A CARBON BUDGET TO ESTIMATE SOIL CARBON SEQUESTRATION POTENTIAL FOR SUGARBEET PRODUCTION

L.F. Overstreet
North Dakota State University, Soil Science Dept.

INTRODUCTION

Sugarbeet production can sequester carbon (C) in intermediate- and long-term pools as soil organic matter, soil inorganic matter, and sugar products. Reducing fossil fuel combustion and slowing the rate of organic matter decomposition will also slow the rate of atmospheric CO_2 concentration increase.

The purpose of this work was to identify and quantify potential C credits resulting from sugarbeet production that can offset C emissions from sugar factories.

Management practices considered as variables in this project were *tillage*, *lime application*, and *cover crop production*. Estimates of C emission to the atmosphere and C addition to the soil were based on data from peer-reviewed sources, research data, and records from sugar cooperatives.

Carbon emissions from the following sources were included in the C audit:

- Soil respiration
- CO_2 off-gassed following tillage
- Fertilizer and lime production
- Operations related to tillage, fertilization, and lime application

METHODOLOGY

An estimate of potential carbon sequestration for sugarbeet production was determined using a simple set of summation equations (Eq. 1-3) for all permutations of tillage, cover crop, and liming scenarios considered.

$$\text{Potentially Sequestered C (PSC)} = C_{orgC} + C_{lime} - C_{atm} \quad (1)$$

C_{orgC} is C added to soil as organic C. C_{lime} is C added to soil as sugar factory spent lime. C_{atm} is C lost to the atmosphere as CO_2. C_{orgC} includes C removed from soil with the harvested sugarbeet roots (C_{harv}). The value for C_{harv} is 6245 kg C/ha.

$$C_{orgC} = C_{gpp} + C_{urea} \quad (2)$$

C_{gpp} is Gross Primary Production and C_{urea} is C added to soil as urea fertilizer. Urea is a nitrogen (N) fertilizer source containing 20% C.

$$C_{atm} = C_{mach+prod} + C_{off\text{-}gas} + C_{resp} + C_{lime\ ox} \quad (3)$$

$C_{mach+prod}$ is C evolved as CO_2 during operation of equipment & production of agricultural inputs. $C_{off\text{-}gas}$ is C emissions released from soil as a flush of CO_2 immediately following tillage. C_{resp} is C removed from soil as a result of root & microbial respiration in the form of CO_2. The C_{resp} value consists of respiration by soil microorganisms, animals, & plant roots. The derivation of this value is derived from the exponential equation of Lloyd & Taylor (1994). $C_{lime\ ox}$ is a fraction of total C applied as lime lost from soil due to lime oxidation.

The tillage practices compared in this study are conventional tillage (two fall chisel plow operations and two spring cultivator operations) and fall strip tillage. C_{urea} and C_{lime} are assumed not to change as a result of different tillage systems. The following parameters are assumed to differ as a result of different tillage systems: $C_{mach+prod}$, $C_{off\text{-}gas}$, C_{resp}, $C_{lime\ ox}$. The C_{gpp} value increases for scenarios that include cover crops.

RESULTS

Total C input to the conventional sugarbeet production system is estimated to be 14,196 kg C ha^{-1} (Table 2). Carbon from harvested tap root accounts for 44% of total C inputs. The remaining 7,950 kg C ha^{-1} is sugarbeet photosynthate C plus a small amount from urea fertilizer application. An additional net 103 kg C ha^{-1} is added to soil in stable pools by applying sugarbeet factory spent lime in conventional tillage systems. Incorporating a rye cover crop provides an additional 278 kg C ha^{-1}, not considering C losses from additional respiration or planting operations. When tillage and fertilization requirements are reduced and SOM is protected in a strip tillage system, C emissions are estimated to be 9.5% less than in conventional tillage systems.

