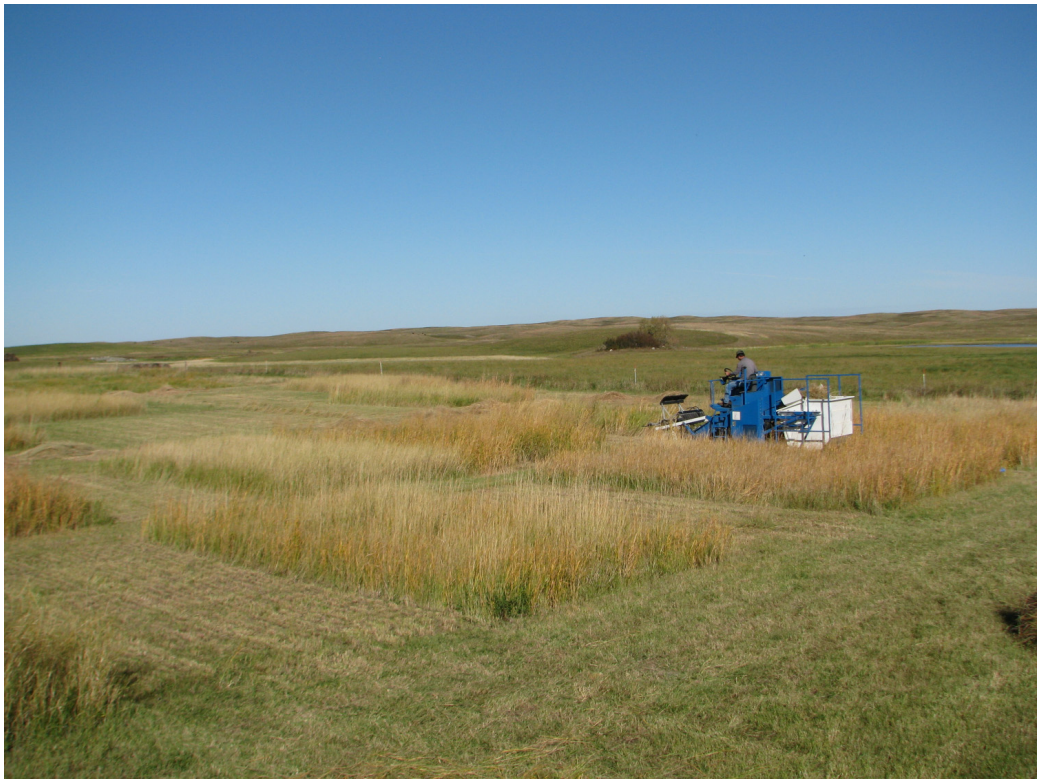
Perennial Forages for Biofuel Production in Central and Western North Dakota

Paul E. Nyren,Guojie Wang,and Bob Patton, NDSU Central Grasslands Research Extension Center, Streeter; Gordon Bradbury, Williston Research Extension Center; Eric Eriksmoen, Hettinger Research Extension Center; Mark Halvorson, North Central Research Extension Center, Minot; Ezra Aberle, Carrington Research Extension Center



Biomass harvest at Central Grasslands REC, Streeter

Introduction

The Federal Government has set some very lofty goals for the reduction of use of fossil fuels. The Energy Policy Act of 2005 set the following goals:

> *Requires the Secretary of Energy to ensure that, to the extent economically feasible and technically practicable, the following amounts of the total electricity consumed by the Federal Government come from renewable energy: Not less than 3% in fiscal years 2007-2009; not less than 5% in fiscal years 2010-2012; and not less than 7.5% in fiscal year 2013 and thereafter*,

while the Energy Policy Act of 2007 set new goals for new Federal buildings as follows*:*

> *Requires new buildings and major renovations of Federal buildings to reduce fossil fuel consumption relative to 2003 by: 55% by 2010, 65% by 2015, 80% by 2020, 100% by 2030*.

Whether or not these goals can be achieved there is no doubt that renewable energy is here

to stay. While in the past months the cost of fuels has dropped to more manageable levels it is beginning to increase again and, as the economy strengthens, increased demand will likely cause the price to continue to rise. The use of perennial forages for the production of biofuels is a renewable resource that is very well suited to North Dakota. The state has over seven million acres of highly erodible and saline crop land, with some counties in the western part of the state having as high as 90 percent of the crop land highly erodible. Perennial energy crops would achieve more long-term sustainability on these lands by reducing erosion, adding organic matter, reducing greenhouse gases and sequestering carbon. Several publications have indicated that North Dakota would be a leading state in the production of biomass from herbaceous crops.

In 2006 the Central Grasslands REC took the lead on a research trial to evaluate perennial forages for biofuel production. The objectives of this trial are to:

1. Determine the biomass yield and select chemical composition of perennial herbaceous crops.
2. Compare annual and biennial harvest of biomass yield and maintenance of the stands.
3. Evaluate carbon sequestration and storage of the various perennial crops.

Table 1 shows the contributors and supporters of the project managed by the North Dakota Natural Resources Trust.

