Effects of Input Level and Crop Diversity on Energy Use Efficiency of Cropping Systems in the Dark Brown Soil Zone

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INTRODUCTION

Declining commodity prices coupled with rapidly rising input costs are causing many producers in western Canada to question the merits of conventional high-input agricultural production systems. In response, producers have become increasingly interested in extending and diversifying their cropping systems, and in adopting low-input and organic management practices. However, little is known about the impacts of these land use changes on the requirements for non-renewable energy inputs and energy use efficiency.

OBJECTIVES

To study non-renewable energy inputs, energy output, and energy use efficiency of nine cropping systems, representing three levels of input usage [high (recommended rates of inputs required), reduced (reduced use of pesticides, fertilizers and fuel), and organic (non-chemical pest control, legume green manure, and later seeding date)], and three levels of cropping diversity (low crop diversity, diversified annual grains, and diversified grain/forage). The paper draws on data from the first 6 years of a long-term field experiment being conducted in the Dark Brown soil zone at the Scott Experimental Farm.

MATERIALS AND METHODS

Experimental Data

- Initiated in 1995 in the Dark Brown soil zone at the Scott Experimental Farm.
- Data from the intial year (i.e. 1995) are excluded from the analysis because all crops were not yet in proper sequence and thus would not refelct the true treatment effects.
- Crop Rotations:

Crop diversity	Input level	Crop sequence[1]
LOW (low diversity of annual grains)	High	F_T-W-W-F_T-C-W
	Reduced	L_{GM}-W-W-F_C-C-W
	Organic	L_{GM}-W-W-L_{GM}-C-W
DAG (diversified using annual grains)	High	C-R-P-B_M-F_X-W
	Reduced	C-R-P-B_M-F_X-W
	Organic	L_{GM}-W-P-B_M/S_C-S_{CGM}-C
DAP (diversified using annual grains and perennial forages)	High	C-W-B_F-O/B_R&A-H-H
	Reduced	C-W-B_F-O/B_R&A-H-H
	Organic	C-W-B_F-O/B_R&A-H-H

[1] F_T = tillage fallow, W = wheat, C = canola, L_{GM} = lentil green manure, F_C = chemical fallow, P = field pea, B_M = malt barley, B_F = feed barley, S_C = sweet clover, S_{CGM} = sweet clover green manure, R = fall rye, F_X = flax, O = oats, B_R&A = bromegrass-alfalfa, and H = hay.

Energy Analysis

- All direct and indirect nonrenewable energy going into manufacture, formulation, packaging, transportation, maintenance and application of all inputs used in each production system were included.
- Energy output was taken as gross energy content (as measured by bomb calorimeter) of harvested grain less seed requirements.
- Energy use efficiency was calculated as: i) net energy produced (energy output minus energy input), and ii) ratio of energy output to energy input.

RESULTS AND DISCUSSION

Overall Annual Energy Performance

- Total annual production of each cropping systems varied greatly among years (Figure 1), reflecting the effects of growing season weather conditions on crop yields.
- Annual total production was greatest in 1996, 1999, and 2000 when growing season precipitation was above normal, and lowest in the drier years of 1997 and 1998.

