Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

National Inventory of C change for Agricultural Soils in Canada

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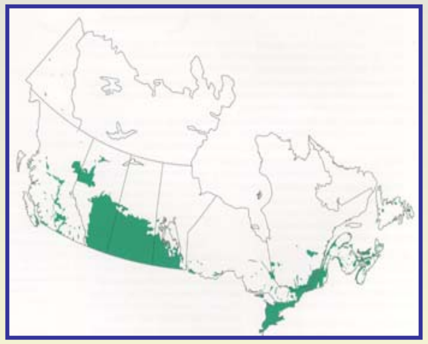
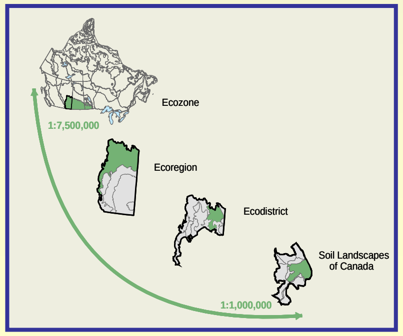
Inventory of Agricultural Soil Carbon Change

- Greenhouse Gases
  - Required under the United Nations Framework Convention on Climate Change (UNFCCC) and
  - Required under Kyoto Protocol (KP)
    - When cropland management and/or grazing land management elected
  - Must follow Good Practice Guidance for Land Use, Land-Use Change, and Forestry (IPCC 2003). (http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.htm)
- Sustainability Indicator
  - Already used in Canada as indicator to help assess regional and national sustainability of agricultural practices for domestic policy purposes
- Accounting for C change part of Canadian Agricultural Greenhouse Gas – Monitoring, Accounting, and Reporting System (CanAG-MARS)
  - Collaborative project between Agriculture and Agri-Food Canada and Environment Canada and Natural Resources Canada



Due to climatic and soil limitations, only 7% of Canada's land area (the shaded portion) is used for agriculture. About 80% of the agricultural land is in the prairies of western Canada.



Canada's land is subdivided in a hierarchical ecostratification, the National Ecological Framework, which provides the systematic basis for scaling spatial information. The hierarchical ranges of ecozone, ecoregion, ecodistrict, and Soil Landscapes of Canada provide increasing scale and distinction of biotic (e.g., soil, vegetation) and abiotic (e.g., climate, topography) features and information.

Accounting Methods

- Canada's C change inventory within CanAG-MARS uses Tier 2 accounting methodology.
- Basic equation:

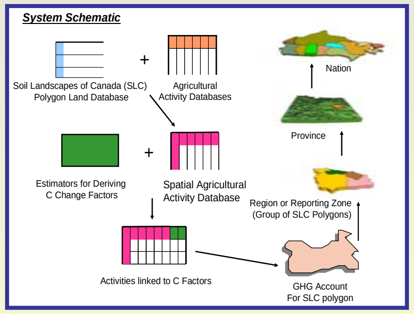
$$\Delta C = F \times A \quad (1)$$

where ΔC is the 0-30 cm C change for a specific year (Mg) F is the factor (coefficient) of carbon change (Mg ha^{-1} yr^{-1}) and A is the area (ha) of change in land management or land use (LMC) over one year (ha yr^{-1}).

- For soil organic C (SOC), change in year, Y, CanAG-MARS considers LMC from 1952 to inventory year. Each vintage of LMC has own C change factor. Hence:

$$\Delta C_Y = \sum_{y=1}^{Y} \left(F_y \times A_y\right) \quad (2)$$

- where ΔC_Y is C change in year Y, F_y is the factor of C change for year Y resulting from LMC that occurred in year y, and A_y is the area of LMC that occurred in year y.