Table 1. Contributors to the Biofuels project managed by the North Dakota Natural Resources Trust.
North Dakota Natural Resources Trust
ND Department of Commerce
NDSU Agricultural Experiment Station
USDA-ARS Northern Great Plains Research Laboratory
USDA-Renewable Energy and Products
ND Game and Fish Department
ND Farmers Union
Jamestown/Stutsman Development Corporation
Dakota West RC&D
Dakota Prairie RC&D
Ducks Unlimited
Natural Resources Conservation Service

Methods

Six sets of plots were located at five sites across central and western North Dakota. Each set of plots contains ten species/varieties of perennial grasses planted alone and in combination in two harvest treatments (annual and biennial). The plots are randomized and have four replications.

In 2009 two additional sets of plots were seeded at the USDA-ARS Northern Great Plains Field Laboratory in Mandan and at the Ducks Unlimited Ranch north of Wing. Also in 2009 an additional study was sponsored by Ducks Unlimited to evaluate the effect of a 10" vs. 3" stubble height on the yield and longevity of the perennial forages. In all sets of plots seeded in 2009, prairie cordgrass was substituted for the Basin and Altai wildrye plots, as they had not shown much promise in plots at the other locations.

Results and Discussion

Total Biomass Production

Each year's data adds some new understanding of the potential of these perennial forages for use as biofuel crops. In 2010 the total biomass yields on plots at Minot and Hettinger improved in production with Dakota switchgrass at Minot yielding over 4 tons/acre (Table 2). In Hettinger all plots except two yielded over 2 tons/acre while in 2009 none reached 1.75 tons. (The warm season grasses, switchgrass and big bluestem, did not establish at Hettinger, however. Those plots mostly consist of other grasses.) We again see the wheatgrasses, tall and intermediate, yielding best at Streeter with Alkar tall wheatgrass at 2.91 tons/acre and intermediate wheatgrass at 2.82 tons/acre. While Alkar tall wheatgrass yielded highest at Carrington with 4.13 tons/acre it was not significantly better than Sunburst switchgrass at 4.04 tons/acre. None of the yields on the dryland site at Williston (Table 3) or Hettinger (Table 2) were significantly different. Switchgrass continues to yield best on the wetter sites such as the Williston irrigated site and at Minot.

In 2008 and again in 2010 the biennial harvest treatment plots were not harvested. In 2009 these plots were harvested and Table 2 shows the results. The 2009 biennial harvest yields were divided by two to indicate the average production to date. The final column shows the percent difference between the annual and biennial harvests. There seems to be no pattern between locations or species on the percent of decrease due to a biennial harvest. All treatments had lower total yields due to biennial harvest except Williston irrigated Basin + Altai wildrye which showed a slight 0.6 percent increase. The biennial plots will be sampled again in 2011 and perhaps some trends will start to emerge then.

The average annual harvest yields supports the conclusion that wheatgrasses are best on drier sites with the long term average of 1.96 tons/ac for CRP mix (wheatgrass + legumes) at Hettinger. Intermediate wheatgrass yielded best at the Williston dryland site at 1.12 tons/acre and at Streeter at 2.96 tons /acre. Switchgrass and its mixtures yielded highest for the three-year average at Carrington, Williston irrigated and Minot.

Weed Control

On May 17, 2010 the Sunburst switchgrass plots at Streeter were sprayed with 2 qt/acre of glyphosate to control quack grass and brome. The treatment worked well and the switchgrass responded positively. The key to a successful glyphosate treatment is to apply it to the plots just before the warm season grasses emerge from their winter dormancy and the cool season unwanted grasses are already at the 3 to 4 leaf stage. If weather conditions are optimal in the spring of 2011 we plan to apply this herbicide to all sites to eliminate unwanted cool season weeds from the warm season plots.

A treatment of *Milestone* was also applied to the Streeter stubble height plots and the Ducks Unlimited plots to control Canada thistle. This worked well but these plots and the ones at the ARS Mandan will need a repeat treatment next spring. The irrigated plots at Williston, and the dryland plots at Minot and Carrington all have good stands of the seeded species. The plots at Streeter have good stands of the seeded species with the exception of the Trailblazer switchgrass and the Sunburst/Big bluestem plots that were not sprayed with glyphosate this spring.

Production of Seeded Species

In Tables 2, 3, and 4 the total production of the plots is used and includes species other than those that were planted. During the harvest we visually estimate the percent of the total production contributed by the seeded species in the plot. Table 5 shows this percentage and the yield of the seeded species in each plot in 2010. If the biomass produced is to be

burned for its energy then the total yield is what is important. However, if the product is to be used for ethanol then a more pure product may be needed and the amount of other species in the biofuel crop may decrease its value. The need for a pure crop for ethanol production could pose a problem for a producer trying to raise cool season forages such as wheatgrasses. In switchgrass or other warm season grass stands, glyphosate or other chemicals can be used to control the cool season weedy grasses. There is no chemical on the market that can control cool season weedy grasses in wheatgrass stands. Maintaining a pure crop will be an added expense to the producer.

