Biomass producer decision making: direct and indirect transfers in different spheres of interaction

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Outline

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- Objectives
- Approaches
  - Conceptual framework
  - Case study: Corn stover for ethanol in Iowa, USA
- Key findings
- Summary

Motivation

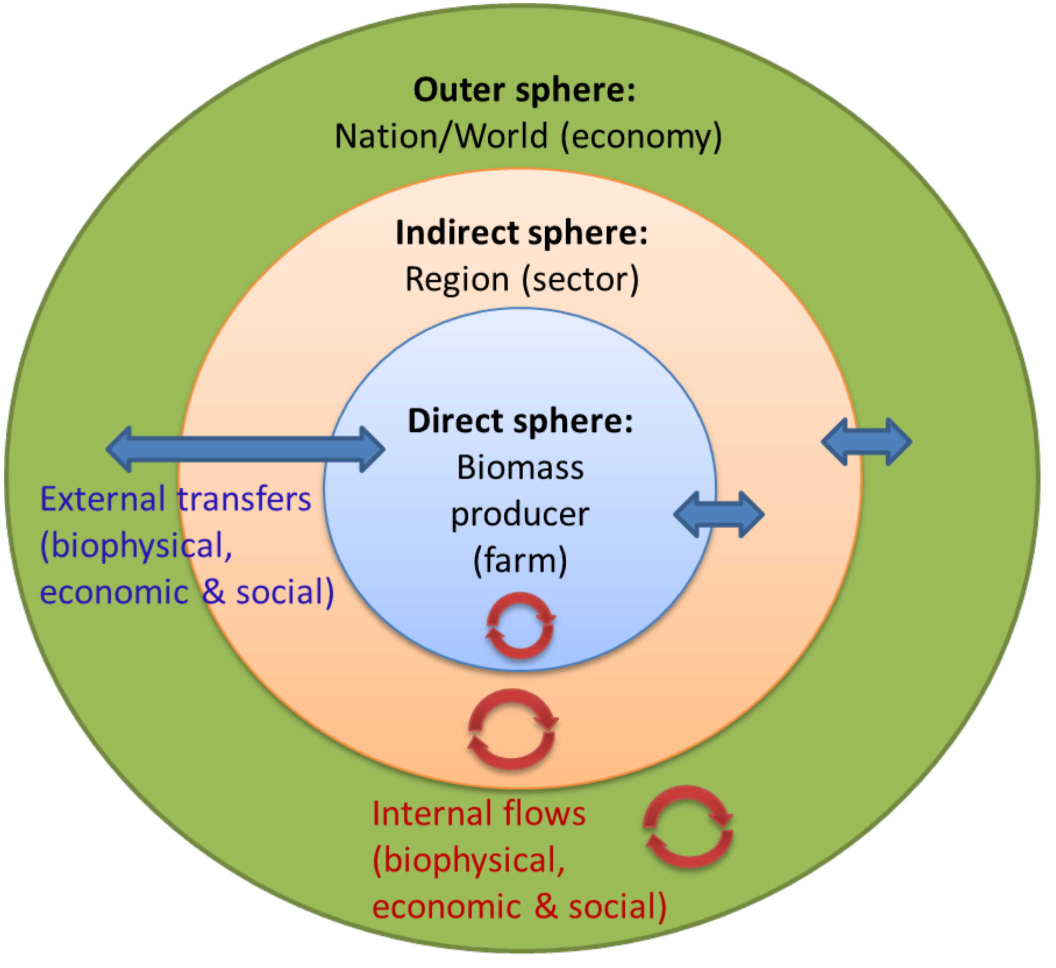
- Inconsistency between the boundaries defining an agent's decision space and consequence space
- Interest of stakeholders in various scopes of impacts
- Needs for more comprehensive assessments of impacts

