Decoding your fuel bill
What is your farm's real energy bill?

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Summary

Prairie farmers, like all Canadians, are becoming very conscious of the high cost of energy. Agriculture on the Canadian prairies is very dependent on fossil fuel energy. With diesel fuel priced at more then a dollar a litre, and fertilizer at record highs, we decided it was time to take a closer look at prairie agriculture's total energy bill. Our results might surprise you.

Your tractor may burn more then $1000 dollars diesel fuel a day during seeding but nitrogen fertilizer is the main energy input. Fertilizer energy accounts for about 50% of prairie agriculture energy input[7]; fuel energy is not quite 30%. Nitrogen fertilizer production requires high amounts of energy (mostly natural gas) to produce and it's especially important for cereal and oilseed production.

History of Energy Use in Agriculture

Energy has always been an important input to prairie agriculture. In the early pioneer days, horses and oxen were the main sources of physical energy for farm work. Draft animals didn't burn diesel fuel but they still required energy. Farmers had to devote a high proportion of their cultivated land to produce feed crops for these animals, mainly hay and oats. During this period, purchased energy inputs were minimal. Crop production was totally reliant on utilizing the rich nutrient resources stored in prairie soils. When accounting for the energy consumed by draft animals, we estimated from cropping area and production data the ratio of human food energy production to energy input was about 2.0[11]. Net food energy production was also low; it took 1.3 acres of land to produce enough food to feed one person for a year.

As farms mechanized in the 1930s and 1940s, tractors soon replaced draft animals and fossil fuel replaced hay and oats as the main energy input. Soil tillage was intensive and used to control weeds, prepare the seedbed, and keep summerfallow weed-free. A high proportion of the land was summerfallowed each year as a means to enhance crop yields through increased soil water conservation and the build-up of available soil nutrients. The dominant crop rotation was wheat-summerfallow. Fertilizer and herbicide purchases were still minimal, although some herbicides, for broadleaf weed control (2,4-D), and some phosphate fertilizer, had started to be used.

While prairie farms are highly dependent on the use of fossil fuels for nearly all farm activities and inputs, no-till practices and diversified crop rotations reduce some of the energy requirements. Prairie farms are able to produce enough food to feed about 80 people per acre per year. Photo credit: Eric Oliver

Nitrogen continued to be supplied by the decomposition of soil organic matter built up by the native prairie grasslands prior to cultivation. The ratio of energy produced to energy inputs purchased was high because few crop production inputs like fertilizer, herbicides etc. were purchased. We estimated an acre of land would have produced enough food to feed about 3 persons for a year[1]. Grain transportation distances were short, mainly from field to farm storage and then to local elevators.

Energy use on Canadian Prairie farms has continued to grow. Fertilizer, especially nitrogen, became an essential input for crop production. Grain trucking distances have increased from field to farm, because farm sizes have increased. The distance from farm to elevator has also gone up as the elevator network consolidated along the main railway lines.

There have been some energy savings too. Reduced tillage intensity, on cropped and summerfallow land, has reduced fuel energy inputs. Summerfallow use has been declining. Since 1981 it has declined by 62%[11]. Herbicides have replaced much of the tillage, and higher quality seeding equipment, designed for excellent seed placement in high residue systems, has eliminated the need for seedbed preparation with tillage. No till production practices reduce energy requirements for fuel and machinery, and reduce total energy use by up to 20%. There are other benefits too. Reduced summerfallow, combined with good fertility management, has resulted in increased soil organic matter, reduced soil erosion, and improved environmental quality.

At a time when food shortages have captured the world's attention, we estimate that prairie farmers produce about four times more food energy than they use to produce their crops. Perhaps more importantly for a hungry planet an acre of annual crops will now produce enough food yearly for about eight people. Crop production systems continue to produce more food energy than the energy in the fossil fuel-based inputs used in crop production. However, current production systems remain heavily dependent on fossil fuel-based energy inputs.