Table 5 shows that the dryland plots at Minot all had 100 percent of the seeded species while the irrigated plots at Williston had nearly pure stands of the seeded species with the exception of Magnar basin wildrye + Mustang Altai wildrye. Generally the Basin and Altai wildrye plots had poor stands. These are large bunch grasses in their native state and when seeded tend to have large open areas in the stand that fill with unwanted plants. Because of this, we substituted prairie cordgrass for the wildryes in the plots seeded in 2009. Hettinger has the most plots with no visible signs of the seeded species, mainly the warm season species - switchgrass and big bluestem - and the wildryes mentioned earlier. The low rainfall at Hettinger makes it difficult to establish switchgrass and big bluestem since these species require more precipitation.

Stubble Height Study

In 2009 two sets of plots were seeded to examine the effect of harvesting the perennial biomass crops at two stubble heights. These plots were seeded at the Central Grasslands REC (Streeter) near the existing biomass production study and at the Ducks Unlimited Ranch North of Wing, ND. One set of plots was harvested at 3" above the ground and the other at 10". Table 6 shows the results of the 2010 harvest of these plots in tons/acre as well as the percent difference between the high and low stubble height. Among the 3” stubble plots at the Ducks Unlimited site, tall wheatgrass yielded highest with 2.97 tons/acre followed closely by Sunburst switchgrass + Tall wheatgrass which yielded 2.75 tons/acre. At Streeter the highest yield was 1.17 tons/acre for the CRP Mix with legumes followed closely by Sunburst switchgrass + Tall wheatgrass at 1.14 tons/acre. Neither site has reached its full production potential and we would expect higher yields in 2011. The Ducks Unlimited site was sprayed with *Milestone* in July 2010 to control thistle but still had some residual weed growth and will be sprayed earlier in the season in 2011.

Table 6 also shows the percent difference between the high and low stubble height. The harvest yield difference at the Ducks Unlimited site ranged from a 62.7% decrease for the 10" stubble on the Sunburst switchgrass + prairie cordgrass plots to just over 22% for intermediate wheatgrass. At Streeter the difference ranged from 74% for tall wheatgrass and 26% for intermediate wheatgrass. This difference was due in part to the short growth of the plots which should be taller in future years. While the first year has shown a significantly lower amount harvested for the taller stubble height there is no doubt that the taller stubble height will trap more snow and provide better nesting habitat for upland birds in the spring of 2011. It is also possible that the taller harvest height will be less stressful on the plants, which may result in higher yields in the coming years.

Table 2. Total forage production of seeded and non-seeded species (tons/acre) on non-irrigated annual and biennial harvest systems at each location 2008-2010. Bolded numbers in each column show the top producing treatment at each location each year.

Location and Species	Total Annual Harvest Yield			Total Biennial Harvest Yield	Average Long Term Yield		
	2008	2009	2010	2009	Annual Harvest 2008-10	Biennial[1] Harvest	Difference Between Annual and Biennial Harvests (%)
Carrington							
Alkar Tall Wheatgrass	4.37 abc[2]	3.95 bcd	**4.13** a	4.04 bc	4.15 ab	2.02 bc	51.3
CRP Mix (Intermediate + Tall Wheatgrass)	3.75 bcd	3.42 de	3.23 de	3.47 c	3.47 cd	1.73 c	50.0
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	3.79 cd	3.23 e	3.28 de	3.18 c	3.43 cd	1.59 c	53.7
Haymaker Intermediate Wheatgrass	3.35 bcd	3.22 e	2.96 de	3.42 c	3.18 d	1.71 c	46.2
Magnar Basin + Mustang Altai Wildrye	3.12 d	3.11 e	2.76 e	3.08 c	2.99 d	1.54 c	48.6
Sunburst Switchgrass	**5.13** a	**4.91** a	4.04 ab	5.36 ab	**4.70** a	2.68 ab	43.0
Sunburst Switchgrass + Mustang Altai Wildrye	4.96 ab	4.43 ab	3.42 bcd	**5.76** a	4.27 ab	**2.88** a	32.6
Sunburst Switchgrass + Sunnyview Big Bluestem	4.86 ab	4.21 bc	3.95 abc	5.24 ab	4.34 ab	2.62 ab	39.6
Sunburst Switchgrass + Tall Wheatgrass	4.00 abcd	3.99 bcd	3.47 bcd	4.11 bc	3.82 bc	2.05 bc	46.3
Trailblazer Switchgrass	4.57 abc	3.69 cde	3.35 cde	4.02 bc	3.87 bc	2.01 bc	48.1
LSD 0.05	1.25	0.67	0.65	1.59	0.61	0.79	
R^2	0.55	0.75	0.66	0.59	0.76	0.59	
Minot							
Alkar Tall Wheatgrass	4.10 a	**3.13**	3.32	**5.42**	3.51	2.71	22.8
CRP Mix (Intermediate + Tall Wheatgrass)	3.58 ab	2.04	2.10	4.08	2.57	2.04	20.6
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	3.23 ab	2.80	2.88	4.19	2.97	2.09	29.5
Dakota Switchgrass	1.32 c	2.36	**4.02**	3.21	2.56	1.60	37.5
Haymaker Intermediate Wheatgrass	**4.13** a	2.45	2.73	3.76	3.10	1.88	39.5
Magnar Basin + Mustang Altai Wildrye	2.47 bc	2.72	2.77	4.20	2.65	2.10	20.8
Sunburst Switchgrass	1.63 c	2.23	3.48	4.33	2.45	2.17	11.5
Sunburst Switchgrass + Mustang Altai Wildrye	3.57 ab	3.09	3.22	4.38	3.29	2.19	33.4
Sunburst Switchgrass + Sunnyview Big Bluestem	1.68 c	2.03	3.82	3.59	2.51	1.79	28.5
Sunburst Switchgrass + Tall Wheatgrass	4.09 a	3.25	3.45	5.33	**3.59**	**2.66**	25.9
LSD 0.05	1.35	NS	NS	NS	NS	NS	
R^2	0.73						

