Production and distribution of cereal straw on the Canadian prairies

S. Sokhansanj[1], S. Mani[1]*, M. Stumborg[2], R. Samson[3] and J. Fenton[4]

*[1]Department of Chemical and Biological Engineering, University of British Columbia, Vancouver, British Columbia V6T 1Z3, Canada; [2]Semiarid Prairie Agricultural Research Centre, Agriculture and Agri-Food Canada, Swift Current, Saskatchewan S9H 3K2, Canada; [3]Resource Efficient Agricultural Production (REAP) Canada, 21111 Lakeshore Road, Ste-Anne-de-Bellevue, Quebec H9X 3V9, Canada; and [4]Jim Fenton & Associates, 8 Graham Avenue, St. Albert, Alberta T8N 1T5, Canada. *Email: msudhagar@chml.ubc.ca*

Sokhansanj, S., Mani, S., Stumborg, M., Samson, R. and Fenton, J. 2006. **Production and distribution of cereal straw on the Canadian Prairies**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **48**: 3.39 - 3.46. Alberta, Saskatchewan, and Manitoba produce collectively more than 37 Mt of wheat, barley, oat, and flax grain annually. A portion of the available straw must remain on the field to prevent soil erosion and to maintain soil health and fertility. Straw in excess of this amount can be removed in a sustainable manner for other economic purposes, depending upon the cost of its collection and delivery. An estimate of the straw available was derived by extracting data on land area, yield, and total grain production for wheat, barley, oats, and flax over a period of 10 years (1994-2003) from the Canadian Agricultural Statistics and provincial crop production data bases. The yield and grain production were converted to equivalent straw by using an average straw to grain mass ratio developed for the Canadian prairies. The straw yield was reduced to account for straw that must be left on the soil for wind and water erosion. Livestock demand on straw for feeding and bedding was also investigated. The grain production yields approximately 37 Mt of straw, i.e. Alberta 13.6 Mt, Saskatchewan 18.7 Mt, and Manitoba 5 Mt. The amount of straw required for soil conservation ranges from 0.75 t/ha (conservation tillage) to 1.5 t/ha depending on soil type. An average straw coverage of 1 t/ha was assumed for soil protection against wind and water erosion. The net available straw was calculated to be about 8.8 Mt for Alberta, 9.8 Mt for Saskatchewan, and 2.4 Mt for Manitoba for a total of 21 Mt from the entire prairie region. These quantities decreased to 5.6, 7.9, and 1.5 Mt for Alberta, Saskatchewan, and Manitoba, respectively, to satisfy livestock requirements. The total straw available for the prairies thus amounts to just over 15 Mt, with a wide annual variation from a maximum of 27.6 Mt to a low of 2.3 Mt. This wide range is indicative of the uncertainties in straw availability and the regional considerations in straw availability. In establishing an industrial plant, it is essential to investigate the local producing areas, yields, and harvest practices and the economic, environmental, and social competition for the straw. The long term average grain production on the Canadian prairies from 1976 to 2004 has been 38.5 Mt. During this period, the annual production fell below 30 Mt three times (1978, 1987, and 2002). This is approximately 10% of the years. **Keywords:** straw availability, straw production, straw distribution, Canadian prairies.

Ensemble, les provinces de l'Alberta, de la Saskatchewan et du Manitoba produisent annuellement plus de 37 millions de tonnes de blé, orge, avoine et lin. Une portion de la paille disponible doit rester au champ pour prévenir l'érosion des sols et contribuer au maintien de la bonne santé et fertilité des sols. La paille excédentaire peut être récoltée à d'autres fins tout en respectant l'environnement et selon le coût des opérations de récolte et de transport requises. Une estimation de la paille disponible a été complétée en utilisant des bases de données sur les productions végétales provenant des gouvernements fédéral et provinciaux. Les données portant sur les superficies cultivées, les rendements et la production totale de blé, d'orge, d'avoine et de lin sur une période de 10 ans (1994-2003) ont ainsi été utilisées. Le rendement et la production de grain ont été convertis en équivalent de paille en utilisant un ratio pondéral moyen paille : grain développé pour les prairies canadiennes. Le rendement en paille a été réduit en tenant compte de la paille qui doit être laissée sur le sol pour prévenir l'érosion hydrique et éolienne. Les demandes en paille pour l'alimentation et la litière des élevages ont aussi été étudiées. De la production de céréales dans les prairies découle environ 37 Mt de paille soit, 13,6 Mt en Alberta, 18,7 Mt en Saskatchewan et 5 Mt au Manitoba. La quantité de paille requise pour la conservation des sols varie de 0,750 t/ha en régime de travail minimal du sol à 1,5 t/ha selon le type de sol. Une couverture moyenne de paille de 1 t/ha a été retenue pour la protection du sol contre l'érosion. La quantité nette de paille disponible a été estimée à environ 8,8 Mt pour l'Alberta, 9,8 Mt pour la Saskatchewan et 2,4 Mt pour le Manitoba pour un total de 21 Mt de tonnes pour l'ensemble des Prairies. Ces quantités diminuent à 5,6, 7,9 et 1,5 Mt respectivement pour l'Alberta, la Saskatchewan et le Manitoba lorsque les besoins des élevages sont satisfaits. La quantité totale de paille disponible pour les prairies totalise ainsi juste un peu plus de 15 Mt en moyenne avec cependant une variation importante allant d'un maximum de 27,6 Mt à un minimum de 2,3 Mt. Cette large plage est un indicateur des incertitudes liées à la disponibilité de la paille et des considérations régionales qui déterminent cette disponibilité. Pour l'établissant d'une installation industrielle, il est essentiel d'explorer les zones de production locales, les rendements, les techniques de récoltes, ainsi que la compétition économique, environnementale et sociale pour la paille. La production annuelle moyenne à long terme de grain dans les Prairies canadiennes a été de 38,6 Mt entre 1976 et 2004. Durant cette période, la production annuelle a été en dessous de 30 Mt à trois reprises (1978, 1987 et 2002). Ceci représente environ 10% du temps. **Mots clés**: disponibilité de la paille, production de paille, distribution de la paille, Prairies canadiennes.

