Corn carbon budgets: Use of “discretionary carbon”

Mike Edgerton
Biomass 2010
March 31st, 2010

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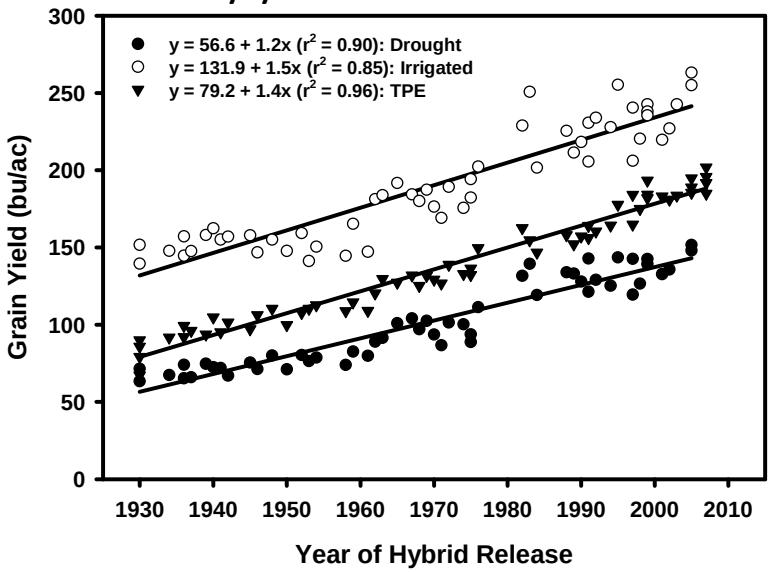
As grain yields increase crop residue is increasing

Yield of Pioneer Hi-Bred hybrids by year of introduction



Duvick et al (2004), Cooper (2009)

- Breeders are continuing to increase crop yield potential
- Residue management is becoming increasingly expensive

Van Horne, IA November 7th 2009

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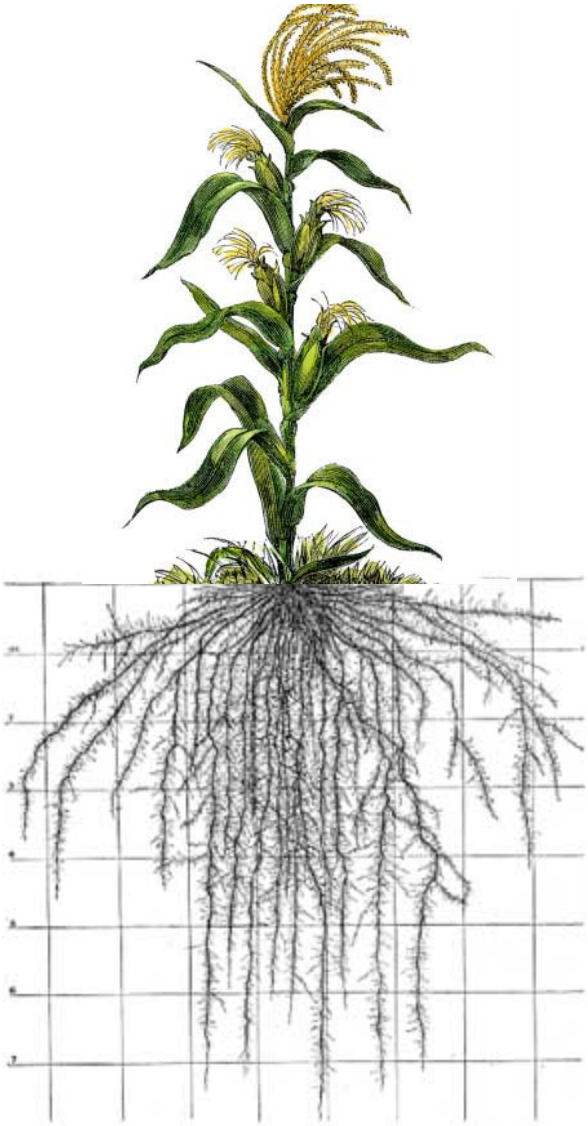
Corn fixed carbon budget