[1]Total 2009 biennial harvest was divided by two to indicate the average production to date. [2]Numbers in the same column followed by the same letter are not significantly different ($p \leq 0.05$)

Table 2. (Continued) Total forage production of seeded and non-seeded species (tons/acre) on non-irrigated annual and biennial harvest systems at each location 2008-2010. Bolded numbers in each column show the top producing treatment at each location each year.

Location and Species	Total Annual Harvest Yield			Total Biennial Harvest Yield	Average Long Term Yield		
	2008	2009	2010	2009	Annual Harvest 2008-10	Biennial[1] Harvest	Difference Between Annual and Biennial Harvests (%)
Streeter							
Alkar Tall Wheatgrass	2.63 ab	2.32	**2.91**	4.02 ab	2.62 abc	2.01 ab	23.3
CRP Mix (Intermediate + Tall Wheatgrass)	2.67 ab	2.69	2.58	3.55 bc	2.65 abc	1.78 bc	32.8
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	1.65 cd	2.06	2.36	2.99 bcd	2.02 bcd	1.50 bcd	26.1
Haymaker Intermediate Wheatgrass	2.74 ab	**3.31**	2.82	2.86 cd	**2.96** a	1.43 cd	51.5
Magnar Basin + Mustang Altai Wildrye	1.51 cd	1.83	2.15	2.51 ed	1.83 cd	1.25 de	31.5
Sunburst Switchgrass	0.74 de	1.98	2.72	1.63 ef	1.81 cd	0.82 ef	55.0
Sunburst Switchgrass + Mustang Altai Wildrye	2.10 bc	2.37	2.18	2.78 cd	2.22 abcd	1.39 cd	37.4
Sunburst Switchgrass + Sunnyview Big Bluestem	1.98 bc	1.86	2.19	2.77 cd	2.01 bcd	1.38 cd	31.2
Sunburst Switchgrass + Tall Wheatgrass	**3.09** a	2.53	2.75	**4.75** a	2.79 ab	**2.37** a	15.0
Trailblazer Switchgrass	0.00 e	1.83	2.70	1.24 f	1.51 d	0.62 f	59.1
LSD 0.05	0.96	NS	NS	1.04	0.92	0.52	
R^2	0.80			0.80	0.52	0.80	
Hettinger							
Alkar Tall Wheatgrass		1.10	2.12	1.43	1.61	0.72	55.7
CRP Mix (Intermediate + Tall Wheatgrass)		1.34	2.23	1.22	1.79	0.61	65.8
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)		**1.68**	2.25	1.59	**1.96**	0.80	59.4
Haymaker Intermediate Wheatgrass		1.64	1.94	**1.75**	1.79	**0.87**	51.2
Magnar Basin + Mustang Altai Wildrye		1.30	1.57	1.35	1.43	0.67	53.0
Sunburst Switchgrass		1.51	2.04	1.27	1.78	0.63	64.3
Sunburst Switchgrass + Mustang Altai Wildrye		1.60	2.18	1.29	1.89	0.64	66.0
Sunburst Switchgrass + Sunnyview Big Bluestem		1.43	2.15	1.41	1.79	0.70	60.7
Sunburst Switchgrass + Tall Wheatgrass		1.52	2.25	1.30	1.88	0.65	65.5
Trailblazer Switchgrass		1.06	**2.43**	1.42	1.75	0.71	59.3
LSD 0.05		NS	NS	NS	NS	NS	
R^2							

[1]Total 2009 biennial harvest was divided by two to indicate the average production to date. [2]Numbers in the same column followed by the same letter are not significantly different ($p \leq 0.05$)

Table 3. Total forage production of seeded and non-seeded species (tons/acre) on dryland and irrigated annual and biennial harvest systems at Williston Research Extension Center 2008-2010. Bolded numbers in each column show the top producing species at each location each year.

