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Determining Optimal Removal Rate and Regional Supply of Corn Stover in Ontario, Canada

Jianbang Gan[1], Charles Lalonde[2], Maria Wellisch[3], Tat Smith[4], Craig Drury[5], Jingyi Yang[5]

1 Department of Ecosystem Science and Management, Texas A&M University (USA)
2 Agren Consulting (Canada)
3 Strategic Policy Branch; Agriculture and Agri-Food Canada (Canada)
4 University of Toronto (Canada)
5 Agriculture and Agri-Food Canada (Canada)

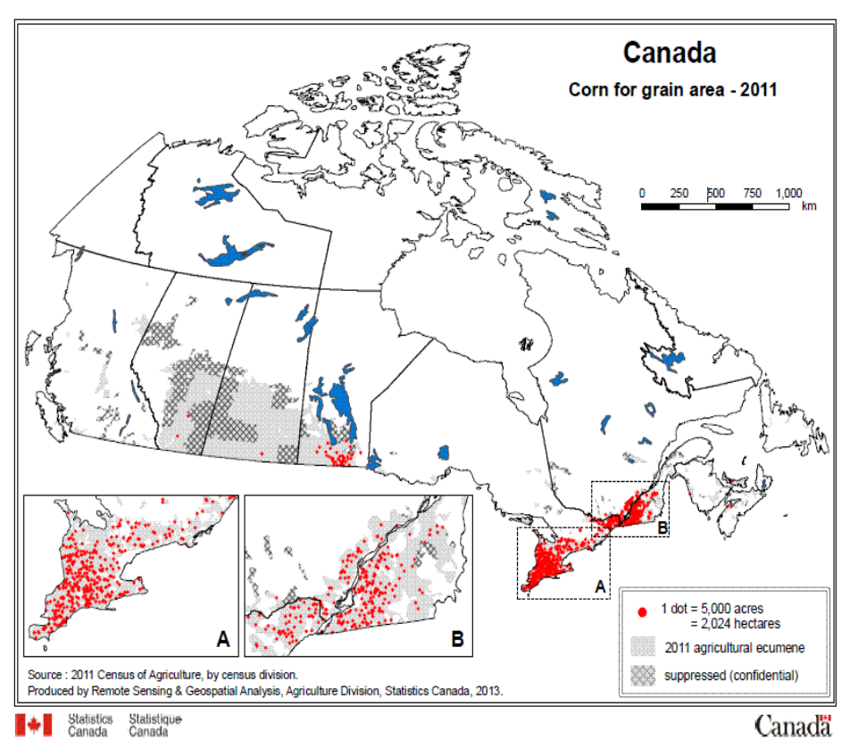
Introduction

Southwestern Ontario has a concentrated regional capacity in six counties to produce corn at high yields (> 150 bushels per acre) and hence the ability to supply significant volumes of corn stover to support bioenergy, biofuels, biochemicals and other bioproduct uses.

A cellulosic sugar plant has been under consideration in this region (Fig 1) that would require a consistent and sustainable supply of 250,000 to 300,000 dry metric tonnes of cellulosic material annually.

Agriculture producers are interested in partial residue collection if it is sufficiently profitable and does not reduce soil productivity. Using the best available information from the region and an econometric model developed at Texas A&M, this analysis aims to determine the optimal rate of stover removal considering both economic and environmental consequences.

Preliminary results using conservative consumptions are presented here, and indicate the lower limit of corn stover removal. This work is referred to in the Agriculture Residues case of the IEA Bioenergy Intertask Study Mobilizing Sustainable Biomass Feedstock Chains.



Materials & Methods

A farm-level decision-making model developed by Gan et al. (2011) described in the equations below was used to determine optimal stover removal. The analysis assumes that individual producers seek to maximize harvest levels and thus maximize profitability.

Profitability is determined by subtracting harvest and baling costs, nutrient loss and future yield loss due to declining soil health (loss of soil organic carbon and soil physical degradation) and increased soil erosion from the additional farm gate income received from the sale of the stover.

