Agriculture Energy Use

of Adaptation Options

to Climate Change

A Report to the

Prairie Adaptation Research Collaborative
(PARC)

By

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Introduction:

The agriculture and agri-food sector of the Canadian economy is a significant user of non-renewable energy both as direct energy (diesel, gasoline) and indirect energy (fertilizer). Direct on-farm energy expenditure for mechanical power accounts for over $1 billion, or about 10% of total farm operating cost in the three Prairie Provinces. Gasoline, diesel and other fuels met over 70% of this requirement; electricity and natural gas constituting the remainder. Primary agriculture production also requires indirect energy embodied in machinery, fertilizer and pesticides. Nitrogen fertilizer can account for up to 70% of the energy used in crop production.

The types of crops produced and the amount of crop inputs will change in response to changes in climate and changes in the relative cost of inputs as they are affected by GHG reduction policies and climate adaptation strategies in other sectors. This project looked at two scenarios; a crop diversification scenario and a nitrogen use scenario to determine the impact on energy use of these possible reactions to climate change.

The Prairie Crop Energy Module:

The Prairie Crop Energy Module (PCEM) has been developed by CAEEDAC in co-operation with the Semi-Arid Prairie Research Centre (SPARC) and Agriculture Canada Policy Branch. Crop area is allocated to 122 cropping activities for each of the 22 crop districts in the three Prairie Provinces. The cropping activities consist of the eight major crops, plus summerfallow, alfalfa, hay and three "other" categories of pulses, oilseeds and cereals for new or minor crops. Each of the activities is produced by one of three tillage systems, conventional, minimum and no-till seeded after either a fallow, cereal, pulse, oilseed, alfalfa, hay or green manure. Micro-level data from Agriculture Canada's Research Centres was scaled up to the farm level using representative farms to obtain cost, yield and energy use. Statistics Canada data was used for the logical splits on the crop area for the 1996 base year and as a consistency check for crop expenses of fertilizer, herbicides and fuel.

PARC Project Description

- Study on farm energy use as it is impacted by changes in climate and by policy changes due to greenhouse gas (GHG) reduction strategies.
- Determine the potential area of adoption and energy use in western Canada of adaptation options available at the farm level.

Adaptation Options:

The PCEM has been updated to include the crops chickpea and dry bean by incorporating cost of production data at the farm-level into the model. A crop diversification scenario was developed to show the impact on energy use and GHG production of the adoption of these newer crop types.

Adoption of a one-pass seed and fertilization operation is one possible adaptation to a more variable climate. Published research on nitrogen efficiency has been incorporated into a scenario for the reduction of nitrogen use and its impact on energy and GHG (Grant et al. 2001, Haderlein et al. 1999, Malhi et al. 1992, Malhi et al. 1999, Nyborg et al. 1999, Pauly et al. 1996). Use of urease inhibitors, sideband and mid-row banding of fertilizer for one-pass seed and fertilization has been incorporated into a scenario on nitrogen fertilizer use.

Crop Diversification Scenario

Description:

The PCEM was updated to include cost, and energy coefficients for dry beans and chickpeas that have the potential to become or remain as significant crops in western Canada. Also, GHG coefficients were developed for all the major inputs required for crop production. The impact on energy use and GHG emissions of increased area devoted to pulse and oilseed crops forecasted to 2005 was accomplished by projecting the trend in increased area from 1997-2000 to 2005. Agriculture Canada's forecast to 2005 of crop area in western Canada was used as a base for comparison with the Crop Diversification Scenario (CDS) as the 2005 forecast has not taken into account the recent trend in increased pulse and oilseed crop production. The increase in pulse and oilseed crop area for each province was 41%, 56% and 51% for Alberta, Saskatchewan and Manitoba, respectively.

Results:

The difference in GHG emissions and energy use between the CDS and the base forecast for 2005 are presented in Table 1 and Table 2, respectively. The net impact for western Canada of increased pulse and oilseed crop production is a decrease of 1% in carbon released (≈17,000 tonnes) and 1% in the energy used (≈1.59 PJ). The increased energy use and GHG emissions due to herbicides is offset by decreased energy use and GHG emissions from machine, fuel and fertilizer. Manitoba energy use and GHG emissions for fertilizer and herbicides are in marked contrast to the results for Alberta and Saskatchewan. The key to understanding these differences in energy use and carbon emissions between provinces is the change in cropping activities. The increase in pulse and oilseed area in Manitoba where there is relatively little summerfallow area has come at the expense of cereal crop area. The change in energy use and carbon emissions is then the difference between input use in cereal crops as compared to pulse and oilseed crops. Therefore we see a substantial decrease in fertilizer energy used and GHG emissions for Manitoba as pulse crops use significantly less nitrogen fertilizer than cereal crops. In Alberta and Saskatchewan a large part of the increase in pulse and oilseed area is the result of a reduction in summerfallow area as crop rotations are extended. This reduction in summerfallow area results in greater phosphorus fertilizer use, as there is more land being cropped and greater nitrogen fertilizer use as more cereal and oilseed crops are seeded on stubble. The net result for Alberta and Saskatchewan is a slight increase in the fertilizer energy used and GHG emissions.