What Are Your Crop Production Energy Inputs?

The most obvious way that producers expend energy producing crops is by burning fossil fuels to power machinery for soil tillage, cultural operations, drying of crops, heating farm buildings, and transporting farm products. It also occurs indirectly through the combustion of fossil-based energy used in the manufacture and repair of farm machinery, and in the manufacture, packaging, and transport of crop inputs[7].

Fuel

Diesel, used for tillage, seeding, and harvesting, is the major fuel source. Conventional tillage with a heavy duty cultivator uses about 2.2 litres (L) of diesel per acre or 85 MJ of energy per acre for every tillage operation[2]. Fall tillage, pre-seeding tillage, and maintaining summerfallow all increase farm fuel use. Reduced tillage systems, such as no till, reduce fuel use by replacing tillage with herbicides for weed control. Fuel use for spraying is about 0.4 L/ac, less than 20% of that required for tillage.

Fuel used to seed with direct seeding equipment can exceed 3 L/ac, depending on the seeding equipment and size of seed and fertilizer tanks. Conventional seeding with hoe drills, for example, uses less fuel for the actual seeding operation but burns much more overall because of the need for the seedbed preparation. Harvesting grain by straight cutting saves a swathing operation (1.1 L/ac of fuel). Since you typically pass less straw through the combine when straight cutting your energy use, associated with the harvesting operation, will also be lower. Fuel use for the combine can be as high as 5 L/ac, but will be much lower for lower yielding crops and crops with less crop residue to process. Seeding, harvesting, and two weed control passes use about 400 MJ/ac of energy. Lube energy (oil, grease) would be an additional 15% above fuel, and if accounting for the entire life cycle of energy inputs, another 22% must be added to account for the energy that goes into extracting, refining and transporting the fuel.

Fertilizer

Nitrogen fertilizer requires more energy to produce (20.5 MJ/lb) than other macro nutrients such as phosphorus, potassium and sulphur[8]. Phosphorus (3.4 MJ/lb of P_2O_5) and potassium (1.5 MJ/lb of K_2O) are mined, so most of their energy input is from mining and transportation. The energy efficiency of nitrogen fertilizer production, in newer processing plants using natural gas, is about 40% higher than production technologies found in older fertilizer plants.

Nitrogen comes from the atmosphere, but energy is required to convert it into an organic form usable by plants. A cereal grain crop, for example, requiring 20 lb of phosphate (phosphorus as P_2O_5) and 50 lb of N per acre, has about 1100 MJ of energy tied up in the fertilizer; most of this energy is used manufacturing the nitrogen.

Producers have few options available to reduce their fertilizer-based energy inputs

Potentially costs can be reduced through increased fertilizer use efficiency, but there is limited knowledge and technology available on how to do this. Nonetheless, three options are available to reduce nitrogen fertilizer use and the associated energy.

The first option producers have is to grow nitrogen fixing legume crops. The second is to utilize grain legumes, like field pea, lentil, or sweet clover as a green manure crop. The third is to grow a legume hay, such as alfalfa, in rotation with annual crops. All of these options would require significant changes to current farming systems if they were to be fully implemented.

Grain legumes, like field pea and lentil, will supply their own nitrogen needs and supply a small amount of residual nitrogen for the subsequent crop. Green manure crops might only be feasible if fallow is already a part of the crop rotation. They could have broader applications in the future if nitrogen fertilizer costs continue to escalate[9,13]. Alfalfa production would have the greatest impact on the cropping systems, and on farm returns. However some different equipment is required, and the alfalfa would still need to be converted to foodstuffs. Cattle and sheep herds would have to increase to utilize the additional forage production.

