Greenhouse Gas Contributions and Mitigation Potential in Agricultural Regions of North America

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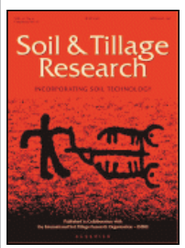


A summary of a special issue in *Soil & Tillage Research* to appear in mid 2005

from a concerted USDA-ARS effort to describe the current state of knowledge and gaps for better understanding the role of agriculture in greenhouse gas (GHG) emission and soil organic C (SOC) storage

Introduction
Franzluebbers AJ, Follett RF

There are still significant gaps in our knowledge about how agricultural management can simultaneously:
(1) satisfy economic livelihoods
(2) reduce threats to environment
(3) improve quality of land

General agricultural characteristics of three countries in North America.

Category	Canada	USA	Mexico
Total land area (Mha)	997[a]	937[a]	196[a]
Human population (10^6)	30[a]	260[a]	94[a]
Farm number (10^3)	247[b]	2129[c]	NA
Farmland (Mha)	68[b]	380[c]	NA
Cropland (Mha)	36[b]	123[c]	16[d]
Cattle/calf inventory (10^6)	16[b]	96[c]	31[d]
Hog/pig inventory (10^6)	14[b]	60[c]	16[d]
Sheep/lamb inventory (10^6)	1[b]	6[c]	15[d]
Layer inventory (10^6)	26[b]	334[c]	143[d]
Broiler inventory (10^6)	87[b]	1389[c]	225[d]
Turkey inventory (10^6)	8.1[b]	93.0[c]	4.9[d]
Arable cropland (Mha)	46[a]	179[a]	27[a]
Fertilizer use (kg · ha^{-1})	54[a]	103[a]	67[a]
Meat production (Tg)	3[a]	35[a]	4[a]
Tractors (10^3)	711[a]	4800[a]	185[a]

[a] From National Geographic Society (1995). [b] From Statistics Canada (2001). [c] From USDA-NASS (2002). [d] From Statistics Agricultural Bureau (2004) with translation provided courtesy of J.R. Salinas-Garcia. [e] From World Resources Institute (2004). NA, not available.

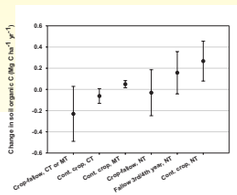
Summary of responses to agricultural management among five regions in North America.

Management comparison	Region in North America[a] NW	NE	Central	SW	SE
Decline in soil organic C concentration from native condition (%)	34 (14)	22 (10)	NA	25 (33)	39 (29)
Soil organic C sequestration (Mg C · ha^{-1} · yr^{-1})					
No tillage versus conventional tillage	0.27 (0.19)	-0.07 (0.27)	0.48 (0.59)	0.30 (0.21)	0.42 (0.46)
More complex cropping systems	0.12 (0.10)	NA	0.18 (0.23)	0.29 (0.17)	0.22 (0.33)
Addition of animal manure	0.15 (0.02)	NA	NA	NA	0.72 (0.67)
Addition of N fertilizer	0.09 (0.08)	NA	NA	NA	0.18 (0.20)
Conversion of cropland to grassland	0.94 (0.66)	NA	0.56 (0.60)	0.32 (0.30)	1.03 (0.90)
Grazed versus ungrazed grassland	0.16 (0.12)	NA	NA	-0.03 (0.19)	0.76 (0.65)
Invasion of woody plants into grassland	NA	NA	NA	0.22 (0.30)	NA
N_2O emission (kg N_2O-N · ha^{-1} · yr^{-1})					
All agricultural systems	3.0 (7.2)	3.2 (5.6)	NA	7.2 (20.8)	NA
Crop systems	3.8 (6.1)	3.7 (6.1)	NA	NA	NA
Grass systems	0.6 (1.5)	1.2 (1.6)	NA	7.2 (20.8)	NA
N_2O emission factor with added fertilizer					
Background (kg ha^{-1} yr^{-1})[b]	0.9	0.8	NA	NA	NA
Proportional rate (% of added fertilizer N emitted)	1.9	1.2	NA	NA	NA
CH_4 emission by soil (kg CH_4-C · ha^{-1} · yr^{-1}) (negative is uptake)					
All cropping systems	-1.4 (0.8)	-0.3 (0.2)	NA	1420 (1730)	NA

[a] Data from regions were obtained in the articles appearing in this issue, i.e. Northwest, western Canada and northwestern USA, Liebig et al. (2005); Northeast, eastern Canada and northeastern USA, Gregorich et al. (2005); Central, central USA, Johnson et al. (2005); Southwest, southwestern USA, Martens et al. (2005); Southeast, southeastern USA, Franzluebbers (2005).
[b] Background N_2O emission represents the y-axis (b) and proportional rate represents the slope (a) from the equation: $y = a \cdot x + b$.