According to Gan et al. (2011), the farmer's decision on stover harvest can be portrayed in the following equations:

$$\boldsymbol{Max\ \pi = p_s x - C(x) - \sum_f p_f \beta_f x - V[E(x)]} \quad (1)$$

$$\boldsymbol{s.t.\ 0 \le x \le x_{max}.} \quad (2)$$

where,

π	is the profit obtained from stover production;
x	is the stover removal rate;
xmax	is the maximum amount of corn stover physically available or removable by the harvesting devices;
ps	is the farm gate price of stover;
C(x)	is the cost of stover harvesting;
f	indicates nutrient type (N, P, and K);
βf	is the concentration of nutrient type f in the stover;
pf	is the price of nutrient type f;
E(x)	is the soil erosion resulting from removing an x amount of stover; and
v[E(x)]	is the annual equivalent value of soil loss caused by removing an x amount of stover.

Results

The preliminary results plotted in Figure 2 for the Brookston soil type under conventional tillage (fall plowing followed by tillage) and assuming a 1% discount rate, show the marginal cost to increase dramatically as corn stover removal rates exceed 25%. Below this rate, the cost of nutrient replacement and stover collection and baling predominate. Above this rate, economic losses due to soil erosion increase dramatically.

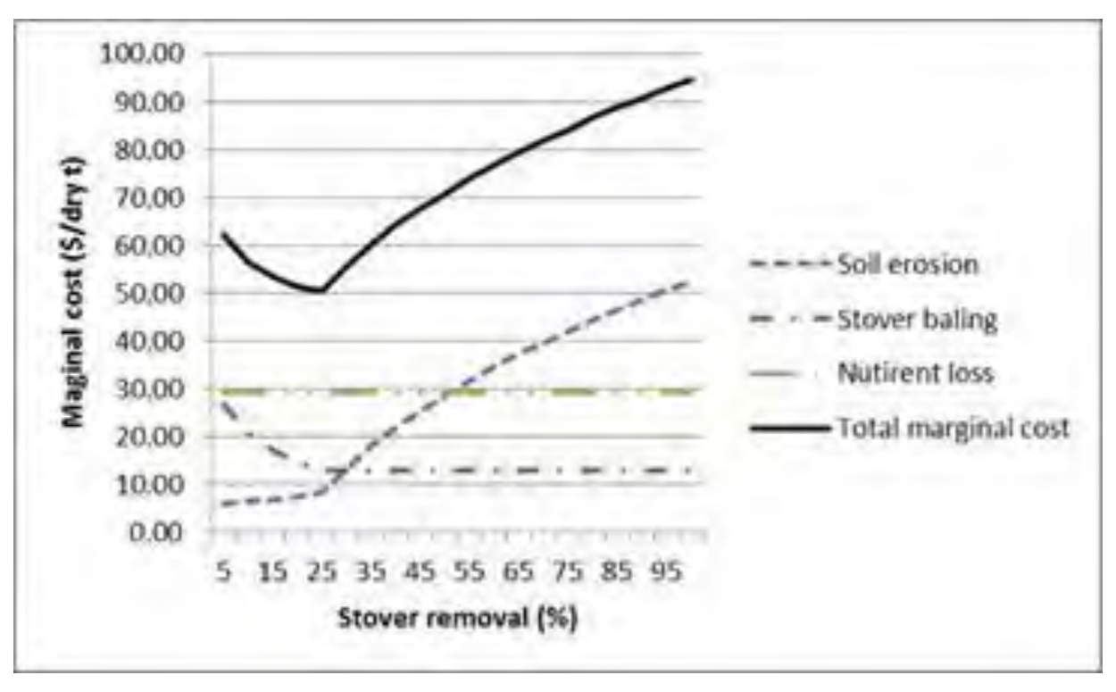
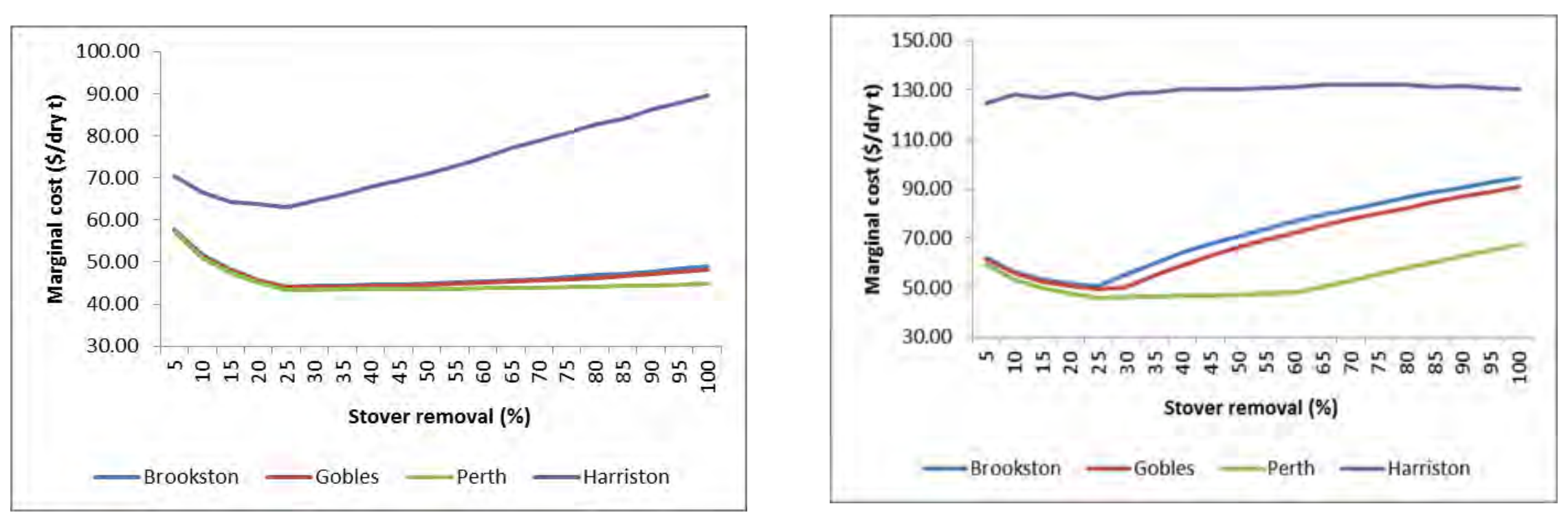