Objectives

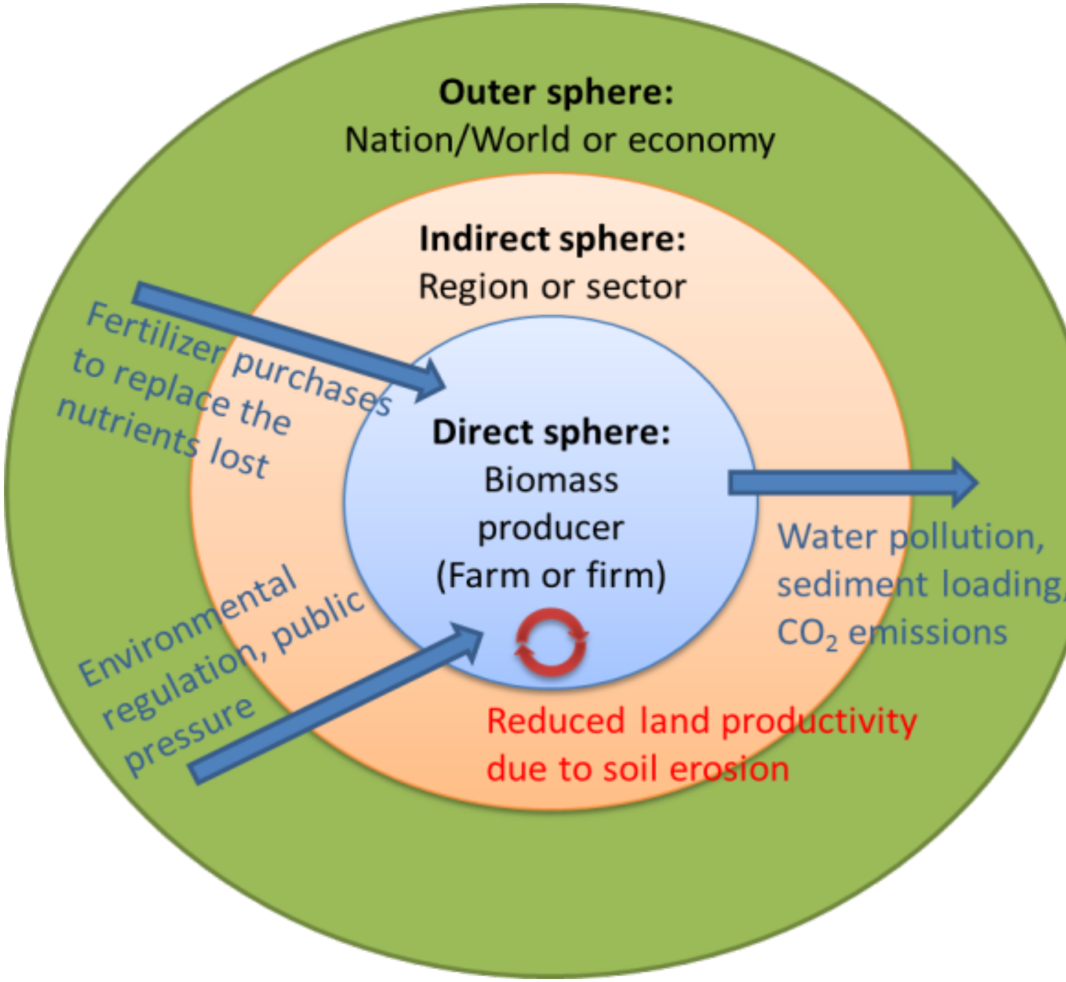
- To develop a conceptual framework for measuring direct and indirect impacts of biomass and bioenergy development
- To apply the framework to a case study to illustration its applicability and identify ways for improvement