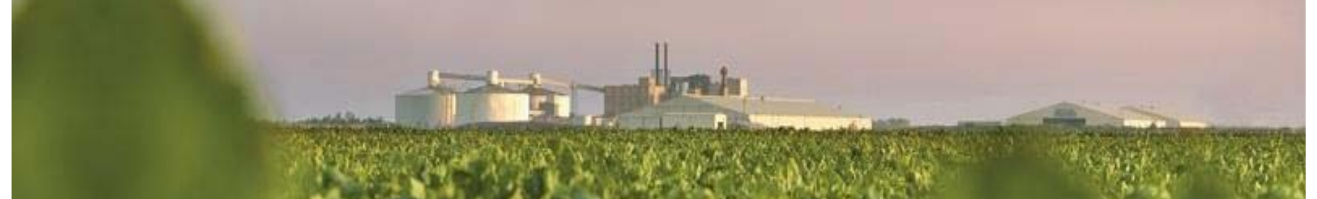
Table 1. Potentially sequestered carbon (PSC) for different agricultural management scenarios. CT = conventional tillage; ST = strip tillage.

Tillage	Lime?	Cover Crop?	**PSC** kg C ha^{-1}	**PSC** (w/o root) kg C ha^{-1}
CT	No	No	4638.5	-1606.6
ST	No	No	5090.2	-1154.9
CT	Yes	No	4741.8	-1503.3
CT	No	Yes	4916.7	-1328.4
CT	Yes	Yes	5020.0	-1225.1
ST	Yes	No	5205.0	-1040.1

DATA & SOURCES

Table 2. Sugarbeet production carbon inputs to soil. CT = conventional tillage; ST = strip tillage; CC = fall rye cover crop; LIME = sugar factory spent lime application; GPP =gross primary productivity

C Source	Scenario	C Addition (kg C ha^{-1} yr^{-1})	Source of Information	Notes
GPP	CT, ST, LIME	14,160	Aubinet et al. 2009	
RYE COVER	CC	278.2	Kuo et al. 2007	Seeding rate in RRV is only 11% of Kuo et al. C add'n value for rye cover det'd rom 11% of Kuo et al. value.
UREA	ALL	35.4		Assumes 177 kg urea ha^{-1} app rate @ 20% C content
LIME	LIME	229.6		Assumes 22.4 Mg ha^{-1} (wet wt) app rate every 4 years. Total C value divided by 4.



American Crystal Sugar Company
Factory and Sugarbeet Field
Drayton, ND

Table 3. Sugarbeet production carbon losses from soil. CT = conventional tillage; ST = strip tillage; LIME = sugar factory spent lime application

SOURCE	SCENARIO	C EMISSIONS (kg C ha^{-1} yr^{-1})	SOURCE OF INFORMATION	NOTES
Chisel Plow	CT	14.9	Downs & Hanson 1998; EPA Emissions Facts 2005	Assumes 2 passes ha^{-1}
Field Cultivator	CT	8.14	Downs & Hanson 1998; EPA Emissions Facts 2005	Assumes 2 passes ha^{-1}
Fertilizer App.	CT	1.2	Griffith & Parsons 1983; EPA Emissions Facts 2005	Assumes all fert. applied together
Strip Tiller	ST	13.6	Schaefer 2007; EPA Emissions Facts 2005	Assumes 1 pass ha^{-1}; also applies fert.
Lime App.	ALL	0.3		Assumes 1 pass ha^{-1}; value divided by 4 for per year basis
N Fert Prod'n	ALL	69.8	West & Marland 2002, Table 3	Assumes 177 kg urea ha^{-1} app rate
P Fert Prod'n	CT	6.9	West & Marland 2002, Table 3	Assumes 41 kg P_20_5 ha^{-1} app rate
P Fert Prod'n	ST	5.5	West & Marland 2002, Table 3	Assumes 20% reduction in P rate for band app w/ strip tiller
K Fert Prod'n	CT	1.1	West & Marland 2002, Table 3	Assumes 9.5 kg K_20 ha^{-1} app rate
K Fert Prod'n	ST	0.9	West & Marland 2002, Table 3	Assumes 20% reduction in K rate for band app w/ strip tiller
Lime Prod'n	LIME	41.4	West & Marland 2002, Table 3	Assumes 22.4 Mg ha^{-1} (wet wt) app rate every 4 years. Total C value divided by 4.
Lime Oxidation	LIME CT	126.6	Hamilton et al. 2007; West and McBride 2005	Assumes 55% of C oxidizes; lime is 9.1% C
Lime Oxidation	LIME ST	115.4	Hamilton et al. 2007; West and McBride 2005	Assumes 50% of C oxidizes; lime is 9.1% C
Soil Respiration	CT	9297.1	Lloyd & Taylor 1994 ; Moureaux et al. 2006;	
Soil Respiration	ST	8997.0	Lloyd & Taylor 1994; Moureaux et al. 2006; Overstreet unpublished	
C Off-Gassing	CT	31.8	Curtin et al. 2000; Fortin et al. 1996 ; Ellert & Janzen 1999	Curtin et al. was primary source. Other papers used for corroboration
C Off-Gassing	ST	3.6	Curtin et al. 2000; Fortin et al. 1996 ; Ellert & Janzen 1999	