Figure 2: Marginal Costs of Corn Stover Supply from Brookston Soils under Conventional Tillage

Shown in Fig 3 are the marginal costs of corn stover removal for the four major soil types under conventional tillage. The lowest marginal cost occurs at approximately 25% of stover removal rate for all the four soil types. This removal rate coincides with earlier work (Oo and Lalonde, 2012) that assumed sustainable removal rates in this region to lie between 25 and 33%. The marginal costs are highly sensitive to assumed discount rates, which reflect the farmer's time preference of economic benefits and costs. The highest costs are shown for Harrison soil which is the fine silt loam, most susceptible to erosion losses.



Discount rate = 3%

Discount rate = 1%

Figure 3: Marginal Cost of Corn Stover Removal assuming (a) 3% discount rate and (b) 1% discount rate.

The corn stover supply curves for the six counties in Ontario are presented in Figure 4. The quantity of stover that can be supplied from the region varies with stover price and the assumed discount rate. At a 1% discount rate, no stover would be harvested if the stover farm gate price is below US$45/dry tonne. Whereas at 3%, the farm gate price would have to be at least US $ 45/dry tonne, Over time, discount rates are expected to vary, hence the analysis presents two possible scenarios. In both cases, at least 500,000 dry metric tonnes could be collected annually at feedstock costs below US$50/dry tonnes stover at the farm gate.

In terms of maximum availability, over 2 million dry tonnes could be harvested from this area at 32% +/- 5% removal rates. However the farm gate feedstock cost would range from 45 to 75 US$/dry t.

