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FORAGE
TECHNICAL BULLETIN

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Impact of alfalfa and fertilizer on pastures: Energy Use Efficiency

Introduction

Fossil fuels provide energy to manufacture fertilizer, fuel, pesticides and other inputs used to produce agricultural products, but they also produce greenhouse gases responsible for climate change. In the past few decades, there has been significant growth in the use of non-renewable energy inputs for agricultural production. Agriculture is increasingly dependent on inorganic nitrogen fertilizers and fossil fuels. For example, on-farm fertilizer and fuel use represents more than 80% of the total energy inputs used in conventional grain production systems.

The efficiency of energy use in Western Canadian agriculture has decreased in recent years because the use of energy inputs is rising faster than crop yields. The optimal use of energy inputs through improved management practices can increase the profitability of agricultural production while promoting sustainable energy use.

Table 1. Pasture Types and Fertilizer Treatments used in the Study

1) Meadow bromegrass No added fertilizer	3) Meadow bromegrass + Alfalfa No added fertilizer
2) Meadow bromegrass + Fertilizer	4) Meadow bromegrass + Alfalfa + Fertilizer

Research Study

A ten-year grazing study was conducted at the Agriculture and Agri-Food Canada Brandon Research Centre from 1994-2004. The goal was to evaluate the efficiency of non-renewable energy use on four different pasture systems.

In the spring of 1994, pastures were established on a Souris fine sandy loam. The study used rotational grazing on four combinations of pasture type and fertilizer management. There were two different pasture types (100% grass or mixed alfalfa-grass) and two different fertilizer treatments (no fertilizer, or spring fertilization to full soil test recommendation levels). This resulted in a total of four treatments, shown in Table 1.

The grass-only pastures were seeded with 10 lb/acre 'Paddock' meadow bromegrass. The mixed alfalfa-grass pastures were seeded with 7 lb/acre 'Paddock' meadow bromegrass and 3 lb/acre 'Spredor II' alfalfa. Starting in 1995, fertilizer was surface-applied as a dry blend prior to grazing each spring. The concentration of each nutrient in the blend was based on soil samples collected the previous fall.

In order to evaluate the efficiency of non-renewable energy use of beef production in these four different pasture systems, both energy inputs and energy outputs were calculated. Energy inputs were determined from the non-renewable energy inputs into the grazing systems.

All direct and indirect non-renewable energy inputs used in the manufacturing, formulation, packaging,

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transportation, maintenance and application of all purchased inputs were included.

Direct energy inputs are those that can be easily converted into energy units; for example, the diesel fuel used to seed a pasture. Amounts of fuel and lubricants used by machinery were determined from the Saskatchewan Agriculture, Food and Rural Revitalization Farm Machinery Custom and Rental Rate Guide (2004 & 2007).

Indirect energy inputs are not as easily measured. For example, the energy required to manufacture the metal frame and rubber tires of the tractor used to seed the pasture is an indirect energy input.

The amounts of both the direct and indirect energy inputs used were calculated in Megajoules per acre (MJ/acre). As a comparison, burning one litre of gasoline produces approximately 40 MJ of energy. Table 2 shows the energy inputs that were included in the study as well as those that were not.

Energy outputs were determined from the energy retained in the beef produced by the cattle grazing the different pasture types.

Table 2. Energy Inputs included and not included in the Study

Energy inputs included	Energy inputs not included
• Fuel & lubricants • Machinery • Fertilizer • Pesticides • Infrastructure (fencing, corrals, water, etc.)	• Human labour (it accounts for less than 0.2% of the energy input in most cropping systems) • Plant nutrients removed from soil • Increases or decreases in soil organic matter • Energy captured directly from the sun by growing plants • Transportation and processing of crops beyond the farm • Heating and electricity for home/farm buildings • Seed (it was subtracted from harvested forage yield)

The use of non-renewable energy was measured in two different ways:

1. Total energy inputs per acre (MJ/acre)
2. Efficiency of non-renewable energy use. This is the energy output per MJ of non-renewable energy input used.

Study Results

Fertilizer Inputs

The average amount of fertilizer applied each spring to each pasture type is shown in Table 3. The amount of nitrogen (N) applied on fertilized grass-only pastures was three times higher than that applied on fertilized mixed alfalfa-grass pastures.

Table 3. Fertilizer Applied Annually to each Pasture Type, 10 year average

Pasture Management	N	P	K	S
	(lb/ac)			
Unfertilized grass-only	0	0	0	0
Unfertilized alfalfa-grass	0	0	0	0
Fertilized grass-only	99	26	23	7
Fertilized alfalfa-grass	32	30	20	11

Total Non-renewable Energy Inputs per Acre

Fertilizer, especially N fertilizer, accounts for a large amount of the total non-renewable energy input. Fertilizer was responsible for 93% of the total energy input for fertilized grass-only pastures and 75% for fertilized alfalfa-grass pastures.

Energy Use Efficiency

Figure 1 shows that the energy input per acre was highest for fertilized grass-only pastures, requiring more than 3700 MJ/acre. This is approximately equivalent to burning 96 litres of gasoline per acre (see Table 4). In comparison, the total energy input for both unfertilized pastures was very low, requiring about 200 MJ/acre, approximately equivalent to burning 5 litres of gasoline per acre.