Herbicide energy use and GHG emissions increased under the CDS especially for Alberta and Saskatchewan as a result of more area in crop and the higher amount of herbicide used to grow pulse and oilseed crops. Machine and fuel energy use and GHG emissions decreased as pulse and oilseed production increased. The decrease in machine and fuel energy used and GHG emissions is greater for Manitoba than for Alberta and Saskatchewan. This again is due to the difference in where the area for the increase in pulse and oilseed area comes from.

Table 1: Crop Diversification Scenario 2005 GHG[1] Difference (Tonnes C)

Prov.	Machine	%[2]	Fuel	%[2]	Fertilizer	%	Herbicides	%[2]
Alb.	(405)	(0.9%)	(3,193)	(1.1%)	554	0.1%	2,665	7.4%
Sask.	(109)	(0.1%)	(2,092)	(0.4%)	274	0.0%	3,859	5.2%
Man.	(928)	(3.9%)	(5,365)	(3.7%)	(13,256)	(4.3%)	954	3.3%
Net	(1,441)	(1.0%)	(10,650)	(12%)	(12,428)	(0.9%)	7,478	5.4%

1. Greenhouse gas emissions are direct emissions for Fuel and the indirect or embodied for Machine, Fertilizer and Herbicides.
2. The percentage change in GHG for the 2005 CDS compared to the 2005 base.

Table 2:Crop Diversification Scenario 2005 Energy[1] Difference (PJ)

Prov.	Machine	%[2]	Fuel	%[2]	Seed	%[2]	Fertilizer	%[2]	Herbicides	%[2]
Alb.	(0.03)	(0.9%)	(0.15)	(0.1%)	(0.18)	(5.9%)	0.04	0.1%	0.16	5.5%
Sask.	(0.00)	(0.1%)	(0.10)	(0.4%)	(0.23)	(2.8%)	0.03	0.1%	0.26	5.1%
Man.	(0.06)	(0.8%)	(0.25)	(0.7%)	(0.26)	(8.3%)	(0.89)	(4.3%)	0.06	3.2%
Net	(0.09)	(1.0%)	(0.50)	(0.2%)	(0.67)	(4.2%)	(0.82)	(0.9%)	0.48	4.8%

1. Energy is direct energy use for Fuel and the indirect or embodied for Machine, Fertilizer and Herbicides.
2. The percentage change in energy for the 2005 CDS compared to the 2005 base.

The differences between the 2005 forecasted costs and the CDS costs are presented in Table 3. There is a net increase in costs for Saskatchewan of 3.5% or \$123.3 million. The difference in cost reflects the increased seeded area resulting in higher fixed, repair, seed, fertilizer, interest and chemical costs. Lower fuel and labour costs are mainly the result of lower yields for cereal and oilseed crops because more of these crops are being grown on stubble. There is a net increase in costs for Alberta of 2.5% or \$54.4 million for the CDS. The cost increase for Manitoba under the CDS is 0.1% or \$1.1 million. The reduction in area seeded to cereal crops in Manitoba results in significantly less nitrogen fertilizer being used as the pulse crops can supply all or part of their nitrogen requirement. Although, there is an increase in the amount spent on fertilizer for Saskatchewan and Alberta the increase is not very large, 0.30% and 0.34%, respectively. The difference in fixed and repair cost between Saskatchewan and the other two provinces is a reflection of the greater reduction in summerfallow area as the crop rotation is extended in Saskatchewan. The savings in fuel and labour are significantly less in Saskatchewan compared to Alberta and Manitoba especially on a per seeded hectare basis.