Estimate of fixed carbon in 200 bu/ac corn crop

	Dry weight (tons/ac)	Carbon (tons/ac)	CO2 eq (tons/ac)
Grain	4.7	2.1	7.6
Stover	3.8	1.5	5.5
Below ground	4.1	1.7	6.1
Total	12.6	5.2	19.2

Assumptions :

Harvest index (grain/(grain + stover)) = 0.56
- (Monsanto, unpublished 2008)

Root/shoot ratio ((root + exudates))/(grain + stover)) = 0.55
Grain = 44% carbon. Stover and below ground = 40% carbon
- (Johnson et al, 2006)

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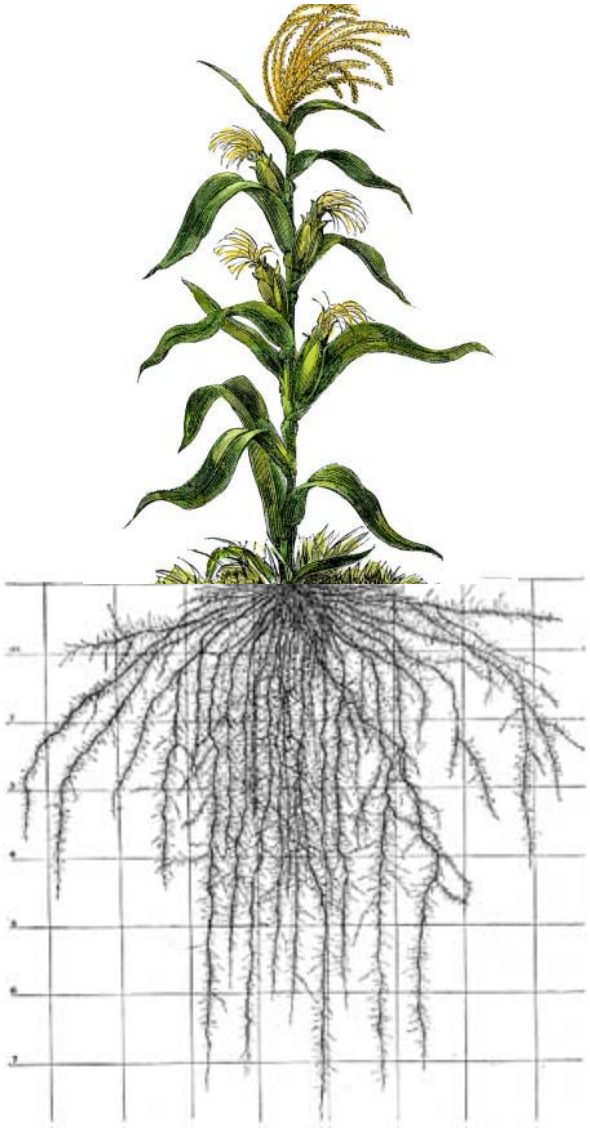
Discretionary spending is about 2 tons of CO_2



Total fixed CO_2	19.2 tons CO_2 eq/ac
Carbon removed from field	
Grain	7.6 tons CO_2 eq/ac
Carbon left on field	
Erosion/SOM maintaince	3.2 tons CO_2 eq/ac
Below ground	6.1 tons CO_2 eq/ac
Discretionary carbon	2.3 tons CO_2 eq/ac (12%)

Assumption:

Corn-bean rotation in Iowa, 2.2 dry tons/ac stover needed to control erosion and maintain soil organic matter.
Deere, ADM, Monsanto corn stover project; USDA (2006)

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Corn stalks used for bedding and power, nutrients recycled