Figure 2 shows the forage yield of the different pasture management strategies. Although fertilizing grass-only pastures doubled the forage yield compared with unfertilized grass-only pastures, it also required more than 20 times the energy input. Similar yield increases were also achieved in fertilized alfalfa-grass pastures; however, this required less than half the energy input required in fertilized grass-only pastures. Adding alfalfa without applying fertilizer also increased forage yield (by 55%), although the yield increase was less than that achieved by adding fertilizer to either grass-only or alfalfa-grass pastures. However, the unfertilized alfalfa-grass pastures required only a small increase in energy input (11%) compared to unfertilized grass-only pastures.

Efficiency of Non-renewable Energy Use

Another way of measuring non-renewable energy use is to calculate the ratio of energy output to energy input. This ratio shows how much energy is produced for every MJ of energy input. Higher ratios mean more energy is produced per MJ of energy input, resulting in a more efficient use of non-renewable energy.

Figure 3 (next page) shows the efficiency of energy use for the four pasture systems. The highest efficiency of energy use was calculated for unfertilized alfalfa-grass pastures, with 4.6 MJ of energy produced for every MJ of non-renewable energy input. The fertilized pastures had the lowest efficiency of energy use. Again, this is due to the high energy cost associated with the manufacturing of chemical fertilizers.

Figure 1. Energy Input and Output in MJ/acre (10 year average)

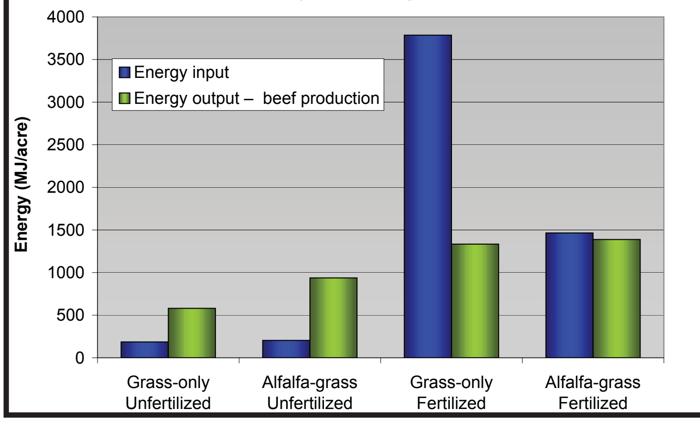
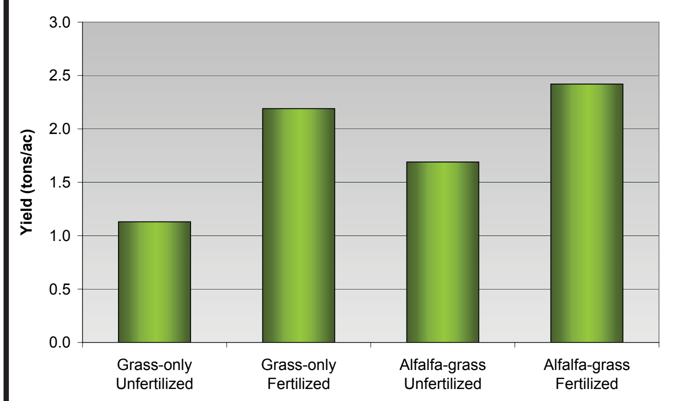


Table 4. Energy Input and Output in Equivalent Litres of Gasoline/acre (10-year average)

Pasture management	Energy input	Energy output – beef production
	(Litres of gasoline/acre*)	
Unfertilized grass-only	4.7	14.7
Unfertilized alfalfa-grass	5.2	23.7
Fertilized grass-only	95.6	33.7
Fertilized alfalfa-grass	37.0	35.0

*Gasoline contains approximately 39.6 MJ per litre.

Figure 2. Forage Yield (10 year Average)



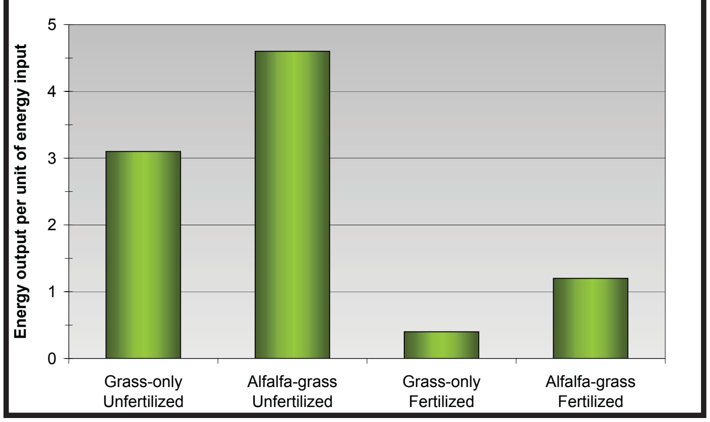
Energy Use Efficiency

Conclusion

The unfertilized grass-only pasture used the least amount of non-renewable energy. Improving grass-only pastures by adding fertilizer and/or alfalfa required additional non-renewable energy inputs; however, the additional energy required for unfertilized alfalfa-grass pastures was minimal compared to the fertilized pastures. In the fertilized pastures, N fertilizer accounted for most of the total energy input. Since there was no fertilizer applied to the unfertilized pastures, they required much less energy.

Of the four pasture management strategies, adding alfalfa to grass pastures without adding fertilizer had the highest efficiency of energy use. The unfertilized alfalfa-grass pasture was also the best choice in terms of net revenue (see the publication "Impact of Alfalfa and Fertilizer on Pastures: Economics"). Based on energy use and economic performance, the unfertilized alfalfa-grass pasture was the most efficient pasture system.

Figure 3. Efficiency of Non-Renewable Energy Use



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