Table 3: Crop Diversification Scenario 2005 Cost Difference ($)

Prov.	Fixed	Repair	Fuel	Labour	Seed	Fertilizer	Interest	Herbicides
Alb.	(1,847,325)	(1,386,853)	(1,031,119)	(2,060,489)	27,594,406	1,883,095	2,390,805	28,894,158
Sask.	5,732,397	1,683,755	(852,562)	(1,452,468)	54,471,870	2,346,358	4,881,032	56,554,295
Man.	(8,922,895)	(814,794)	(1,991,826)	(3,262,011)	7,013,038	(13,989,275)	602,833	22,550,563

The impact of soil zone on the changes in costs between the 2005 forecasted values and the CDS is presented in Table 4 for Saskatchewan crop districts. The Brown and Dark Brown soils are mainly in crop districts 1a, 2, 3, 4, 6 and 7 with crop districts 1b, 5, 8 and 9 comprised mainly of Gray and Black soils. Soil zones that have greater use of summerfallow have increased costs (Brown and Dark Brown soils), which is in marked contrast to soil zones with low summerfallow area (Black and Gray soils).

Table 4: Differences in Cost by Saskatchewan Crop District ($)

CD	Fixed	Repair	Fuel	Labour	Fertilizer
1	(1,024,407)	(205,495)	(328,685)	(369,386)	410,405
2	2,050,780	533,598	103,671	47,927	(184,330)
3	1,949,086	790,692	199,770	231,511	1,318,164
4	589,357	159,717	39,802	14,525	399,496
5	(2,942,017)	(794,597)	(763,357)	(980,937)	(715,990)
6	2,775,651	931,803	218,674	105,482	476,229
7	2,445,891	686,180	294,232	281,260	1,503,967
8	(232,622)	(187,724)	(298,570)	(378,475)	(837,301)
9	120,677	(230,421)	(318,099)	(404,375)	(24,283)

Nitrogen Fertilizer Use Scenario

Description:

The costs, GHG and energy coefficients associated with nitrogen fertilizer application in the PCEM were modified to reflect the adoption of a one-pass seed and fertilization operation for all tillage systems for the nitrogen fertilizer use scenario (NFS). The pre-seed tillage operations for conventional tillage and minimum tillage remain unchanged, as these operations are required for weed control and residue management. The same quantity of fertilizer that would have been banded in the fall would still be purchased in the fall for spring application under the new scenario. Therefore, the interest cost to the farmer would be the same however; the cost was adjusted for storage of the fertilizer for six months. The impact on energy use and GHG emissions of the adoption of a one-pass seeding system uses Agriculture Canada's forecast of 2005 crop area for the base and NFS.

The one-pass seed and fertilization operation is assumed to be the method used to apply all the required nitrogen. Most of the farmers in the Brown and Dark Brown soil zones would be able to apply the nitrogen with the seed for all cereal crops and use a urease inhibitor with the nitrogen when seeding oilseed crops. The use of the urease inhibitor is assumed to increase the cost of the applied nitrogen by 25% as the fertilizer industry is expected to develop an economically viable product by 2003-2005(Fleury 2000). Farmers in the Black, Thin Black and Gray soil zones would sideband or mid-row band the nitrogen, as the amount of nitrogen applied makes seed placement of nitrogen a risky option. A 10 % reduction in fertilizer use is assumed for all soil zones, as better placement of the nitrogen will increase the nitrogen use efficiency allowing farmers to reduce the amount of applied nitrogen.

Results:

GHG emissions and energy use for the nitrogen fertilizer scenario are presented in Tables 5 and 6, respectively. The net result of the adoption of a one-pass seeding system and a 10% reduction in nitrogen use is a decrease in GHG emissions of ≈136,000 tonnes (5.5%) and a reduction in the use of energy of ≈8.1 PJ (4.8%). The increased GHG and energy use due to more machinery and repairs as a one-pass seeding system is adopted is offset by the reduction in GHG and energy use due to reduced nitrogen fertilizer. GHG emissions and energy use remained unchanged for herbicide, fuel, and seed as the base and NFS had the same area cropped and crops produced.

Table 5: Nitrogen Fertilizer Scenario GHG[1] Difference (Tonnes C)

	Machine	%[2]	Fertilizer	%[2]	Net	%[2]
Alb.	359	0.8%	(39,729)	-9.1%	(39,371)	-4.9%
Sask.	482	0.6%	(69,190)	-12.1%	(68,709)	-5.8%
Man.	314	1.3%	(28,304)	-9.1%	(27,990)	-5.5%

1. Greenhouse gas emissions are direct emissions for Fuel and the indirect or embodied for Machine.
2. The percentage change in GHG for the 2005 CDS compared to the 2005 base.