Amana, Iowa Feb 3rd 2010

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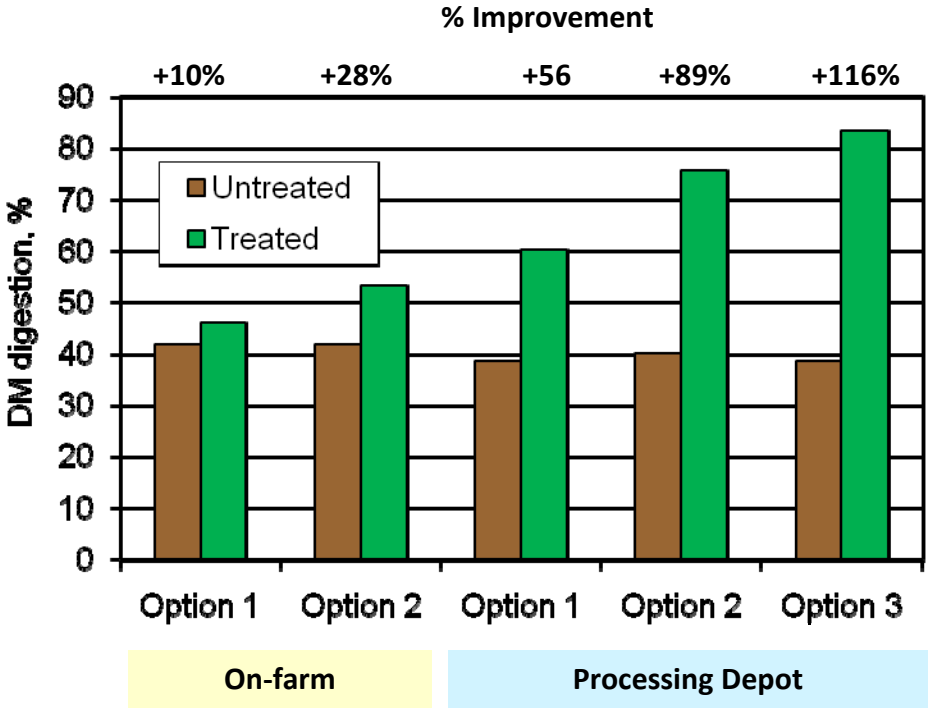
Alkaline “upgrading” of corn stalks for cattle feed

Ames, IA October 20th 2009



- **Pre-treat and blend fibrous feedstocks with commodities**
  - Agricultural residues: corn stover, corn cobs, wheat straw
  - Processing co-products: DGS, CGF, distillers solubles, steep liquors
- **Replace roughage (hay) and corn grain in diets**
  - Pre-treatment can enhance fiber digestion, improving usable calories 30-50%
  - Fully replace corn silage or hay, partially replace grain
- **Favorable economics (better cost of gain)**

Data courtesy of Mike Cecava, ADM

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Power generation with corn stalks

Cedar Rapids, IA February – June 2009

Delivered GHG content

Corn stover[1]	9.9 kg +/- 0.7 CO_2 eq/mmbtu
Coal[2]	94 kg CO_2 eq/mmbtu
Natural gas[2]	53 kg CO_2 eq/mmbtu

[1] Deere, ADM, Monsanto corn stover research project, stover LCA

[2] http://www.epa.gov/climateleaders/documents/resources/industrial_boiler_protocol.pdf