INTRODUCTION

Canada has about 36.4 Mha of crop lands available for agricultural production. Out of that, more than 85% (about 32 Mha) are located on the Canadian Prairies (Alberta, Saskatchewan, Manitoba) and a small portion of northeast British Columbia (Campbell et al. 2002). Seeded area is dominated by cereal crops, followed by oilseeds and pulse crops. After grain harvesting, most crop residues are left on the field. Some of these residues have been used for livestock

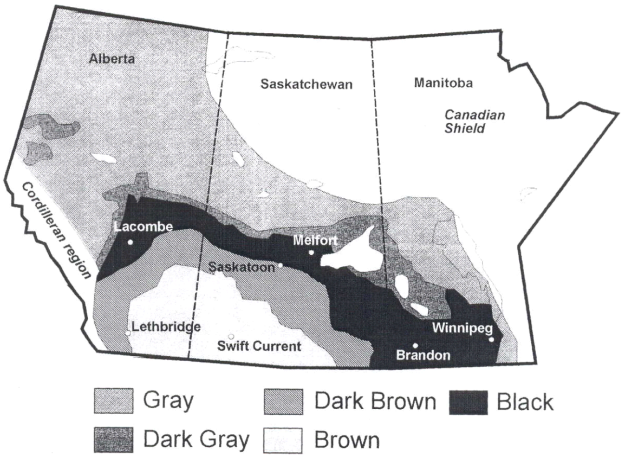

Fig. 1. Classification of different soil zones of Canadian prairies (Campbell et al. 2002). Black and Dark Brown zones are the high yielding straw producing areas.

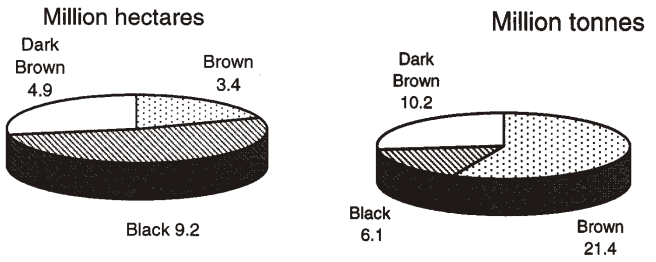

Fig. 2. Distribution of arable land under cereal production and the tonnage of cereal production for three soil zones in Canadian prairies. Note: Black is aggregate for the Black, Gray, and Dark Gray soil zones.

feeding, bedding, insulation, and mulching. In terms of feed quality, wheat, barley and oat residues have relatively low crude protein and digestible dry mater content as compared to sorghum and corn residues (Shanahan et al. 1999). Oat and barley straws are preferred to wheat straw because oat and barely straws have higher energy content and are more palatable (Hamilton 2004).

Canada, similar to other countries in the world, has become interested in the use of crop residues for the production of composite boards and other products, especially liquid fuels and chemicals (Bowyer and Stockmann 2001). Some of the barriers to the economic use of agricultural crop residue are uncertainty in its availability, its quality, cost of collection, transport, and storage, and its location. Information on residue distributions and low cost collection and transportation systems will help reduce the risks associated with utilization of the crop residues. The main objective of this study was to assess the availability, distribution, seasonality, and production of agricultural residues from wheat, barley, oat, and flax crops in Alberta, Saskatchewan and Manitoba.

DISTRIBUTION OF CROP RESIDUES ON THE PRAIRIES

The 32 Mha of arable land on the Canadian Prairies are divided into five soil zones. The Brown soil zone (21%) and Dark Brown soil zone (22%) occupy the drier south and central regions of the prairies (Fig. 1). The balance of the soil falls in the Black, Dark Gray, and Gray soil zones that occupy the northern part of the region (Campbell et al. 2002).