	Total Annual Harvest Yield			Total Biennial Harvest Yield	Average Long Term Yield		
Location and Species	2008	2009	2010	2009	Annual Harvest 2008-10	Biennial[1] Harvest	Difference Between Annual and Biennial Harvests (%)
Williston - Dryland							
Alkar Tall Wheatgrass	0.70	1.05 ab[2]	1.08	1.16	0.94	0.58	38.7
CRP Mix (Intermediate + Tall Wheatgrass)	0.72	1.05 ab	1.15	**1.40**	0.97	**0.70**	28.2
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	0.62	0.78 c	1.14	0.95	0.84	0.47	43.9
Dakota Switchgrass	0.60	0.84 bc	1.13	1.16	0.86	0.58	32.2
Haymaker Intermediate Wheatgrass	**0.79**	**1.27** a	**1.32**	1.22	**1.12**	0.61	45.6
Magnar Basin + Mustang Altai Wildrye	0.61	0.90 bc	1.00	1.22	0.84	0.61	27.2
Sunburst Switchgrass	0.50	0.93 bc	1.03	1.35	0.82	0.68	17.1
Sunburst Switchgrass + Mustang Altai Wildrye	0.75	0.85 bc	0.99	1.31	0.86	0.66	24.2
Sunburst Switchgrass + Sunnyview Big Bluestem	0.69	1.00 bc	1.07	1.15	0.92	0.58	37.5
Sunburst Switchgrass + Tall Wheatgrass	0.68	0.93 bc	1.05	1.24	0.89	0.62	30.1
LSD 0.05	NS	0.26	NS	NS	NS	NS	
R^2		0.54					
Williston - Irrigated							
Alkar Tall Wheatgrass	3.16 e	3.84 bcd	3.23 def	5.48 c	3.41 e	2.74 c	19.7
CRP Mix (Intermediate + Tall Wheatgrass)	3.24 e	2.80 d	3.41 cde	4.18 d	3.15 e	2.09 d	33.8
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.80 e	3.48 cd	2.75 ef	3.82 d	3.01 e	1.91 d	36.5
Dakota Switchgrass	4.91 c	4.75 ab	4.25 bc	5.43 c	4.64 c	2.72 c	41.4
Haymaker Intermediate Wheatgrass	3.35 e	3.72 bcd	2.51 f	3.93 d	3.19 e	1.97 d	38.4
Magnar Basin + Mustang Altai Wildrye	3.06 e	3.31 cd	3.43 cde	6.57 bc	3.27 e	3.29 bc	-0.6
Sunburst Switchgrass	**7.28** a	**5.76** a	5.33 a	6.96 b	**6.12** a	3.48 b	43.2
Sunburst Switchgrass + Mustang Altai Wildrye	5.69 b	5.72 a	**5.44** a	**7.09** ab	5.62 ab	3.55 ab	36.9
Sunburst Switchgrass + Sunnyview Big Bluestem	5.87 b	5.02 a	5.11 ab	8.23 a	5.34 b	**4.12** a	22.9
Sunburst Switchgrass + Tall Wheatgrass	4.27 d	3.92 bc	3.95 cd	6.12 bc	4.04 d	3.06 bc	24.3
LSD 0.05	0.59	1.04	0.87	1.62	0.58	0.58	
R^2	0.96	0.79	0.85	0.86	0.94	0.86	

[1] Total biennial harvest was divided by two to indicate the average production to date. [2]Numbers in the same column followed by the same letter are not significantly different ($p \leq 0.05$)

Table 4. Forage production (tons/acre) on non-irrigated annual harvest systems of selected species at two new locations in 2010. Bolded numbers in each column show the top producing species at each location.

Location and Species	2010	Location and Species	2010
Ducks Unlimited, Wing, ND		**USDA-ARS Northern Great Plains Field Station, Mandan, ND**	
Alkar Tall Wheatgrass	2.13 ab[1]	Alkar Tall Wheatgrass	2.18
CRP Mix (Intermediate + Tall Wheatgrass)	1.44 bc	CRP Mix (Intermediate + Tall Wheatgrass)	**3.26**
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	**2.36** a	CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.80
Manifest Intermediate Wheatgrass	1.24 c	Manifest Intermediate Wheatgrass	3.23
Prairie Cordgrass	1.08 c	Prairie Cordgrass	2.95
Sunburst Switchgrass	1.42 bc	Sunburst Switchgrass	2.45
Sunburst Switchgrass + Mustang Altai Wildrye	0.85 c	Sunburst Switchgrass + Mustang Altai Wildrye	1.68
Sunburst Switchgrass + Sunnyview Big Bluestem	0.94 c	Sunburst Switchgrass + Sunnyview Big Bluestem	2.65
Sunburst Switchgrass + Tall Wheatgrass	2.29 a	Sunburst Switchgrass + Tall Wheatgrass	3.21
Trailblazer Switchgrass	0.94 c	Trailblazer Switchgrass	2.56
LSD 0.05	0.83	LSD 0.05	NS
R^2	0.66	R^2	

[1]Numbers in the same column followed by the same letter are not significantly different ($p \leq 0.05$)

Table 5. Total yield (tons/acre), percent of total yield contributed by the seeded species and yield of the seeded species at each site in 2010.