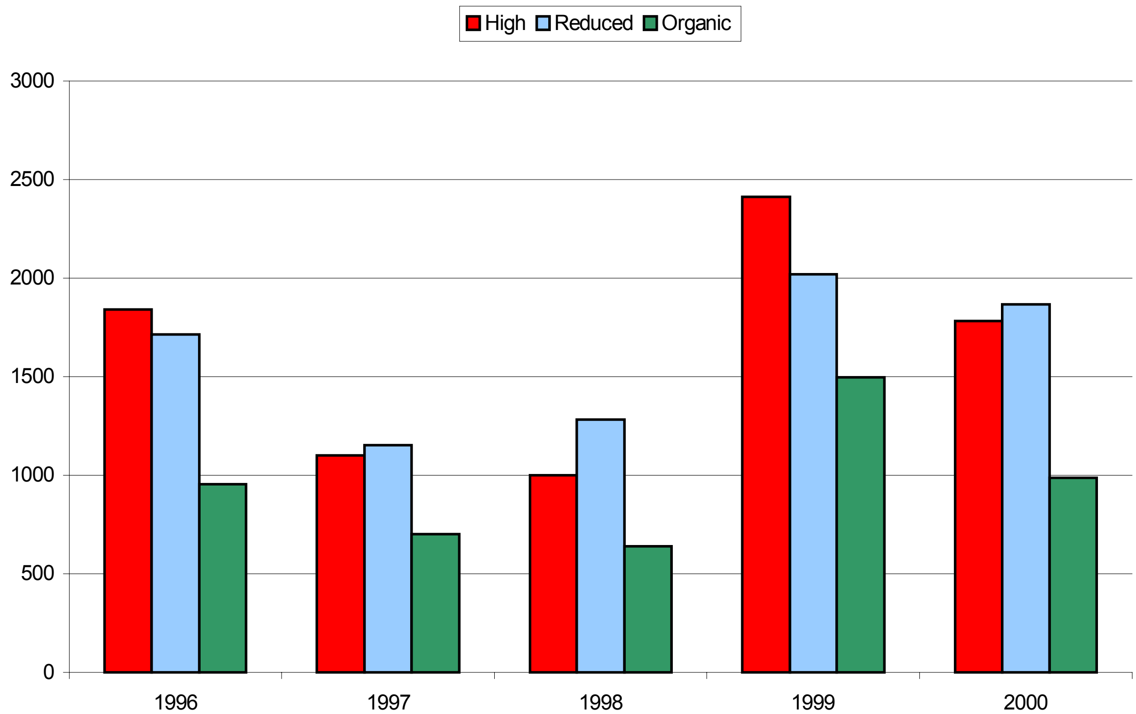


Figure 1. Average Annual Total Production

Overall Annual Energy Performance

- The energy performance of the production systems, differed greatly among years (Table 1).
- Gross energy output, net energy production, and energy output/input ratio were highest in 1996 and lowest in 1998.
- Total energy inputs were highest in 2000, intermediate in 1997 and generally similar from 1996, 1998, and 1999.

Table 1. Mean Annual Energy Performance (MJ ha^{-1})

Energy Parameter	1996	1997	1998	1999	2000
Gross Energy Output	35399	23396	17716	41689	30786
Total Energy Input	2739	2881	2627	2701	3903
Net Energy Production	32660	20515	15089	38988	26883
Energy Output/Input Ratio	12.9	8.1	6.7	15.4	7.9

Effect of Crop Diversity on Energy Performance

- Gross energy production ranged from 26621 MJ ha^{-1} for the DAP (with organic inputs) treatment to 59502 MJ ha^{-1} for DAG (with high inputs) (Table 2).
- Overall, gross energy output tended to be highest for DAG, intermediate for LOW (17% less) and lowest for DAP (33% less) treatments.

- Total energy input was highest for DAG, and lowest (and about equal) for DAP and LOW treatments(19% less).
- Net energy production displayed similar trends as for gross energy output.
- Energy output/input ratios were highest for DAG (with reduced inputs), and lowest for DAP (with high inputs).

Table 2. Effect of Crop Diversity and Input Level on Energy Performance (MJ ha^{-1})

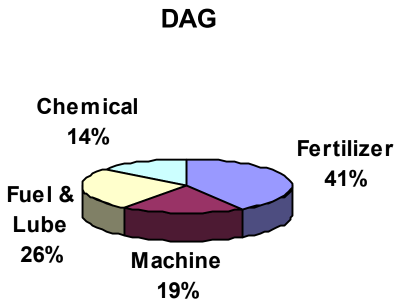
5-Year Average		Input Level			
Crop Diversity	**Energy Parameter**	**High**	**Reduced**	**Organic**	**Mean**
DAG	Gross Energy Output	59502	52854	37729	50028
	Total Energy Input	4145	3522	1635	3101
	Net Energy Production	55357	49332	36094	46928
	Energy Output/Input Ratio	17.8	15.3	21.5	16.1
DAP	Gross Energy Output	39726	34110	26621	33486
	Total Energy Input	2601	3403	1356	2453
	Net Energy Production	37125	30707	25265	31032
	Energy Output/Input Ratio	15.0	12.3	18.4	13.7
LOW	Gross Energy Output	52009	41819	30835	41554
	Total Energy Input	2658	3476	1514	2549
	Net Energy Production	49351	38343	29322	39005
	Energy Output/Input Ratio	16.6	8.7	19.5	16.3
Mean Gross Energy Output		50412	42928	31728	41689
Mean Total Energy Input		3135	3467	1501	2701
Mean Net Energy Production		47278	39460	30227	38988
Mean Energy Output/Input Ratio		16.0	12.4	21.1	15.4