Campbell et al. (2002) investigated the trends in production of grain crops (cereals, oilseeds, pulse crops) on the prairies from 1976 to 1994. Figure 2 was extracted from their data to show the distribution of cereal grains on three soil zones, Brown, Dark Brown, and Black. The greatest quantity of cereals was produced in the Black soil zones, followed by Dark Brown and Brown. The arable land area in the Black soil zone was also the largest of the three soil zones. Figure 2 shows the distribution of black soils which can produce adequate straw for industrial use (Stumborg et al. 1996). The collection and supply of adequate quantities of straw to a biomass conversion plant is affected by climate conditions, local demand for animal bedding, cereal variety, and cropping rotations (Johnston et al. 2005).

AVAILABILITY OF CROP RESIDUES

Table 1 lists the area, yield, and total production of major cereal grains in Alberta, Saskatchewan, and Manitoba. The data are averaged over 10 years from 1994 to 2003. Saskatchewan led the other prairie provinces having approximately 9 Mha of cultivated land, producing, on average, 17.5 Mt of grain annually. Alberta produced approximately 12.9 Mt of cereals on an area of more than 4.8 Mha. Manitoba produced 6.3 Mt on 2.5 Mha. Oat production followed wheat and barley at 0.815 Mt in Alberta and nearly 1.4 Mt in Saskatchewan. Production of oats in Manitoba, at 0.884 Mt, was higher than in Alberta. The production of flaxseed was the highest in Saskatchewan, at approximately 0.552 Mt, followed by Manitoba at 0.295 Mt. The production of flax in Alberta was low, approximately 0.031 Mt.

The yield of grain was generally the highest in Alberta for the 10 year period 1994-2003. Average wheat yield was 2.51 t/ha in Alberta, followed by 1.89 t/ha in Saskatchewan, and 1.80 t/ha in Manitoba. Barley yield was also highest in Alberta, at 3.05 t/ha compared to Saskatchewan at 2.55 t/ha and Manitoba at 2.40 t/ha. The oat yield was 2.33 t/ha in Alberta, 2.19 t/ha in Saskatchewan, and 2.07 t/ha in Manitoba. Flaxseed yield was the lowest of all small grain crops, with 1.18 t/ha in Saskatchewan and 0.93 t/ha in Manitoba. Average yield of flax straw in Alberta was difficult to quantify from the available crop production statistics.

Straw production was estimated from the mass ratio of material other than grain to grain (MOG/G) that varies from one estimate to another (Wood and Layzell 2003). The amount of residue produced varies considerably with growing conditions and crops grown (PAMI 2001). Long term averaged straw to grain mass ratio was used for estimating crop residue. Stumborg (1996) used the ratios in Table 2 for estimating the amount of straw for various crops and soil zones. Agriculture and Agri-Food Canada's Prairie Farm Rehabilitation Administration (PFRA) recommends a single ratio for all soil zones. Slightly different straw to grain mass ratio was used by Lindstorm et al. (1979) to estimate the straw availability. The ratios adopted for this study are shown in Table 2. Table 3 lists the results of

Table 1. Average cultivated area, production, and yield of cereal grains in the Canadian prairie provinces fo 10 years (1994-2003).

Cereal grains		Alberta[1]			Saskatchewan[2]			Manitoba[3]		
		Area (Mha)	Prod (Mt)	Yield (t/ha)	Area (Mha)	Prod (Mt)	Yield (t/ha)	Area (Mha)	Prod (Mt)	Yield (t/ha)
Wheat	Avg	2.734	6.557	2.51	6.215	11.746	1.89	1.582	3.642	1.80
	Max	2.935	8.219	2.84	7.267	16.641	2.29		4.377	2.80
	Min	2.470	3.729	1.80	4.972	6.712	1.35		3.158	0.61
Barley	Avg	1.781	5.491	3.05	1.684	4.294	2.55	0.445	1.470	2.40
	Max	2.146	7.076	3.52	1.984	5.972	3.01		2.112	3.66
	Min	1.134	2.569	2.26	1.377	2.424	1.76		1.176	0.87
Oat	Avg	0.327	0.815	2.33	0.618	1.353	2.19	0.324	0.884	2.07
	Max	0.466	1.188	2.55	0.749	1.932	2.58		1.095	2.74
	Min	0.182	0.370	1.91	0.486	0.831	1.71		0.625	0.91
Flax	Avg	0.023	0.031	1.46	0.468	0.552	1.18	0.176	0.295	0.93
	Max	0.036	0.053	1.57	0.555	0.788	1.42		0.404	1.69
	Min	0.014	0.018	1.35	0.332	0.322	0.97		0.196	0.31
Total	Avg	4.842	12.894	2.63	8.935	17.521	1.95	2.527	6.291	1.80
	Max	5.547	16.536	2.97	10.555	24.593	2.33		7.987	2.72
	Min	3.786	6.686	1.99	7.167	10.392	1.45		5.154	0.67

[1] Alberta Agriculture Statistics Yearbook (2004)
[2] Saskatchewan Agriculture and Food (2004)
[3] Manitoba Agriculture Yearbook (2003)

calculating the amount of straw produced in each of the provinces and the average on the prairies. The quantities of straw were calculated by multiplying the grain production values in Table 1 by the straw to grain mass ratios in Table 2. The quantity of straw mass was reduced by multiplying it by 0.88 assuming that the moisture content of the grain was at 12% (wet basis). Table 3 shows that approximately 37 Mt of straw were produced on the Prairies annually; but this annual production ranged from a high of 52.6 Mt to a low of 20.8 Mt. As it was expected, most of the straw was produced in Saskatchewan (more than 18.7 Mt), followed by Alberta (approximately 14 Mt), and Manitoba (5 Mt).