Location and Species	2010 Total Yield		2010 Percent of Seeded Species	2010 Yield by Percent of Seeded Species		Location and Species	2010 Total Yield	2010 Percent of Seeded Species	2010 Yield by Percent of Seeded Species	
Carrington						**Minot**				
Alkar Tall Wheatgrass	4.13	a[1]	100	4.13		Alkar Tall Wheatgrass	3.32	100	3.32	
CRP Mix (Intermediate + Tall Wheatgrass)	3.23	de	100	3.23		CRP Mix (Intermediate + Tall Wheatgrass)	2.10	100	2.10	
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	3.28	de	100	3.28		CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.88	100	2.88	
Haymaker Intermediate Wheatgrass	2.96	de	100	2.96		Dakota Switchgrass	4.02	100	4.02	
Magnar Basin + Mustang Altai Wildrye	2.76	e	89	2.45		Haymaker Intermediate Wheatgrass	2.73	100	2.73	
Sunburst Switchgrass	4.04	ab	69	2.80		Magnar Basin + Mustang Altai Wildrye	2.77	100	2.77	
Sunburst Switchgrass + Mustang Altai Wildrye	3.42	bcd	72	2.46		Sunburst Switchgrass	3.48	100	3.48	
Sunburst Switchgrass + Sunnyview Big Bluestem	3.95	abc	75	2.96		Sunburst Switchgrass + Mustang Altai Wildrye	3.22	100	3.22	
Sunburst Switchgrass + Tall Wheatgrass	3.47	bcd	100	3.47		Sunburst Switchgrass + Sunnyview Big Bluestem	3.82	100	3.82	
Trailblazer Switchgrass	3.35	cde	72	2.40		Sunburst Switchgrass + Tall Wheatgrass	3.45	100	3.45	
LSD 0.05	0.65			NS		LSD 0.05	NS		NS	
R^2	0.66					R^2				
Streeter						**Hettinger**				
Alkar Tall Wheatgrass	2.91		100	2.91	a	Alkar Tall Wheatgrass	2.12	91	1.93	a
CRP Mix (Intermediate + Tall Wheatgrass)	2.58		96	2.49	ab	CRP Mix (Intermediate + Tall Wheatgrass)	2.23	69	1.55	ab
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.36		100	2.36	ab	CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.25	66	1.48	ab
Haymaker Intermediate Wheatgrass	2.82		100	2.82	a	Haymaker Intermediate Wheatgrass	1.94	89	1.72	a
Magnar Basin + Mustang Altai Wildrye	2.15		18	0.38	c	Magnar Basin + Mustang Altai Wildrye	1.57	2	0.03	c
Sunburst Switchgrass	2.72		95	2.58	a	Sunburst Switchgrass	2.04	0	0.00	c
Sunburst Switchgrass + Mustang Altai Wildrye	2.18		82	1.79	abc	Sunburst Switchgrass + Mustang Altai Wildrye	2.18	0	0.00	c
Sunburst Switchgrass + Sunnyview Big Bluestem	2.19		71	1.54	abc	Sunburst Switchgrass + Sunnyview Big Bluestem	2.15	0	0.00	c
Sunburst Switchgrass + Tall Wheatgrass	2.75		100	2.75	a	Sunburst Switchgrass + Tall Wheatgrass	2.25	39	0.88	b
Trailblazer Switchgrass	2.70		36	0.96	bc	Trailblazer Switchgrass	2.43	0	0.00	c
LSD 0.05	NS			1.62		LSD 0.05	NS		0.78	
R^2				0.52		R^2			0.82	

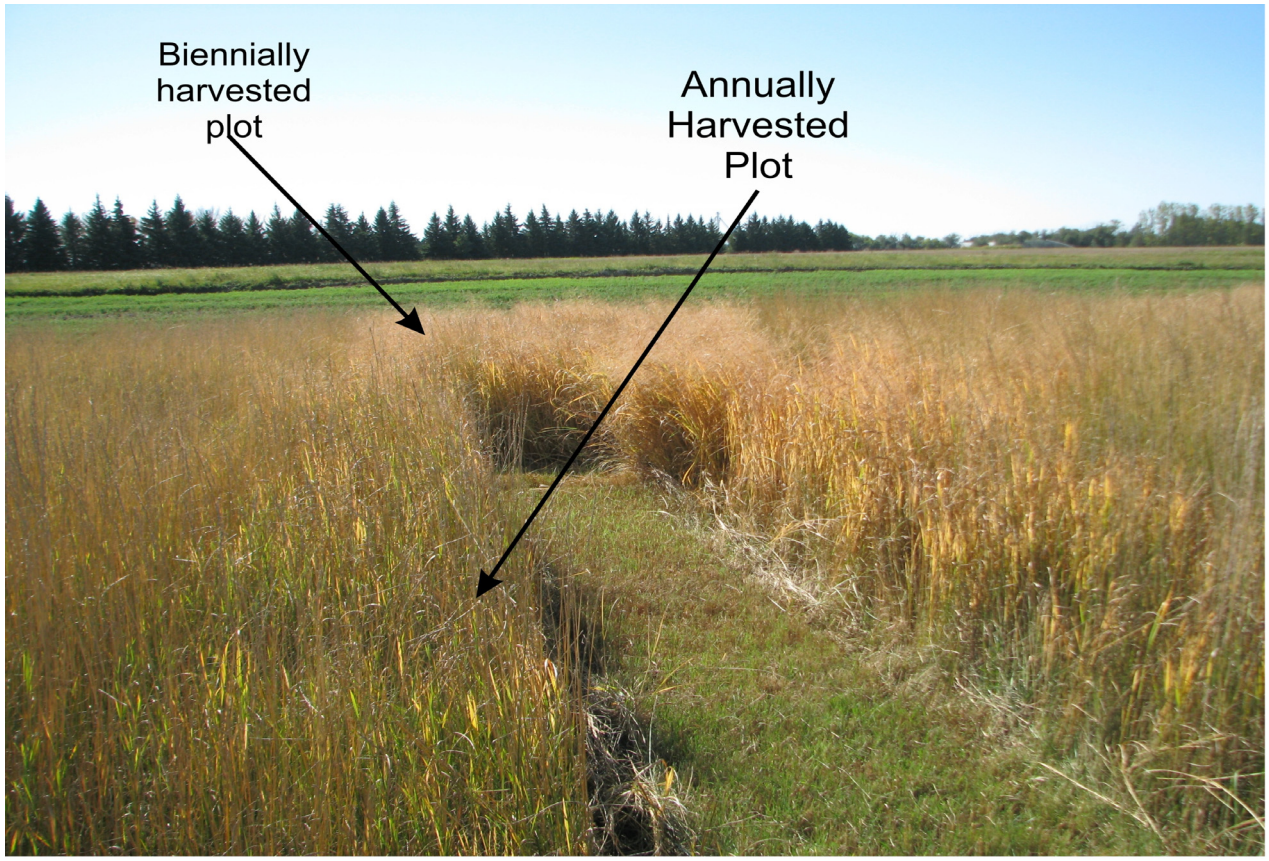
[1]Numbers in the same column followed by the same letter are not significantly different ($p \leq 0.05$)