Greenhouse gas contributions and mitigation potential of agricultural practices in northwestern USA and western Canada
Liebig MA, Morgan JA, Reeder JD, Ellert BH, Gollany HT, Schuman GE

Researchers in the region are challenged to fill the large voids of knowledge regarding CO_2, N_2O, and CH_4 flux from cropland and rangeland in the region.



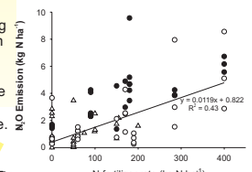
Mean N_2O emission for rangeland and cropland.

Agroecosystem	N_2O emission (g N ha^{-1} d^{-1})	CV(%)[a]	n[b]
Rangeland			
Northern grassland transition	0.07	71	6
Sagebrush steppe	0.57	42	4
Shortgrass steppe	1.00	105	8
Cropland			
Non-irrigated, 0 to 50 kg N ha^{-1}	2.6	85	8
Non-irrigated, >50 kg N ha^{-1}	3.7	51	10
Irrigated, 0 to 50 kg N ha^{-1}	5.1	104	9
Irrigated, >50 kg N ha^{-1}	11.1	69	13
Irrigated with manure/sludge	56.1	103	5

[a] CV, Coefficient of variation. [b] Number of observations.

Greenhouse gas contributions of agricultural soils and potential mitigation practices in eastern Canada
Gregorich EG, Rochette P, VandenBygaart AJ, Angers DA

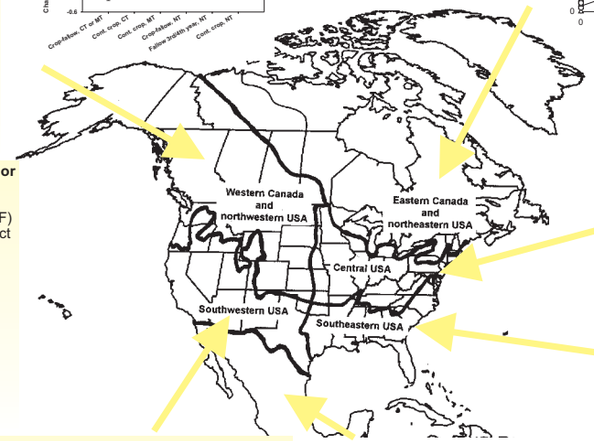
Elevated N_2O emission during freeze/thaw periods in winter/spring suggests that annual N_2O emission based only on the growing-season would be underestimated. Management practices may involve tradeoffs, e.g. soil C storage and emission of N_2O may both increase.



Greenhouse gas reduction through agricultural carbon enhancement network (GRACEnet)
Jawson MD, Shafer SR, Franzluebbers AJ, Parkin TB, Follett RF

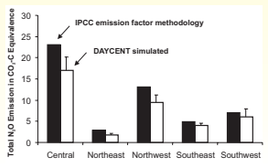
The primary objectives of GRACEnet are to:
(a) identify and develop agricultural strategies that will enhance soil C sequestration and reduce greenhouse gas (GHG) emissions
(b) provide a scientific basis for possible C credit and trading programs to reduce net GHG emissions and improve environmental quality

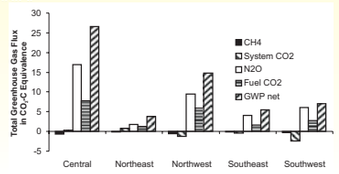
Four possible scenarios will be investigated, including:
(1) A business-as-usual system, i.e., the most typical agricultural management practices for the region
(2) A system that maximizes soil C sequestration.
(3) A system that minimizes net global warming potential (CO_2, N_2O, CH_4).
(4) A system that maximizes total environmental benefits, e.g. soil, water, and air quality.