Net straw yield

Not all of the straw produced can be removed. The amount of surface residues required for erosion control vary depending on soil texture and field slope. Coarse textured (sandy) soils require relatively large quantities of residue for control of wind erosion, while medium textured soils require less. The amount of residues required to control water erosion increases with field slope. Campbell and Coxworth (1999) recommended an average of 1.3 Mt/ha on all soils for soil erosion purposes. Kline (2000) recommended 30 to 50% of the straw residues be left to effectively protect the soil from wind and water erosion. Lindstrom et al. (1979) used 50 to 75% of straw residues to protect soil from wind and water erosion.

Table 4 lists the recommended straw coverage for wind and water erosion. Stumborg et al. (1996) used a value of 1.5 Mt/ha coverage for conventional tillage and 0.75 Mt/ha coverage for reduced or no tillage in order to estimate residue availability. Given the current farming practices, an average of 1Mt/ha was assumed as a reasonable estimate of the straw to be left on the land for soil conservation. The available yield was calculated by subtracting 1 Mt/ha from the straw yields listed in Table 3.

Table 2. Straw to grain mass ratios.

Cereal grains	PFRA estimates[1]	Stumborg et al (1996)[2]			PAMI (2001)[2]	Values used
		Black	Dark brown	Brown		
Wheat	1.60	1.50	1.10	0.75	1.0 - 1.5	1.1
Barley	1.00	1.10	0.75	0.60	-	0.8
Oats	-	-	-	-	-	1.1
Flax	1.20	-	-	-	1.0 - 1.2	1.2

[1] Agriculture and Agri-Food Canada (2003)
[2] Harvestable straw to total straw is generally near 80% (Stumborg et al 1996; PAMI 2001)

Table 3. Estimation of straw produced in Canadian prairie provinces for years 1994 - 2003 based on straw to grain mass ratios from Table 2 and grain production form Table 1.

Cereal grains		Alberta		Saskatchewan		Manitoba		Total for prairies	Average for prairies
		Prod (Mt)	Yield (t/ha)	Prod (Mt)	Yield (t/ha)	Prod (Mt)	Yield (t/ha)	Prod (Mt)	Yield (t/ha)
Wheat	Avg	7.475	2.86	13.390	2.15	4.152	2.05	25.017	2.36
	Max	9.370	3.24	18.971	2.61	4.990	3.19	33.330	3.01
	Min	4.251	2.05	7.652	1.54	3.600	0.70	15.503	1.43
Barley	Avg	4.434	2.46	3.467	2.06	1.187	1.94	9.088	2.15
	Max	5.714	2.84	4.822	2.43	1.705	2.96	12.242	2.74
	Min	2.074	1.82	1.957	1.42	0.950	0.70	4.981	1.32
Oat	Avg	0.921	2.63	1.529	2.47	0.999	2.34	3.449	2.48
	Max	1.342	2.88	2.183	2.92	1.237	3.10	4.763	2.96
	Min	0.418	2.16	0.939	1.93	0.706	1.03	2.063	1.71
Flax	Avg	0.037	1.75	0.662	1.42	0.354	1.12	1.054	1.43
	Max	0.064	1.88	0.946	1.70	0.485	2.03	1.494	1.87
	Min	0.022	1.62	0.386	1.16	0.235	0.37	0.643	1.05
Total	Avg	13.618	2.81	18.736	2.09	4.493	1.92	37.347	2.27
	Max	17.618	3.18	26.299	2.49	8.705	2.91	52.622	2.86
	Min	8.057	2.13	11.113	1.55	1.614	0.72	20.784	1.47

Table 5 lists the net yield and quantities of straw available after deductions for soil conservation. The net straw available on the prairies decreased from an average of 37.3 Mt to slightly over 20.9 Mt. In some cases, the net yield of straw dropped below 1 t/ha. In the case of flax, the 1 t/ha deduction for soil conservation may not be applicable because flax residue left in the field can interfere with subsequent tillage operations. Farmers usually chop the flax straw during combining, bale the straw for removal, or bunch the straw and burn the piles in the field.

COMPETITION FOR STRAW TO SUPPORT LIVESTOCK

Much of the straw baled on the Prairies is used for animal feeding and bedding, mostly for raising beef and dairy cattle. The number of days in a year that the straw is used for livestock depends on the region. For southern Alberta and Saskatchewan, straw was used for approximately 100 days for feeding and 50 days for bedding. For south central regions, the estimates were 135 days for feeding and 90 days for bedding. For northern regions, straw was used for 170 days for feeding and 140 days for bedding (Table 6).