Herbicides

The energy used to produce herbicides varies from product to product. For example the energy required to produce a typical herbicide for broadleaf weed control in cereals can range from 30 to 100 MJ/ac. Grassy weed control can range from 30 to more than 100 MJ/ac, while controlling weeds prior to seeding (burn-off) or chemical fallow would take about 80 MJ/ac. The weed spectrum will dictate the herbicide and rate of application, and thereby the energy in herbicides applied. On average, burn-off herbicides require less energy than tillage.

Machinery Use

The manufacture of steel, required for building and repairing agricultural implements, as well as the non-steel components of equipment, all require energy for their production and maintenance. Tractors, combines, seeders, sprayers, etc. wear out over time, so energy required to build their replacements has to be apportioned to the energy used for crop production. The amount of energy apportioned will directly depend on the usage of the machines. A conventional tillage system, using a tractor and cultivator for multiple tillage passes, will have equipment wear out faster than a no till system. Therefore energy associated with conventional tillage systems will be higher and are proportional to their fuel use. Machinery related energy will be about 20% of the fuel and lube energy required for crop production[7].

Cropping Systems

Tillage

As previously indicated, the intensity of tillage has a large impact on farm energy use. By moving from conventional tillage systems to no till or minimum tillage systems, fuel use can be reduced by 30%[14,15]. Fuel savings with no till will be higher in the moist Parkland region because of the higher tillage intensity with conventional tillage. Energy savings by moving to no till will be highest for canola because more tillage operations are required for seed bed preparation, next highest will be spring seeded cereals, and the lowest will be for winter cereals and pulse crops. Regardless of the tillage system, fuel is still required for seeding, spraying, harvesting, and trucking. Estimates of energy use for seed, fuel, fertilizer, herbicides and machinery are shown listed in Table 1. These are more representative of the Parkland region of the prairies, so one would expect lower values for the drier areas of the prairies. However, the relative difference between conventional and no till systems will be similar.

No till systems can require higher fertilizer rates (2-3%), especially when first moving to no till since nutrient cycling in the soil has not adjusted to the changes in management[14]. As soil quality improves, it is expected that this difference in fertilizer rates will become negligible.

Fertilizer placement and timing is important for efficient fertilizer use, especially nitrogen. Placing fertilizer in the soil at time of seeding is very efficient[6]. The new generation of no till seeding equipment can place fertilizer with high precision. This more efficient placement of fertilizer, with the no till seeding equipment, can lower overall rates of fertilizer.

Herbicide use will be higher with no till systems[14]. Depending on the crops and herbicides used, this could translate into 30% higher herbicide energy use. This increase is more than offset by the savings in reduced energy consumption through fewer machinery operations in no till systems.

Crops

The main crops grown in western Canada fall into four categories: cereal (spring and winter), oilseed, pulse, and forage. Wheat is the main cereal crop, but barley, oat, and rye use the same technology and have similar crop management inputs as wheat. Fertilizer requirements will vary among these crops. The primary energy input in cereal grain production (up to 55%) is the energy associated with fertilizers, especially nitrogen. The actual amount of nitrogen fertilizer applied will vary by region, soil type and quality, and cropping history. Herbicide use, and associated energy use, will depend on the herbicide, rate and weed spectrum.

Canola requires high amounts of nitrogen to realize its full yield potential in higher rainfall areas[4]. Growing canola with conventional tillage will require more field operations to prepare a good seedbed than what is required for cereals. With no till, the number of field operations is similar for canola and cereals. As with cereals, the energy embodied in nitrogen fertilizer is the main energy input (about 50%) for growing canola[10] (Table 1). Herbicide energy will differ by canola type (herbicide tolerance, for example), and the weeds to be controlled. Herbicide energy is less than 10% of total energy input for no till production of canola.

Field preparation for seeding pulse crops is similar to spring cereals. Seeding requires less time, and fuel energy, because nitrogen fertilizer does not need to be applied. While less time is required for filling fertilizer tanks and less weight (nitrogen) needs to be pulled around the field, seeding rates for some pulse crops are higher so filling time is about the same as cereals. Some nitrogen is typically applied with pulse crops but only because it is part of the current phosphate and sulphur fertilizers. With pulse crops, the main energy use is for fuel and lubricants (>50%). A pulse crop will require about half the energy used for a cereal crop (Table 1).