American Crystal Sugar Company
Factory and Sugarbeet Field
Drayton, ND

CONCLUSIONS

The results of this analysis indicate that sugarbeet production does store C in stable pools over intermediate to long time periods.

This study also indicates that sequestration of soil C can be enhanced in sugarbeet production systems by adopting management practices such as strip tillage, lime application, and cover cropping.

Treatment of the harvested crop material is an important consideration for carbon audits such as this and will also have critical repercussions for agricultural commodities if carbon tax legislation is implemented.

References

Aubinet, M. C. Moureaux, B. Bodson, D. Dufranne, B. Heinesch, M. Suleau, F. Vancutsem, A. Vilret. 2009. Carbon sequestration by a crop over a 4-year sugar beet/winter wheat/seed potato/winter wheat rotation cycle. Agric. Forest Meterol. 149: 407-418.

Downs, H.W. and R.W. Hansen. 1998. Estimating Farm Fuel Requirements. Colorado State Univ. Extension Bulletin no. 5.006. Available online: http://www.ext.colostate.edu/PUBS/FARMMGT/05006.html

EPA Emissions Facts. Feb. 2005. *Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel* (EPA420-F-05-001)

Griffith, D.R. and S.D. Parsons. 1983. Energy Requirements for Various Tillage-Planting Systems. Purdue University Extension Bulletin NCR-202-W.

Hamilton, S.K.; A.L. Kurzman, C. Arango, L. Jin, and G.P. Robertson. 2007. Evidence of carbon sequestration by agricultural liming. Global Biogeochem. Cycles, 21, GB2021

Schaefer, G.M. 2007. Energy Conservation on Irrigated land in Eastern Montana. USDA-NRCS Economics Technical Note No. MT-9

Kuo, S.; U.M. Sainju, E.J. Jellum. 1997. Winter cover crop effects on soil organic carbon and carbohydrate in soil. Soil Sci. Soc. Am. J. 61: 145-152.

Lloyd, J. and J.A. Taylor. 1994. On the temperature dependence of soil respiration. Funct. Ecol. 8: 315-323.

Moureaux, C.; A. Debacq, B. Bodson, B. Heinesch, and M. Aubinet. 2006. Annual net ecosystem carbon exchange by a sugar beet crop. Agric. Forest Meteorol. 139: 25-39.

West, T.O. and G. Marland. 2002. A synthesis of carbon sequestration, carbon emissions, and net carbon flux in agriculture: Comparing tillage practices in the United States. Ag Ecosys. Environ 91: 217-232.

West, T.O. and A.C. McBride. 2005. The contribution of agricultural lime to carbon dioxide emissions in the United States: dissolution, transport, and net emissions. Ag. Ecosys. Environ, 108: 145-154.

NDSU

Acknowledgement: Funding for this project was provided by American Crystal Sugar Co., Minn-Dak Farmers Cooperative, and Southern Minnesota Beet Sugar Cooperative