The above quoted straw quantities for feeding and bedding may be over-estimated for a continuous feeding situation. A cow may consume 2.5 kg/d of straw for a few days in each year, but not for every day of the feeding season. Alberta Agriculture, based on producer surveys, estimates an average requirement of 1.1 kg/d for feeding and 2.4 kg/d for bedding on a 180 day feeding period. Ontario Ministry of Agriculture and Food (Hamilton 2004) recommends approximately 2.5 kg of hay/straw per day. Unfortunately, it was difficult to find more precise information on this, and thus we used 5 kg/d as an overall conservative estimate for both feeding and bedding requirement. Table 6 is constructed based on 5 kg/head and the data from Statistics Canada (Statistics Canada 2001) on the population and type of cattle in Alberta. The distribution of the herds in Alberta was extracted from Spiess (2003). Number of cattle in each region was estimated based on the total number of head in the province and the assumed percentage distribution for each region. The number of cattle was multiplied by the amount of straw required for each animal and by the number of feeding and bedding days in a year.

Alberta's annual straw requirement to support livestock was slightly more than 3.2 Mt (Table 6). The amount of straw demand for livestock in Saskatchewan at nearly 1.8 Mt was almost half of that in Alberta. The straw demand for livestock in Manitoba was less than 1 Mt.

The net straw available shown in Table 5 was calculated after deductions were made for soil conservation and for livestock use. We note that

Table 4. Minimum straw cover required for soil protection from wind and water erosions as recommended by PFRA (Agriculture and Agri-Food Canada 2003).

Wind erosion		Water erosion	
Soil texture	Residue required (t/ha)	Field slope (%)	Residue required (t/ha)
medium (loam)	1.0	gentle (6 - 9)	0.8 - 1.15
fne (clay)	1.5	moderate (10 - 15)	1.15 - 1.7
coarse (sandy)	2.0	steep (16 - 30)	continuous grass

Table 5. Net yield and quantities of straw available after deductions of 1.0 t/ha for soil conservation and the amount allowed to meet livestock feeding and bedding requirements.

Cereal grains		Alberta		Saskatchewan		Manitoba		Net total for prairies	Net average for prairies
		Prod (Mt)	Yield (t/ha)	Prod (Mt)	Yield (t/ha)	Prod (Mt)	Yield (t/ha)	Prod (Mt)	Yield (t/ha)
Wheat	Avg	5.089	1.86	7.176	1.15	1.585	1.05	13.850	1.36
	Max	6.567	2.24	11.704	1.61	3.748	2.19	22.020	2.01
	Min	2.598	1.05	2.680	0.54	0	0	5.278	0.53
Barley	Avg	2.605	1.46	1.784	1.06	0.462	0.94	4.851	1.15
	Max	3.954	1.84	2.838	1.43	1.227	1.96	8.019	1.74
	Min	0.935	0.82	0.580	0.42	0	0	1.515	0.42
Oat	Avg	0.534	1.63	0.911	1.47	0.493	1.34	1.938	1.48
	Max	0.877	1.88	1.435	1.92	0.976	2.10	3.287	1.96
	Min	0.211	1.16	0.453	0.93	0.009	0.03	0.672	0.71
Flax	Avg	0.017	0.75	0.195	0.42	0.026	0.12	0.238	0.43
	Max	0.032	0.88	0.391	0.70	0.322	1.03	0.745	0.87
	Min	0.009	0.62	0.054	0.16	0	0	0.063	0.26
Total after deductions for soil conservation	Avg	8.776	1.81	9.751	1.09	2.399	0.92	20.926	1.27
	Max	12.071	2.18	15.744	1.49	5.712	1.91	33.527	1.86
	Min	4.271	1.13	3.946	0.55	0	0	11.392	0.64
Total after deductions for soil conservation and livestock[1]	Avg	5.574		7.938		1.509		15.021	
	Max	8.869		13.931		4.822		27.622	
	Min	1.069		2.133		-0.890		2.313	

[1] See Table 6 for calculating straw requirements for livestock.

the average straw available in Alberta is approximately 5 Mt, varying from a low of 1 Mt to a high of approximately 9 Mt. Saskatchewan has the highest straw availability, averaging approximately 14 Mt. Manitoba's average available straw is about 4.8 Mt. For all of the prairies the average is slightly over 15 Mt per year, ranging over the years from 2.3 Mt to 27.6 Mt.

Data in Table 6 show the number of cattle did not fluctuate significantly year to year; ranging from a high of 6.045 million head in 1998, to 6.4 million head in 2004, with an average of 6.15 million head. This low fluctuation in the number of cattle indicates that the surplus straw for industrial use in Alberta may be about 1 Mt if the low end of the net available straw is used. The low end of straw production happens in drought years - for example in 2002. Spiess (D. Spiess, Resource Data Engineer, Agriculture, Food and Rural Development, Edmonton, Alberta, Email:david.spiess@gov.ab.ca) developed a schedule for available straw in Alberta after accounting for soil conservation and animal use. Table 7 is a reprint of Spiess's data showing that the average net straw from wheat, barley, oats, flax was slightly over 6 Mt, with a maximum over 8 Mt and a minimum

Table 6. Number of cattle in prairie provinces (9-year average 1996 - 2004) and estimation of straw use for livestock production (Statistics Canada 2001).