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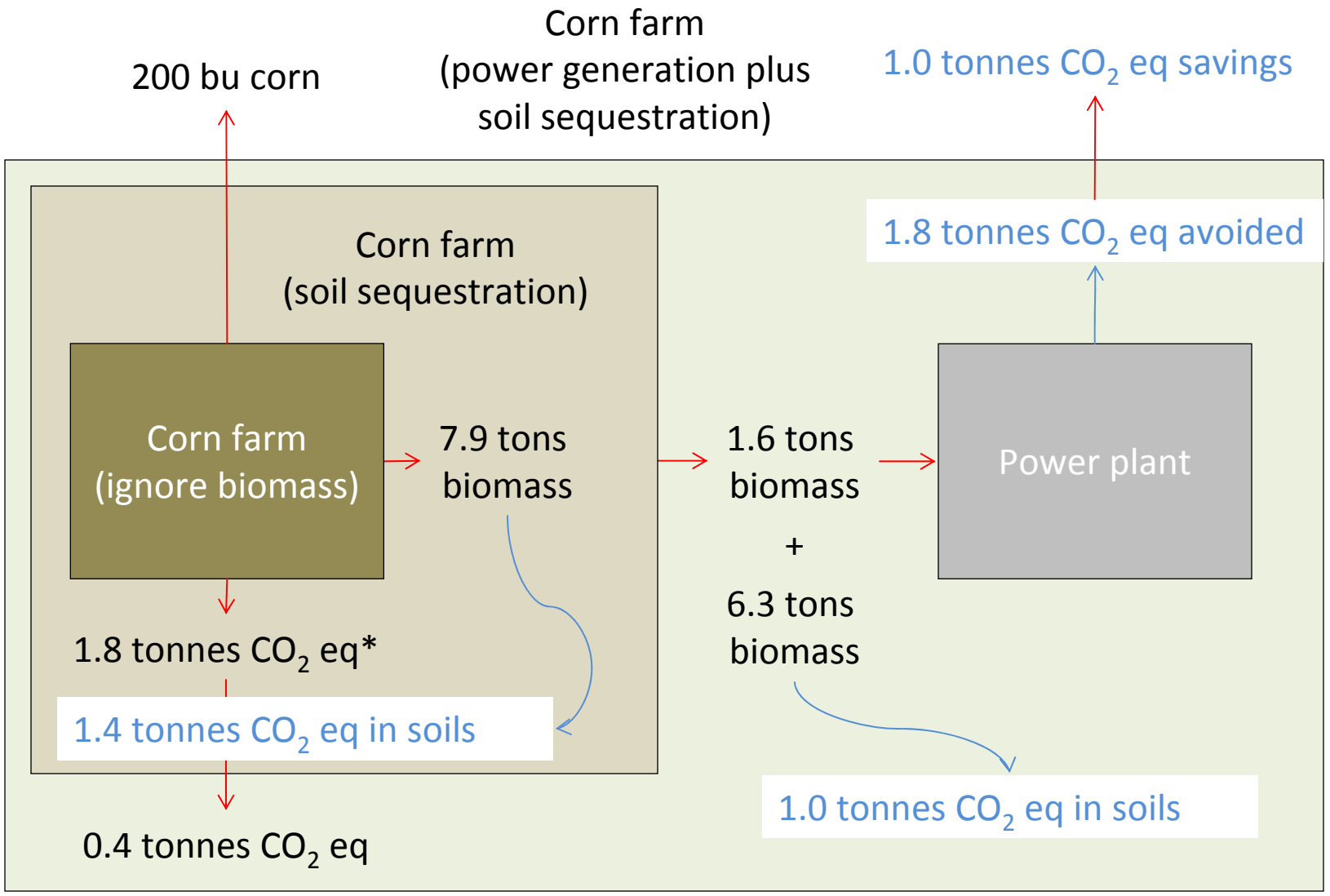
Final carbon budget depends on accounting methods and use of discretionary carbon



*CA LCFS corn ethanol pathway – 27 Feb 2009
10% humification rate (Wilts et al, 2004)

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Corn carbon budget: Summary

- Corn grain, stover and roots are all a part of the same plant and occur in the same field, but are often treated individually and differently in Life Cycle Analysis.
- Most (~90%) of the carbon is “non-discretionary” carbon contained in the grain, roots or required for soil health
- “Discretionary” carbon: Corn stover produced in excess of soil needs
  - Increases as crop yields increase
  - Has several potential uses including animal feed, power generation or possibly fuel production
  - Can be used to significantly change the GHG balance of the overall system
- While most off field uses of stover will reduce system GHG, displacing natural gas offers among the lowest GHG savings.
- A system in which stover is used to replace coal and the grain is used to generate fuel (and feed co-product) can be highly productive, reduce GHG emissions and implemented with technology available today