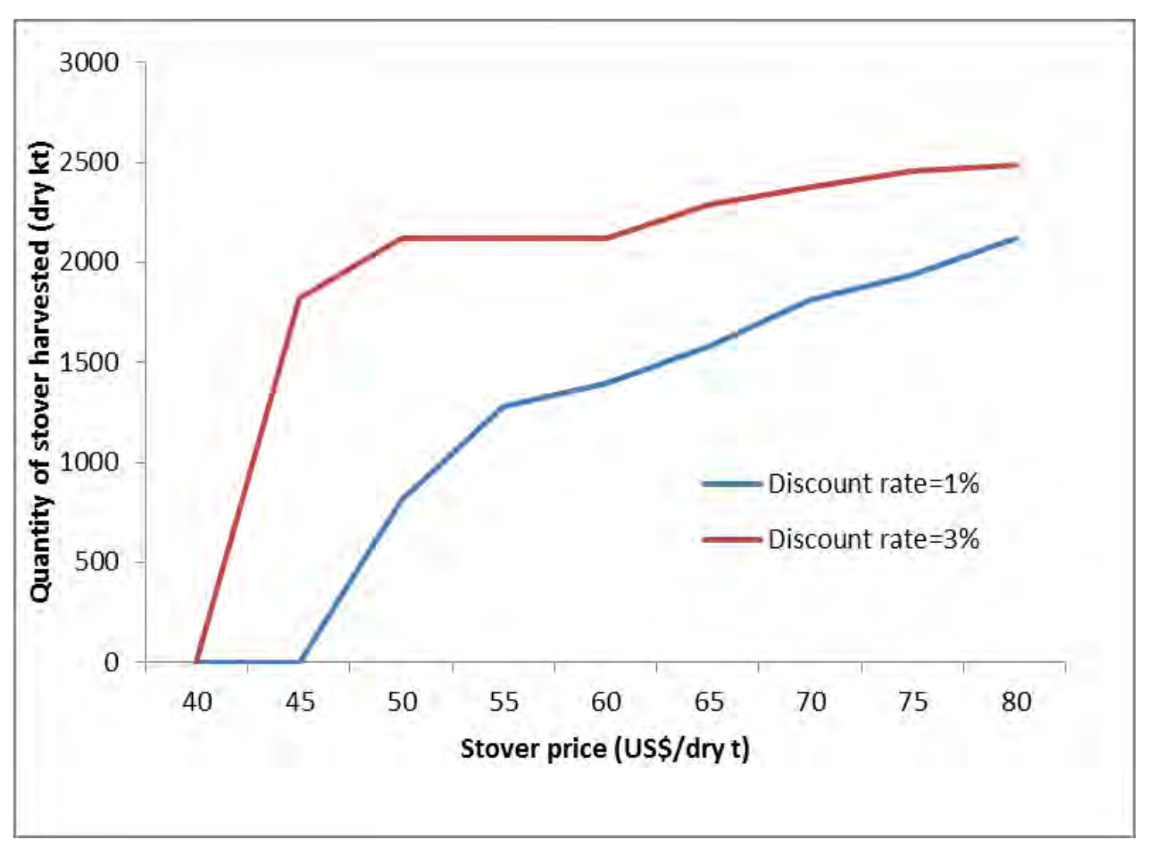


Figure 4. The relationship between the quantity of stover harvested and stover price at a 1% and a 3% discount rate.

Future Research

No till and minimum tillage scenarios by crop rotations should be analyzed as they are already being practiced in the region, as well as management practices such as the use of cover crops. Additional research addressing both production and environmental factors is required to obtain field data to match specific crop rotations to the region, tillage practices and harvesting protocols to support further analysis. Other common rotations (such as corn-soy-winter wheat) used by producers in this area should also be modelled.

Besides soil erosion, stover removal can affect other soil physical and chemical properties such as soil moisture and soil compaction that can also effect crop yield in both positive and negative manner. On the other hand, stover removal can improve yields of the following crops as stover removal can facilitate early planting and emergence. These impacts were not included in this assessment but are highly recommended for future research.

Conclusions

This modeling work has shown the importance of soil type and management practice to prevent soil degradation and soil erosion on the profitability and optimal stover removal rate. One of the four soil types studied (Harriston) showed a high vulnerability to erosion and associated economic losses under conventional tillage practices. Specific harvesting protocols need to be developed for the predominant soil types in a region and the different tillage practices and stover removal techniques. This work confirms the importance of stover (and other crop residue) harvesting to be based on enforceable protocols. This would provide assurances to both agriculture producers and downstream processors of the availability of a consistent and sustainable supply of stover that does not have negative financial or environmental impacts over the long term.

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