The energy for forage production will depend on the forage mix. Alfalfa mixes, or pure stands of alfalfa, will not require nitrogen fertilizer if the seed is properly treated with *Rhizobium* inoculant. Grass hay will require nitrogen fertilizer. Machine energy for harvesting forage (mowing/conditioning, baling, hauling bales) is lower than for annual crop production. Rotational forage stands (4 years) will require energy to establish the stand and to remove the stand, in addition to hay harvesting (Table 1). No till alfalfa will be terminated by herbicides, the conventional by disc. The termination of alfalfa crops will provide nitrogen to subsequent annual crops. In turn, this will reduce the energy required to grow subsequent annual crops for a number of years or increase the ratio of energy produced to energy used[5].

Crop Rotations and Sequences

The crop sequence used will impact field preparations and fertilizer requirements. A crop following summerfallow requires less nitrogen fertilizer, lowering overall energy use to grow that crop. Also, with conventional systems, seedbed preparation after a fallow year will be minimal. However, the energy input required for summerfallow management needs to be taken into account.

High residue producing crops, like cereals, will require more field operations with conventional tillage for seedbed preparations. With no till, an operation with a heavy harrow might be required when there are high residue levels. Conventionally seeded crops following a pulse crop will require less seedbed preparation because of the lower levels of crop residues. Finally, small seeded crops, such as canola, may require different operations to insure a good seedbed and even germination and crop emergence.

Nitrogen requirements will also depend on the crop sequence. Cereal or oilseed crops following a pulse crop tend to require less nitrogen, however, nitrogen carryover from pulse crops can be low because most of the nitrogen fixed by the plants is removed in the harvested seed, and carryover also depends on the pulse crop[12]. The sequence has been found to have more impact on yield than on inputs[15]. Crops following legumes grown specifically to fix nitrogen, either as green manure or as a forage, will require less nitrogen and therefore less energy inputs[13]. The amount of nitrogen and the number of cropping seasons the nitrogen will be available depends on the legume crop. Annual green manure crops will likely supply less nitrogen over time than a legume forage crop like alfalfa[3,5].

Conclusions

Agricultural production on the Canadian prairies will remain dependent on fossil fuel energy for nearly all farm activities and inputs used in production for the foreseeable future. The main energy input is incurred through the manufacturing of nitrogen fertilizer that is essential for efficient, and profitable, cereal and oilseed production. While producers have limited options to reduce their total farm energy inputs, it's important to remember that they do have a few.

No till systems for cereal and oilseed crops use about 20% less energy than conventional tillage systems, and about 11% less for pulse crops. Pulse crop production uses about half the energy of cereal and oilseed production, primarily because pulse crops do not require nitrogen fertilizer. Perennial legume based forage production will use less than 20% of the energy used in annual cereal or oilseed cropping.

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Table 1. Energy inputs (MJ/ac) for selected crops and tillage practices

	Cereals		Canola		Pulse		Rotation Alfalfa	
	Conv.	Zero	Conv.	Zero	Conv.	Zero	Conv.	Zero
Seed	100	80	13	10	80	71	8	8
Fuel	1309	717	1441	758	950	717	1110	846
Fertilizer	1448	1448	1404	1404	145	145	120	120
Herbicide	72	212	52	192	156	295	46	119
Machinery	402	235	423	263	314	235	161	117
Total	3331	2692	3333	2627	1920	1797	1445	1210

Values will differ from other studies, especially the energy for fertilizer. Studies that used the energy values reported in earlier studies, for example, will be about 40% higher those reported here. The energy reported by Natural Resources Canada[8] to produce nitrogen is 20.5 MJ/lb.