Province	Region	Percent of total	Number of cattle (millions)	Feeding		Bedding		Total straw required (Mt)
				days	kg/d	days	kg/d	
Alberta	Southern	45	2.768	100	2.5	50	2.5	1.038
	Central	35	2.153	135	2.5	90	2.5	1.211
	Northern	20	1.230	170	2.5	140	2.5	0.953
	Total	100	6.150					3.202
Saskatchewan	All	100	2.900	150	2.5	100	2.5	1.813
Manitoba	All	100	1.424	150	2.5	100	2.5	0.890
Total								5.905

Table 7. Crop straw estimates for potential industrial applications in Alberta (from Spiess 2003).

Crop	Mean (Mt)	SD (Mt)	Maximum (Mt)	Minimum (Mt)
Wheat	3.233	0.864	4.471	1.478
Barley	1.985	0.487	2.810	0.777
Oats	0.937	0.169	1.329	0.584
Flax	0.004	0.001	0.006	0.919
Total	6.159	1.419	8.122	2.840

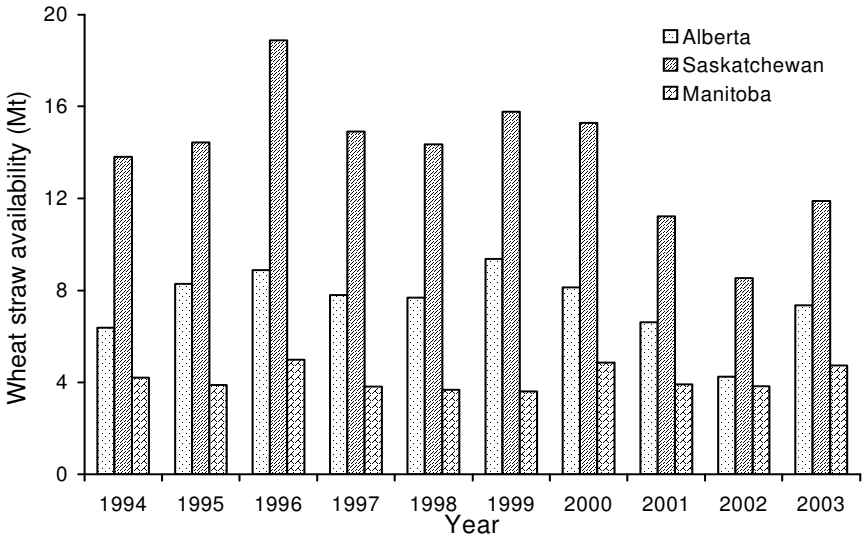

Fig. 3. Annual variation of wheat straw availability in the three Canadian prairie provinces.

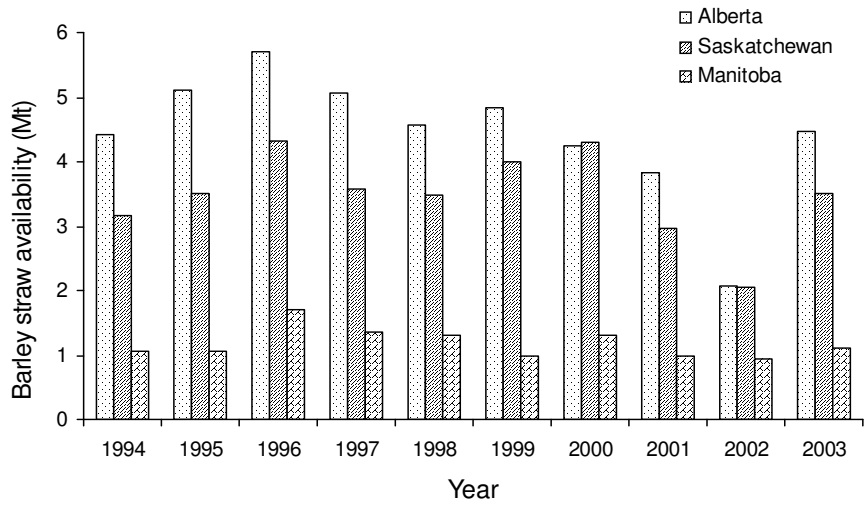

Fig. 4. Annual variation of barley straw availability in the three Canadian prairie provinces.

of less than 3 Mt. Spiess's data agree well with our data on maximum and average available straw in Alberta, but his data over-predicted available straw in drought years for Alberta as compared to our data. A detailed regional analysis, especially for the areas that have a larger concentration of livestock, is needed to make sure that straw is available in the years when the yields are at a minimum needs to be conducted when an industrial use for straw is under consideration.

The straw demands for livestock feed in Saskatchewan are 1.8 Mt, with the net average, maximum and minimum available straw indicating that a surplus of straw, after meeting the demands for conservation and animal production, always exists. This was due to low number of livestock and large cereal production in Saskatchewan. The situation in Manitoba is slightly different. Our calculations show that, although the livestock demand is less than the average available straw, there will be a deficit in the availability of straw for industrial use when straw production is at its minimum in drought years.