Table 5 (continued). Total yield (tons/acre), percent of total yield contributed by the seeded species and yield of the seeded species at each site in 2010.

Location and Species	2010 Total Yield	2010 Percent of Seeded Species	2010 Yield by Percent of Seeded Species
Williston Dryland			
Alkar Tall Wheatgrass	1.08	19	0.20 bc
CRP Mix (Intermediate + Tall Wheatgrass)	1.15	100	1.15 a
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	1.14	100	1.14 a
Dakota Switchgrass	1.13	13	0.14 bc
Haymaker Intermediate Wheatgrass	1.32	94	1.24 a
Magnar Basin + Mustang Altai Wildrye	1.00	0	0.00 c
Sunburst Switchgrass	1.03	32	0.33 bc
Sunburst Switchgrass + Mustang Altai Wildrye	0.99	20	0.20 bc
Sunburst Switchgrass + Sunnyview Big Bluestem	1.07	38	0.40 b
Sunburst Switchgrass + Tall Wheatgrass	1.05	5	0.06 bc
LSD 0.05	NS		0.35
R^2			0.88
Ducks Unlimited, Wing, ND			
Alkar Tall Wheatgrass	2.13 ab	89	1.89 ab
CRP Mix (Intermediate + Tall Wheatgrass)	1.44 bc	89	1.28 ab
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.36 a	91	2.15 a
Manifest Intermediate Wheatgrass	1.24 c	73	0.90 bc
Prairie Cordgrass	1.08 c	0	0.00 c
Sunburst Switchgrass	1.42 bc	0	0.00 c
Sunburst Switchgrass + Mustang Altai Wildrye	0.85 c	1	0.01 c
Sunburst Switchgrass + Sunnyview Big Bluestem	0.94 c	2	0.02 c
Sunburst Switchgrass + Tall Wheatgrass	2.29 a	76	1.74 ab
Trailblazer Switchgrass	0.94 c	6	0.06 c
LSD 0.05	0.83		1.05
R^2	0.66		0.74

Location and Species	2010 Total Yield	2010 Percent of Seeded Species	2010 Yield by Percent of Seeded Species
Williston Irrigated			
Alkar Tall Wheatgrass	3.23 def	100	3.23 de
CRP Mix (Intermediate + Tall Wheatgrass)	3.41 cde	100	3.41 de
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.75 ef	100	2.75 ef
Dakota Switchgrass	4.25 bc	100	4.25 bcd
Haymaker Intermediate Wheatgrass	2.51 f	100	2.51 ef
Magnar Basin + Mustang Altai Wildrye	3.43 cde	53	1.81 f
Sunburst Switchgrass	5.33 a	100	5.33 ab
Sunburst Switchgrass + Mustang Altai Wildrye	5.44 a	100	5.44 a
Sunburst Switchgrass + Sunnyview Big Bluestem	5.11 ab	100	5.11 abc
Sunburst Switchgrass + Tall Wheatgrass	3.95 cd	100	3.95 cd
LSD 0.05	0.87		1.17
R^2	0.85		0.82
USDA-ARS Northern Great Plains Field Station, Mandan, ND			
Alkar Tall Wheatgrass	2.18	88	1.91 a
CRP Mix (Intermediate + Tall Wheatgrass)	3.26	75	2.43 a
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.80	62	1.74 ab
Manifest Intermediate Wheatgrass	3.23	91	2.95 a
Prairie Cordgrass	2.95	0	0.00 c
Sunburst Switchgrass	2.45	3	0.07 c
Sunburst Switchgrass + Mustang Altai Wildrye	1.68	0	0.00 c
Sunburst Switchgrass + Sunnyview Big Bluestem	2.65	13	0.34 bc
Sunburst Switchgrass + Tall Wheatgrass	3.21	72	2.32 a
Trailblazer Switchgrass	2.56	6	0.15 c
LSD 0.05	NS		1.53
R^2			0.70

[1]Numbers in the same column followed by the same letter are not significantly different ($p \leq 0.05$)



This switchgrass-tall wheatgrass plots at Carrington show a better stand of the switchgrass (yellow leaves) in the biennial harvested plot (background) than in the annually harvested plot (foreground). This may be due to the harvest regime.

