12.5	23.8	8.7	14.3	0.0	25.0	22.1	18.5	10.7
Steele	27.7	23.1	20.0	18.1	24.2	23.2	18.0	20.7	0.0	0.0	0.0	0.0	0.0	9.4	4.0
Stutsman	22.7	22.2	21.9	18.8	13.0	18.5	20.4	19.0	15.5	13.0	14.5	17.0	19.5	22.8	12.1
Towner	23.3	25.1	21.4	20.8	20.4	22.1	23.5	19.5	21.5	21.9	22.0	24.5	26.6	0.0	21.9
Traill	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walsh	24.1	25.2	20.8	21.0	24.8	23.3	23.2	22.7	20.8	24.7	27.5	25.0	23.6	21.1	22.7
Ward	22.3	22.2	23.0	22.3	19.3	17.7	24.5	23.6	19.0	19.7	20.5	25.5	22.6	13.2	19.1
Wells	22.1	20.0	21.0	14.6	17.8	21.8	20.9	20.9	11.7	14.4	18.0	15.0	18.9	16.3	13.0
Williams	23.8	22.5	22.7	20.4	17.2	14.4	18.2	19.4	10.7	14.3	11.0	24.5	24.4	13.5	18.4
North Dakota	21.0	21.0	21.0	20.0	17.0	18.0	20.5	21.0	14.5	17.5	17.0	24.0	24.0	16.5	17.5

Source: NASS (2014); Risk management Agency (2010-2012)