Table 6: Nitrogen Fertilizer Scenario Energy[1] Difference (PJ)

	Machine	%[2]	Fertilizer	%[2]	Net	%[2]
Alb.	0.02	0.8%	(2.66)	-9.0%	(2.64)	-5.0%
Sask.	0.03	0.6%	(3.48)	-9.1%	(3.58)	-4.5%
Man.	0.02	1.3%	(1.90)	-9.1%	(1.88)	-5.4%

1. Energy is direct energy use for Fuel and the indirect or embodied for Fertilizer.
2. The percentage change in energy for the 2005 CDS compared to the 2005 base.

Fixed and repair costs increased as a result of the one-pass seeding operation for the conventional and minimum tillage operations. However, these increased costs are offset by a reduction in the cost of fertilizer and interest charges. Sideband or mid-row band nitrogen application will require increased capital expenditure and repair cost for the farmers in the Black and Gray soil zones. The cost of fertilizer will be reduced due to the 10% reduction in nitrogen fertilizer use however; there is an increased cost of fertilizer in the Brown and Dark Brown soil zone for oilseed crops due to the cost of the urease inhibitor.

Table 7: Nitrogen Fertilizer Scenario 2005 Cost Difference (million $)

	Fixed	%[2]	Repair	%[2]	Fertilizer	%[2]	Interest	%[2]	Net	%[2]
Alb.	6.6	1.0%	0.5	0.3%	(32.3)	-5.9%	(1.4)	-2.5%	(26.6)	-1.2%
Sask.	14.2	1.4%	0.6	0.3%	(45.0)	-5.8%	(1.9)	-2.1%	(32.1)	-0.9%
Man.	5.2	1.5%	0.4	0.5%	(24.0)	-6.7%	(1.0)	-2.7%	(19.5)	-1.4%

1 The percentage change in costs for the 2005 CDS compared to the 2005 base.

The net per cultivated hectare benefit of the NFS is $5.00, $1.51 and $2.69 for Manitoba, Saskatchewan and Alberta respectively. The relatively higher nitrogen use in Manitoba compared to Alberta and Saskatchewan results in greater saving in nitrogen offsetting the increased cost due to one-pass seeding. The benefit of adoption of a one-pass seed and fertilization operation is greater for the areas of western Canada that have high nitrogen fertilizer use. The low net returns to the adoption of one-pass seeding in the more arid regions of western Canada may limit the adoption of this practice.

Conclusions

Farm Level Adaptation to Policies to limit GHG Production:
One of the prime reasons for increased pulse crop area other than economic is the benefit of reduced nitrogen application when pulse crops are seeded and the residual nitrogen benefit for subsequent crops. Natural gas, which is a prime feedstock in the manufacture of commercial nitrogen is seen by industry and government as one method to reduce GHG emissions. The increased demand for natural gas if not offset by increased supply in the North American market will result in increased cost of manufacture of commercial nitrogen fertilizer. This in turn will change the relative profitability of growing pulse crops compared to cereal and oilseed crops. The results of the CDS indicate that as farmers respond to the incentives to produce more pulse and oilseed crops there will be added benefits of reduced energy use and GHG emissions.

Farm Level Adaptation to Climate Change:
The recent trend towards increased pulse crop area will present many challenges for producers and researchers as climate change takes place. Some of the crops are new like chickpea or being promoted in non-traditional soil/climate regions such as canola in the Brown soil zone. Pulse crops that have indeterminate growth habits (Lentil) or longer reproductive growth periods (Chickpea) may have an advantage over crops that are more determinant (cereals) or have shorter reproductive growth periods, if precipitation during the growing season is highly variable (Millar et al., 1998). By including pulse and oilseed crops in a crop rotation with these varied reproductive characteristics the likelihood of a total loss of income in any one year may be reduced. A farm operation can then maximize long-term profits and survivability by extending the period of reproductive growth in their crop rotation.

The level of crop diversification and the types of crops produced will impact energy use. The amount of nitrogen fertilizer used in crop production on the prairies will be the prime determinant of energy use in primary agriculture production. Energy use when compared provincially or by soil zone shows significance differences. This in part reflects the different agriculture policies in each province especially input subsidies. Also, soil zone differences reflect the different levels of cropping activities between soil zones in a province and between the same soil zone in different provinces.

Adoption of technologies to improve nitrogen use efficiency will have the potential to significantly reduce energy use and GHG. Also, if precipitation becomes highly variable farmers will want to delay the application of nitrogen until information on current growing season weather is known with greater certainty. Application of all nitrogen at seeding or split with in crop application will reduce the risk of loss of income due to under or over fertilization. However, the low level of nitrogen used in crop production in the drier regions of western Canada will limit the extent to which this practice is adopted unless higher nitrogen use efficiency can be obtained or the real cost of nitrogen increases significantly.

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