DAYCENT model analysis of past and contemporary soil N_2O and net greenhouse gas flux for major crops in the USA, *Del Grosso SJ, Mosier AR, Parton WJ, Ojima DS*

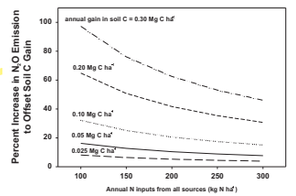
The DAYCENT ecosystem model (a daily version of CENTURY) and an emission factor methodology (EF) used by the Intergovernmental Panel on Climate Change (IPCC) were used to estimate direct and indirect N_2O emission for major cropping systems in the USA.





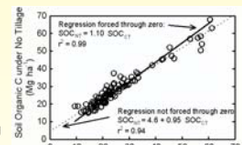
Greenhouse gas contributions and mitigation potential of agriculture in the central USA
Johnson JMF, Reicosky DC, Allmaras RR, Sauer TJ, Venterea RT, Dell CJ

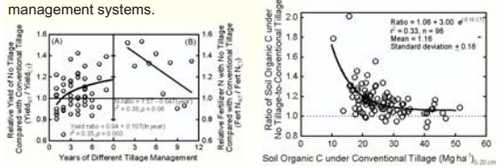
The central USA contains some of the most productive agricultural land of the world. Due to the high proportion of land area committed to crops and pasture in this region, the C stored and GHG emission due to agriculture represent a large percentage of the total for the USA. The relatively few data on GHG emission from cropland and managed grazing land in the region suggest a need for more research to better understand the interactions of tillage, cropping system, and fertilization on SOC sequestration and GHG emission.



Soil organic carbon sequestration and agricultural greenhouse gas emissions in the southeastern USA, *Franzluebbers AJ*

Agriculture in the southeastern USA can be highly productive (i.e., high photosynthetic fixation of atmospheric CO_2) due to warm-moist climatic conditions. A more complete analysis of GHG emission and potential mitigation by agricultural management is needed by expanding research on pastures and quantifying CH_4 and N_2O fluxes from all management systems.





Research and implementation needs to mitigate greenhouse emissions from agriculture in the USA, *Follett RF, Shafer SR, Jawson MD, Franzluebbers AJ*

An urgent need exists to understand which agricultural land uses and land resource types have the greatest potential to mitigate GHG emissions contributing to global change. Covering the threat of accelerated GHG emissions, this paper addresses:
(1) current scientific facts about the attributes of soil and natural resources
(2) strategies for sustainable use of our finite and fragile land resources
(3) advances made by agricultural sciences and their potential role in forming policy

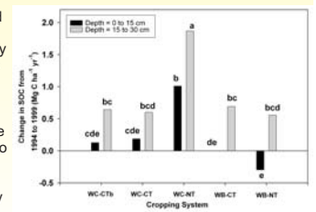
Some research needs:
- Develop agricultural systems that minimize net global warming potential
- Investigate C, N, P, and S cycles together for total ecosystem management
- Simultaneously characterize soil C sequestration and off-site impacts of mgt
- Develop systems to produce biofuels and sustain/improve soil and water quality
- Quantify below- *vs* above-ground plant biomass contributions to SOC
- Conduct more long-term field studies (>10 years) for whole-ecosystem responses
- Conduct integrated farming system research to promote better nutrient cycling

Atmospheric carbon mitigation potential of agricultural management in the southwestern USA
Martens DA, Emmerich W, McLain JET, Johnsen Jr TN

Agriculture in the southwestern USA is limited by water supply due to high evaporation and limited seasonal precipitation. Where water is available, irrigation allows for production of a variety of agricultural and horticultural crops. Irrigated crops under conservation tillage may have greater potential to sequester C compared with native rain-fed grass lands. Soil salinity must be controlled in crop land as SOC content was lower with increasing salinity. Despite 75% of the region's soils being classified as calcic, the potential for sequestration of C as soil carbonate has only been scantly investigated. The region may be a significant sink for atmospheric CH_4, although in general, trace gas flux from semi-arid soils lacks adequate characterization.

Carbon dynamics and sequestration in an irrigated Vertisol in central Mexico, *Follett RF, Castellanos JZ, Buenger ED*

Conservation tillage could enhance SOC sequestration, but is rarely used in cropping systems in Mexico, especially under irrigation. >1.4 Mg ha^{-1} yr^{-1} of aboveground crop residue production was required to increase SOC in the 0-30-cm depth. C-sequestration efficiency of crop residues was about 11%.



WC, wheat/corn; WB, wheat/bean;
CT, conventional tillage; NT, no tillage; b, burned

Presented at the Third USDA Symposium on Greenhouse Gases & Carbon Sequestration in Agriculture and Forestry, 21-24 March 2005, Baltimore MD