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Reference list

Corn non-grain biomass

Amos B, Walters DT (2006) Maize Root Biomass and Net Rhizodeposited Carbon: An Analysis of the Literature. Soil Sci Soc Am J 70:1489-1503 (root/shoot ratio = root biomass/stover biomass)

Johnson JMF, Allmaras RR, Reicosky (2006) Estimating Source Carbon from Crop Residues, Roots and Rhizodeposits Using the National Grain-Yield Database Agron J 98:622-636 (root/shoot ratio = root plus exudate mass/stover plus grain mass)

Note: Different definitions of root/shoot ratio used in the two papers.

Breeding yield improvements

Cooper M, Messina C, Hausmann N, Winkler C, Podlich D (2009) Breeding Maize for Drought Tolerance in the US Corn-Belt. 45th Illinois Corn Breeders School http://imbgl.cropsci.illinois.edu/school/presentations/2009/Cooper.pdf

Dudley (2002) Integrating molecular techniques into quantitative genetics and plant breeding. In Quantitative genetics, genomics, and plant breeding, Kang MS ed. pg 69-83

Duvick DN, Smith JSC, Cooper M (2004) Long-term Selection in a Commercial Hybrid Maize Breeding Program. In Plant Breeding Reviews, Volume 24, Part 2: Long-term Selection: Crops, Animals, and Bacteria. pg 109-151. Janick J (ed)

Field requirements for stover

Andrews SS (2006) Crop Residue Removal for Biomass Energy Production: Effects on Soils and Recommendations http://soils.usda.gov/sqi/management/files/agforum_residue_white_paper.pdf

USDA/NRCS (2006) Crop Residue Removal For Biomass Energy Production: Effects on Soils and Recommendations. Agronomy Technical Note No. 19 http://soils.usda.gov/sqi/management/files/sq_atn_19.pdf

Wilhelm WW, Johnson JMF Karlen D, Lightle, D. (2007) Corn stover to sustain soil organic carbon further constrains biomass supply. Agron J 99:1665-1667.

Alkaline "upgrading" of feed

Berger LL, Fahey GC Jr., Bourquin LD, Titgemeyer EC (1994), Modification of Forage Quality After Harvest. in "Forage Quality, Evaluation, and Utilization" edited by G.C. Fahey, Jr. Based on the National Conference on Forage Quality, Evaluation, and Utilization held at the University of Nebraska, Lincoln, 13-15 April, 1994.

Fahey GC Jr., Bourquin LD, Titgemeyer EC, Atwell DG (1993), Postharvest Treatment of Fibrous Feedstuffs to Improve Their Nutritive Value. in "Forage Cell Wall Structure and Digestibility", edited by H.G. Jung, D. R. Buxton, R. D. Hatfield, and J. Ralph. Based on the International Symposium of Forage Cell Structure and Digestibility sponsored by USDA-ARS and the U.S. Dairy Forage Research Center, Madison, WI, 7-10 October, 1993.

Humification rates

Allmaras RR, Linden DR, Clapp CE (2004) Corn-Residue Transformations into Root and Soil Carbon as Related to Nitrogen, Tillage, and Stover Management. Soil Sci Soc Am J 68:1366-1375

Clay DE, Carlson GC, Clay, SA, Owens V, Schumacher TE, Mamani Pati F. (2010). Biomass estimation approach impacts on calculated SOC maintenance requirements and associated mineralization rate constants. J Environ Quality. In press

Wilts AR, Reicosky DC, Allmaras RR, Clapp CE (2004) Long-Term Corn Residue Effects: Harvest Alternatives, Soil Carbon Turnover, and Root-Derived Carbon. Soil Sci Soc Am J 68:1342-1351