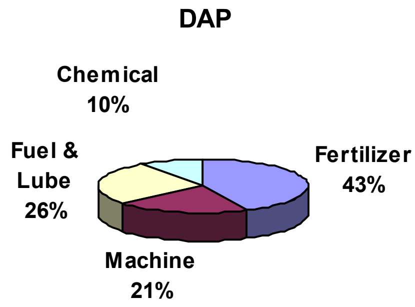
Effect of Input Level on Energy Performance

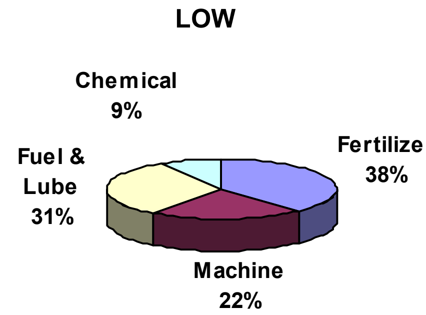
- Gross energy production tended to be highest for High Input, intermediate for Reduced Input (15% less) and lowest for Organic (37%) treatments.
- Non-renewable energy requirements were highest for High Input and Reduced Input treatments and lowest for Organic Input (about 50% less) treatments.
- The energy Output/Input Ratio tended to be highest for Organic Input treatments, intermediate for High Input (24% less) and lowest for Reduced Input (41% less)

Effect of Energy Inputs by Crop Diversity

- As expected, the majority of the energy inputs used consisted of fertilizer and fuels.
- These two categories comprised over two thirds of the total energy inputs for all three diversity treatments.
- Fixed machinery energy was the third highest energy input, accounting for 18% to 22% of total energy inputs.
- DAG required the greatest total energy input, followed by DAP and then LOW.

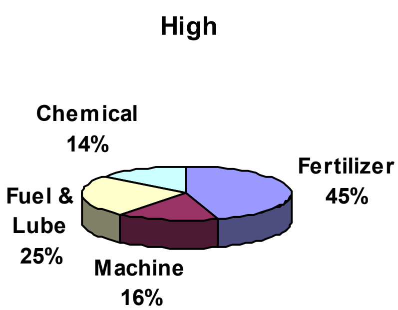


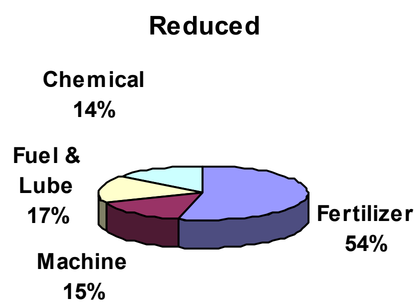


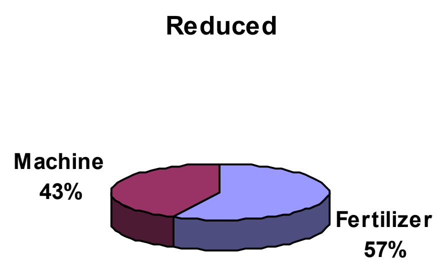


Effect of Energy Inputs by Input Level

- Non-renewable energy requirements were highest and similar for the High Input and Reduced Input treatments and lowest for the Organic Input treatment.
- Savings in energy requirements for fertilizer and chemical in the Organic Input treatments were off-set somewhat by higher energy requirements for fuel.
- Use of Reduced Inputs provided some savings in energy for fuels and lubricants. However, fertilizer energy requirements were higher in proportion to total energy use than in the High Input treatments.







CONCLUSIONS

- Fertilizers (primarily N) and fuel were the major non-renewable energy inputs to all treatments, except organic treatments where fuel alone was the major energy input.
- Gross and net energy production tended to be highest for DAG, intermediate for LOW, and lowest for DAP treatments.
- Gross energy production tended to be highest for High Input and Reduced Input treatments and lowest for Organic Input treatments.
- The use of Organic Input levels showed potential to reduce total energy inputs by up to 50% compared to High Input and Reduced Input treatments.
- Non-renewable energy use efficiency was highest with Organic Input management.

ACKNOWLEDGMENT

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