ANNUAL VARIATIONS IN STRAW PRODUCTION

One of the inherent problems with straw supply is its annual variation, which depends largely on weather conditions. The market price for grain has some effect on the area of land in cereal production within limits set by requirements for crop rotation. Prairie Agricultural Machinery Institute (PAMI 2001) has shown that the amount of straw recoverable actually goes to zero at some low straw yield due to the limitations of current harvest technology.

Wheat straw

Figure 3 shows the fluctuations of wheat straw available in the three prairie rovinces from 1994-2003. The straw availability was low in Alberta and Saskatchewan during 2001 and 2002 due to drought. In a good year, such as 1999, the total wheat straw available in Alberta was 9 Mt. In the drought year of 2002, the amount of straw fell to less than half, at approximately 4 Mt. Saskatchewan experienced a similar situation. In Manitoba, drought does not seem to have been a significant issue.

Barley straw

Barley straw production on the prairies is about 1/3 that of wheat production. The annual production of barley straw was estimated at 4.4, 3.5, and 1.2 Mt for Alberta, Saskatchewan, and Manitoba, respectively. Figure 4 shows the availability of barley straw that can be sustainably collected in each province. It appears that available barley straw dropped by half in Alberta in the dry year of 2002.

Oat straw

Although oat straw production is much lower than wheat and barley straw, oat straw also has the potential for many applications. Figure 5 shows the annual production of oat straw in the three provinces. Average availability of oat straw in

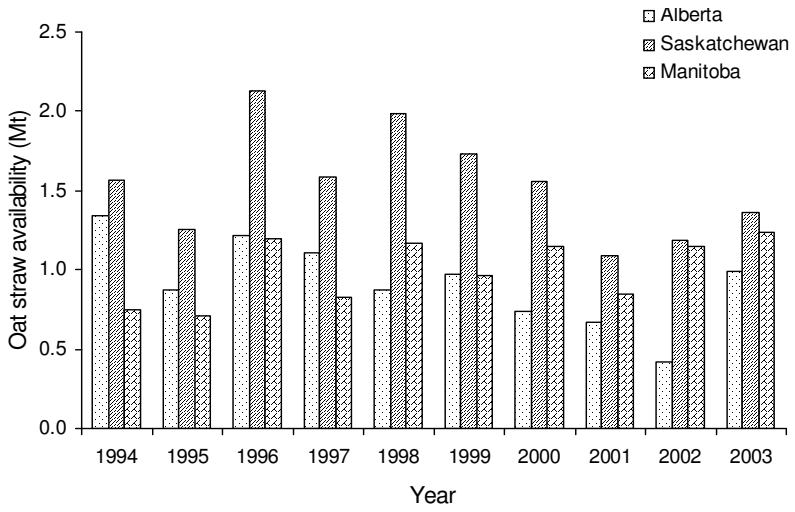

Fig. 5. Annual oat straw production available for collection in the three Canadian prairie provinces.

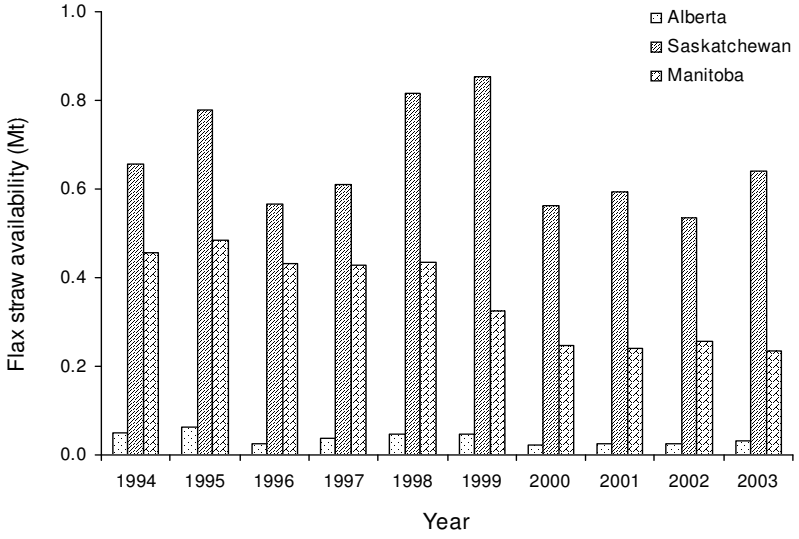

Fig. 6. Annual flax straw production available for collection in the three Canadian prairie provinces.

Alberta, Saskatchewan, and Manitoba over the 10-year period was 0.9, 1.5 and 1.0 Mt, respectively. Saskatchewan produced the highest amount of oat straw, followed by Manitoba and Alberta. Oat crop production responded to a drought situation in a fashion similar to wheat and barley. The effect of drought was lowest in Manitoba. Oats are grown in most regions of the prairie provinces in small, scattered patches, so its collection efficiency for industrial use is questionable unless it can be used interchangeably with wheat and barley straw.