Approaches

Conceptual framework

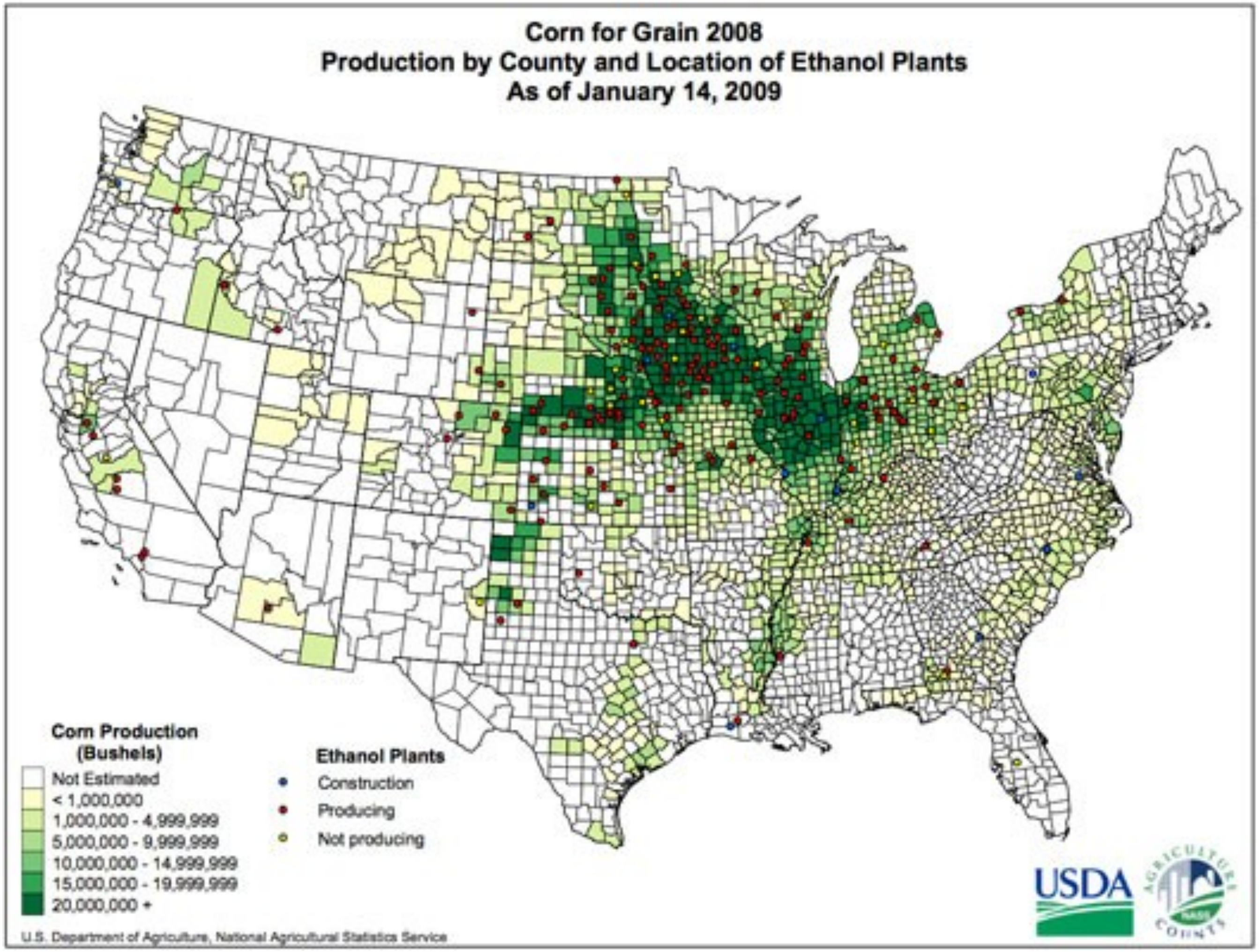


Example: Soil erosion caused by residue removals

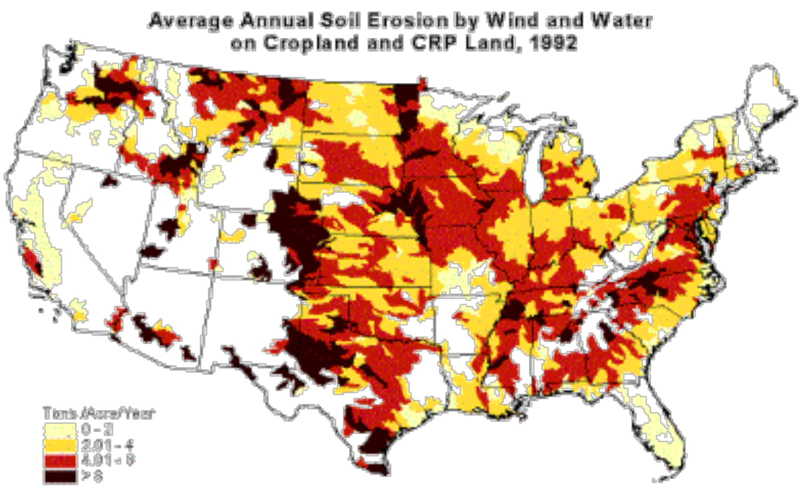


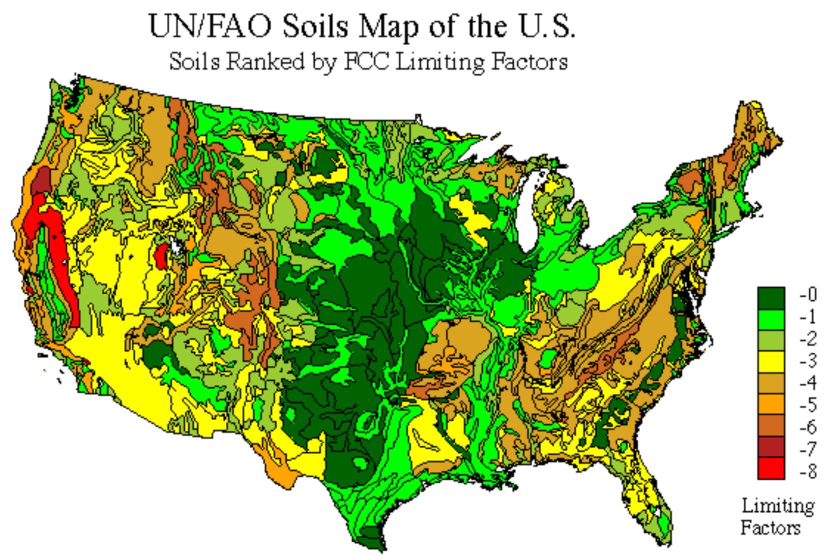
Study case

- LIBERTY project: corn stover ethanol plant in Palo Alto County, located in Northwest Iowa (in the heart of the corn belt), USA.



Soil erosion risk and limiting factors





Profit-maximizing farmer

$$Max\ \pi_l = p_s x - C(x) - \sum_f p_f \beta_f x - V[E(x)]$$

$$s.t.\ \ 0 \leq x \leq x_{max}$$

Profit = revenue from stover sale

- cost of stover harvesting
- cost of nutrient loss associated with stover removal
- cost of increased soil erosion due to stover removal

Optimal stover removal & value to the direct sphere

Optimality condition:

$$p_s = C'(x) + \sum_f p_f \beta_f + V'[E(x)]$$

Marginal revenue = Marginal cost

V_d (value to the direct sphere) = $p_s x^*$

Ethanol production cost & value to the indirect sphere

Minimum possible production cost (Gan and Smith 2010 & 2011):

$$TC^* = \frac{3-2\alpha}{1-\alpha}\left\{\frac{\left[1.76c_h\tau(1+\lambda)\sqrt{\frac{n\theta S_o}{M\phi\eta^3}}\right]^{2(\alpha-1)}}{(1-\alpha)CC_o}\right\}^{\frac{1}{2\alpha-3}} + \frac{p_s}{\eta}$$

V_i (value to the indirect sphere) = TC^*

(assume the ethanol industry is break-even or earns a zero profit in the long run)

Value to the outer sphere

Focus on two important & measurable values:

GHG offsets:

- LCA using GREET
- GHG price

National energy (oil) security premium:

- Estimated based on Leiby 2007, Delucchi & Murphy 2008, Brown & Huntington 2010

Defining multipliers

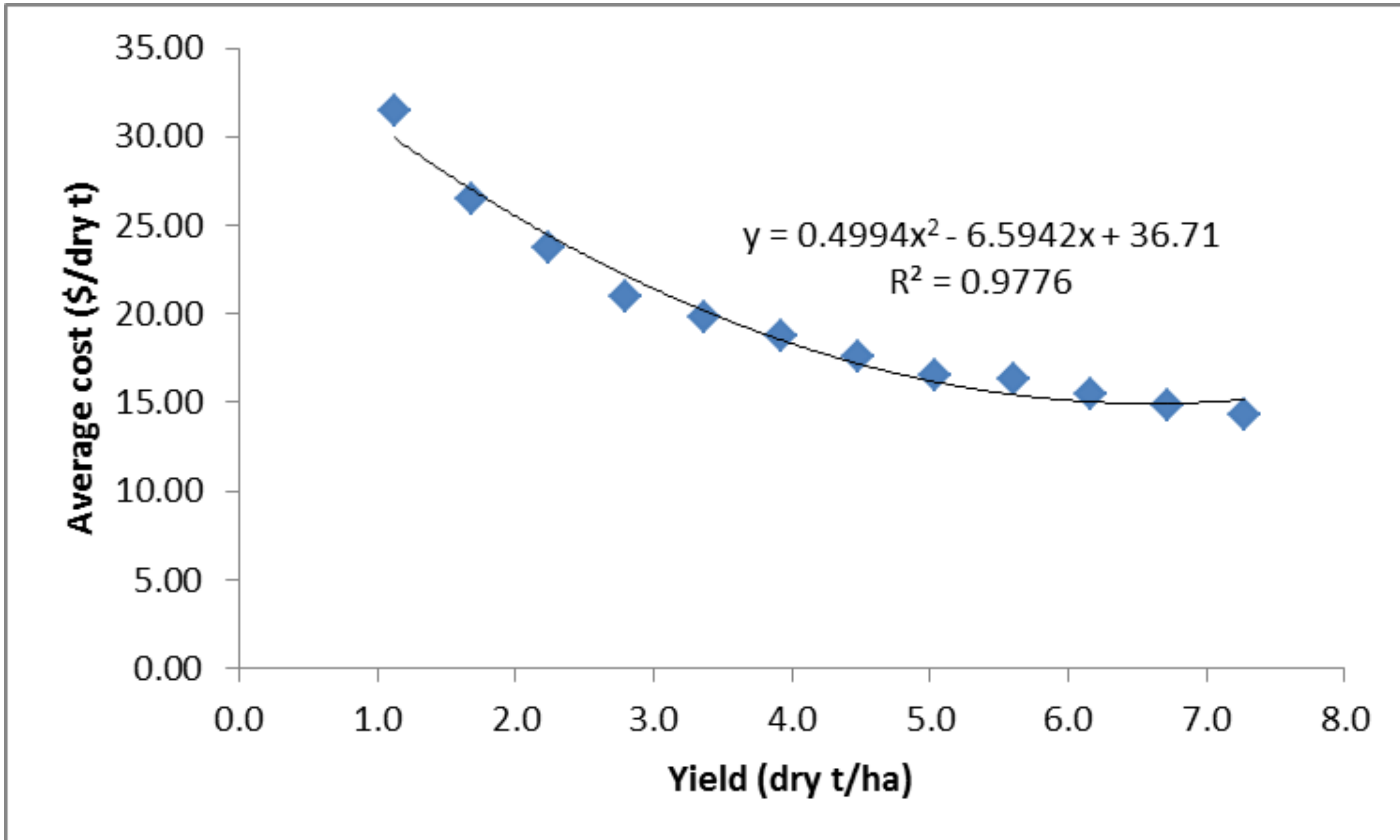
$$Multiplier\ I = V_d + V_i\ / V_d$$

$$Multiplier\ II = V_d + V_i + V_o\ / V_d$$

Subscript indicates *d*irect, *i*ndirect and *o*uter spaces for the measurement V.