Table 6. Yield in tons/acre and percent difference for perennial forages harvested at two stubble heights in 2010.

Location and Species	Stubble Height: Low (3 in)	Stubble Height: High (10 in)	Difference in Yields Between Stubble Heights (%)
Ducks Unlimited Site at Wing, ND			
Alkar Tall Wheatgrass	**2.97** a[1]	2.00 a	32.7
CRP Mix (Intermediate + Tall Wheatgrass)	2.35 abc	1.23 ab	47.6
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	2.41 ab	1.86 a	23.0
Manifest Intermediate Wheatgrass	1.54 bcd	1.20 ab	22.1
Prairie Cordgrass	0.87 d	0.45 b	47.9
Sunburst Switchgrass	1.25 d	0.59 b	52.8
Sunburst Switchgrass + Prairie Cordgrass	1.44 cd	0.54 b	62.7
Sunburst Switchgrass + Sunnyview Big Bluestem	1.09 d	0.70 b	35.6
Sunburst Switchgrass + Tall Wheatgrass	2.75 a	1.68 a	38.9
Trailblazer Switchgrass	1.23 d	0.66 b	45.9
LSD 0.05	0.94	0.84	
R^2	0.70	0.70	
Central Grasslands Research Extension Center, Streeter, ND			
Alkar Tall Wheatgrass	0.96 abc	0.25	74.0
CRP Mix (Intermediate + Tall Wheatgrass)	1.05 abc	0.33	68.6
CRP Mix (Wheatgrasses + Alfalfa + Sweetclover)	**1.17** a	0.47	60.3
Manifest Intermediate Wheatgrass	0.95 abc	0.70	26.2
Prairie Cordgrass	0.35 d	0.08	78.3
Sunburst Switchgrass	0.74 bcd	0.39	47.2
Sunburst Switchgrass + Prairie Cordgrass	0.64 cd	0.30	52.2
Sunburst Switchgrass + Sunnyview Big Bluestem	0.67 cd	0.17	74.0
Sunburst Switchgrass + Tall Wheatgrass	1.14 ab	0.42	63.4
Trailblazer Switchgrass	0.94 abc	0.29	69.2
LSD 0.05	0.42	**NS**	
R^2	0.60		

[1]Numbers in the same column followed by the same letter are not significantly different.

Analysis Report: Chemical and Heat Value Characterization of Perennial Herbaceous Biomass Mixtures

Prepared by Steve Benson and Margaret Laumb, Microbeam Technologies, Inc. Submitted to Karen Kreil, North Dakota Natural Resources Trust; and Sandra Broekema, Great River Energy.

Microbeam Technologies, Inc., completed an analysis of the chemical and heat value of perennial herbaceous biomass mixtures for use in a circulating fluidized bed combustion (CFBC) system. Great River Energy (GRE) is proposing to co-fire biomass with North Dakota lignite in the CFBC system at GRE's Spiritwood Station Power Plant east of Jamestown. Biomass fuel provides a renewable fuel source that is carbon neutral and will decrease the carbon footprint of the power plant by replacing up to ten percent of the lignite used in the CFB boiler.

Twenty blends of biomass fuels composed of grasses from two study sites, along with six replicate blends, were submitted to MTI for characterization. The samples were from two of five study plots (Carrington and Streeter) that were within a 50-mile radius of GRE's Spiritwood Station Power Plant. The biomass fuel samples were characterized using standard ASTM (American Society for Testing and Materials) bulk analysis methods for proximate (moisture, ash, volatile matter, fixed carbon), ultimate (carbon, hydrogen, nitrogen, oxygen by difference), ash composition, chlorine, and heating value analyses. Partial chemical fractionation was performed to differentiate between water-soluble and organically-associated potassium and sodium. The samples were received in two sets – one set of sixteen (composited into six samples) and one set of forty-two (composited to produce fourteen samples). The first set of six composite samples was split into duplicate samples for analysis.

The report includes rankings of perennial herbaceous biomass mixtures for bed agglomeration, ash deposition, and silicate based bonding. The report notes, "Experience in co-firing biomass with North Dakota lignite is very limited. Based on the known interactions of the components in biomass and Falkirk lignite, potential exists for fireside ash deposition and potential corrosion problems for some of the biomass materials characterized in this study. In order to begin to quantify and manage the ash-related problems, the following future directions are suggested:

1. Laboratory scale fluid bed combustion testing to:
   (a). Determine the potential for bed agglomeration and ash deposition using selected combinations of biomass, lignite and bed materials; and

   (b). Identify and test combinations of biomass, lignite, bed materials, and bed additives that minimize bed agglomeration and deposition.

2. Develop coal, biomass, and bed material specifications that can be used to manage agglomeration as a function of changing lignite and biomass composition."

The entire report is posted to the CGREC web site at the following address:
http://www.ag.ndsu.edu/CentralGrasslandsREC/biofuels-research-1/Chemical%20Analysis.pdf.

Reprinted by permission of North Dakota Natural Resources Trust.