Flax straw

Flax straw is a high quality source of fibre feedstock for the production of many bio-based products. Figure 6 shows the annual production of flax straw in the three Prairie Provinces. Flax straw is used in the production of bio-composites such as automotive and structural parts. Saskatchewan produces most of the flax, averaging 0.67 Mt. Manitoba produces 0.35 Mt, and Alberta is the lowest at about 0.04 Mt annually.

DISCUSSION

Although there is good quality data on land use and grain production in Canada, data on the availability of straw residue is missing. Much of the information available on residue is derived from grain production, assuming various straw to grain ratios which varies with location, cultural practices, species, and varieties (PAMI 2001). The term "surplus straw" means the unused quantity of straw after soil conservation and livestock requirements have been met (CIS 2004). The amount that a producer is prepared to remove and supply to an industrial user depends on the producer's perceived value of straw. In a survey conducted for Alberta Agriculture, Food and Rural Development, only 25% of respondents in the survey were ready to sell straw to an industrial user (CIS 2004).

Data on farm lands, yields, and total grain production of four crops: wheat, barley, oats, and flax, were extracted from the Agricultural Statistics data base over the 10 year period from 1994 to 2003. The area, yield, and total grain production data were converted to equivalent cereal straw by using accepted straw to grain mass ratios developed for the Canadian Prairies. The total straw production and yield were reduced to account for straw that must be left on the soil for wind and water erosion. The livestock demand on straw for feeding and bedding on the Canadian Prairies was also investigated.

Alberta, Saskatchewan, and Manitoba collectively produce more than 37 Mt of wheat, barley, oat and flax grain. Several factors entered the calculation of the amount of straw that would be available for removal and for industrial use. These are (1) straw to grain mass ratios, (2) the amount of straw that needs to be left on the field after harvest for soil conservation and nutrition, and (3) the amount of straw that can be physically removed from field using field equipment. Unfortunately there are uncertainties in all of these factors and even when these uncertainties are minimized, there are problems with regional variability and unknowns from one year to another. Additionally, harvest system losses during near drought or drought conditions may further reduce available straw (Boyden and Hill 2001).

Campbell et al. (2002) analyzed the statistical grain production data for the Canadian Prairies to analyze the trend in cereal production and agronomic practices. Figure 7 provides the data from their paper. The average production for the entire 30 years of data was 38.5 Mt. The total production fell below 30 Mt only in three years, 1978, 1987, and 2002.

We found there was a net annual average of 15 Mt straw available on the prairies in excess of conservation and livestock requirements assuming current livestock numbers. The quantities range from a maximum of 27.6 Mt to a minimum of 2.3 Mt. This wide range is indicative of the uncertainties in straw availability and the regional considerations in straw availability. In establishing an industrial plant, it is essential to

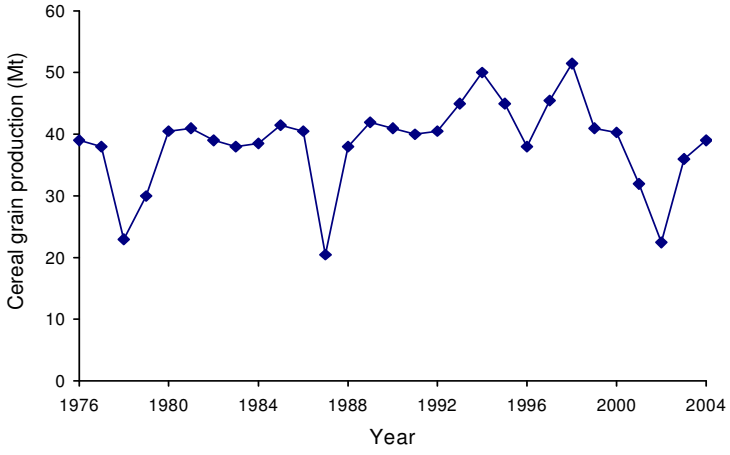

Fig. 7. Cereal grains production on the Canadian prairies from 1976 to 2004. Average annual production for the 22 years was 38.5 Mt. The grain production fell below 30 Mt in 1978, 1987, and 2002.

investigate the local producing areas, yields, and harvest practices and the economic, environmental, and social competition for the straw.

CONCLUSIONS

Alberta, Saskatchewan, and Manitoba collectively produce more than 37 Mt of wheat, barley, oat, and flax grain. The grain production yields approximately 37 Mt of straw, i.e. Alberta 13.6 Mt, Saskatchewan 18.7 Mt, and Manitoba 5.0 Mt. There is a wide range between the minimum and maximum values for net straw available for industrial use. Alberta's net straw ranged from a maximum of 12.1 Mt to a minimum of 4.3 Mt. Saskatchewan's ranged from a maximum of 15.7 Mt to a minimum 3.9 Mt, and Manitoba's range was a maximum of 5.7 Mt to a minimum of 0. These quantities should be reduced to 5.6, 7.9, and 1.5 Mt for Alberta, Saskatchewan, and Manitoba, respectively, due to livestock use. The annual total straw available for the prairies amounts to just over 15 Mt with a wide variation from a maximum of 27.6 Mt to a low of 2.3 Mt. These wide variations call for detailed regional analysis for straw as a secure feedstock for biomass based operations.

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