Key findings

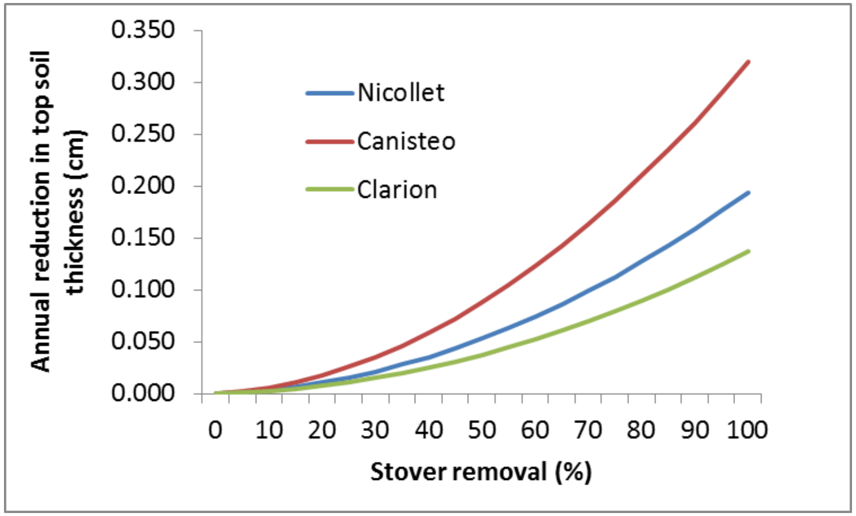
Stover harvesting cost

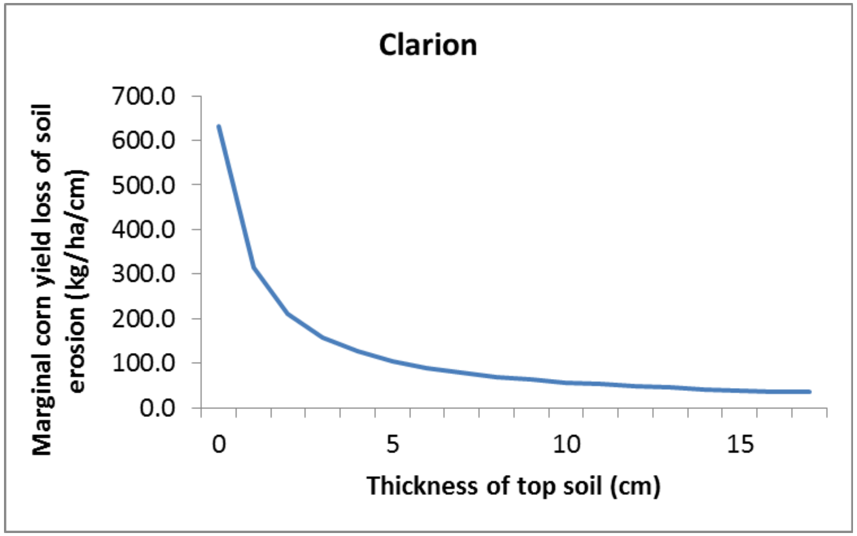


Stover removal, top soil loss, & crop yield

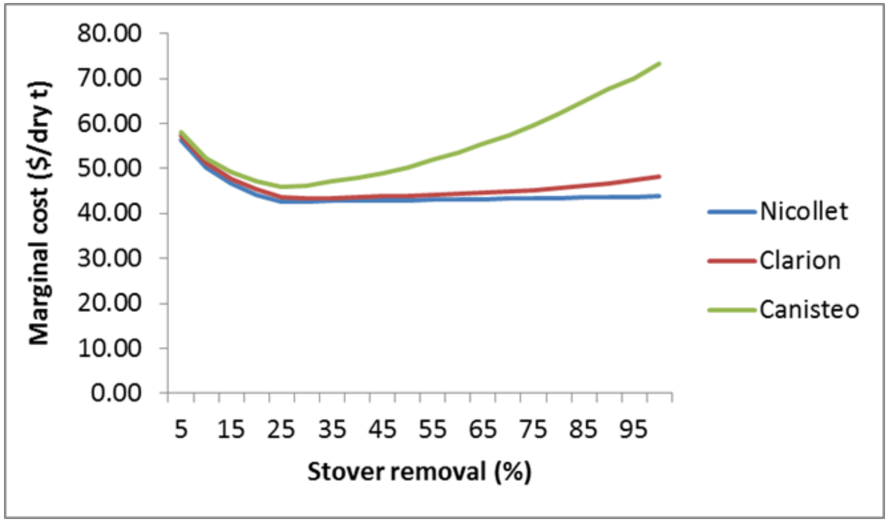
Top soil loss vs. stover removal intensity

Crop yield vs. top soil thickness





Total marginal cost of stover removal



- Marginal cost decreases first and then increases as more stover is removed.
- Soil conditions are a critical factor for determining stover removal intensity.
- For the study case, stover removals from Nicollet and Clarion soil series do not seem to be a problem, yet stover removals from Canisteo should be cautious or prevented.

GHG offsets & energy security premium

GHG offsets:

2.17 kg CO_2-e L^{-1} ethanol

National energy security premium:

US$0.13 L^{-1} ethanol

Multipliers of producing ethanol from corn stover in Palo Alto County, Iowa, USA

Sphere	Value ($ L^{-1})	Multiplier I	Multiplier II
Direct sphere (Farm)	0.19		
Indirect sphere (Region)	0.42	3.23	
Public sphere (Nation)			
Energy security premium	0.13		
GHG offset value @ following CO_2 price (US$ t^{-1})			
5	0.01		3.99
10	0.02		4.05
15	0.03		4.11
20	0.04		4.16
25	0.05		4.22

Summary

Summary

- An increase in stover removal intensity reduces biomass procurement cost, yet increases soil erosion risk.
- Distributional effects of producing biofuels from corn stover vary across stakeholders.
- High multipliers suggest that producing ethanol from corn stover in the study region would benefit stakeholders in the indirect and outer spheres more than corn farmers.
- Multiplier II is sensitive to energy security premium and GHG price.

Implications

- The amount of stover actually supplied could differ significantly from the amount physically available given the indirect costs/benefits considered by stover producers.

- Incentives to stover producers are recommended given the benefits accrued to the indirect and outer spheres.

- Availability of other energy sources (e.g. shale gas) could affect GHG emissions and energy security concerns, thus changing the multiplier values.

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