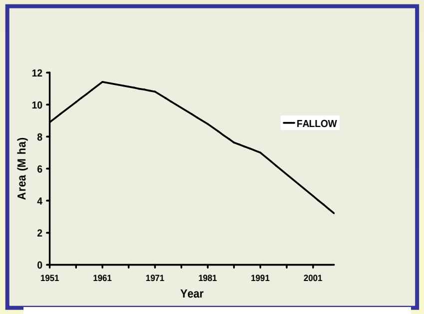
The basic georeferenced analysis units are the Soil Landscapes of Canada (SLC) polygons which are about 1 000 to 100 000 ha. Agricultural activity data for the SLC polygon is spatially referenced but not spatially explicit. The results can be scaled up to reporting zone, provinces, or the nation through the ecostratification framework.

Uncertainties

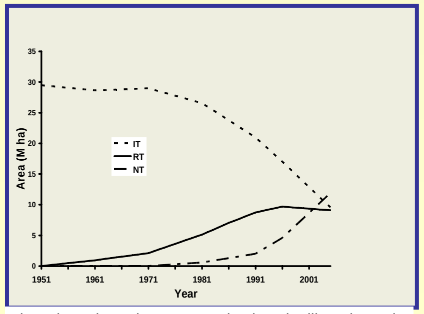
- The national C change inventory involves about one million uncertain quantities. Uncertainty analysis was accomplished using a combination of Monte Carlo method of drawing randomly from the probability distributions and analytical mathematical solutions of uncertainties.

Agriculture Activities

- Activities included in inventory were those for which significant C change expected and for which activity data available
  - Change in area of bare fallow
  - Change in proportion of annual to perennial crops
  - Change in tillage system
  - Cultivation of histosols (organic soils)
  - Change in woody biomass for fruit trees, vineyards, and Christmas tree plantations
  - Land-use change from forestland to cropland and grassland to cropland
- Activities not included in agriculture C inventory because inadequate activity data
  - Change in manure application rates or specific location, change fertilization regime, change in amount, type, or management of cover crops and/or green manure crops, change in management of tame pastures and haylands, change in irrigation regime, change in soil erosion and/or deposition rates, change in non-forest woody biomass on current or abandoned agricultural land
- Activities not included because of inadequate activity data and limited evidence that would be significant C change
  - Grazing on extensively managed rangelands, change in type, cultivar, or management, other than tillage system, of annual crops
- Activity data of the areas of LMC is derived primarily from the Census of Agriculture with supplementary data from various surveys of agricultural management and earth observation. The Census of Agriculture is conducted every 5 years with 2006 being the most recent.



Area of bare fallow has been decreasing since 1960s



There have been important reductions in tillage intensity in recent decades

Carbon Change Factors

- Carbon change factors were estimated three ways:
- Using Century Version 4
  - For tillage and annual-perennial conversions
- Empirical
  - For cultivated histosols (only 16 200 ha in Canada, factor = 18.4 Mg CO2 ha^{-1} yr^{-1} from IPCC 2006 Revised Guidelines (IPCC 2006))
- Combination of empirical and Century
  - Used where good empirical data to scale C change, Century used to determine k
  - Fallow changes, grassland and forestland SOC change

Calculations

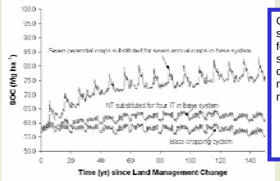
- SOC change was assumed to follow first-order kinetics and so was described by:

$$\Delta SOC_{LMC}(y) = \Delta SOC_{LMC\max} \times \left[1 - \exp(-k \times y)\right] \quad (3)$$

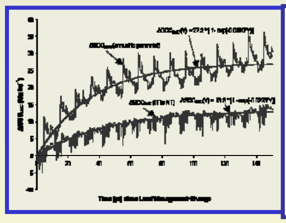
where $\Delta SOC_{LMC}(y)$ is the SOC change (Mg ha^{-1}) from a LMC that occurred y years ago, SOC_{LMCmax} is the maximum C change that will occur when SOC steady state has been attained after the LMC, and k is the rate parameter (yr^{-1}).

- From equation (3), the F for C change for year *y-1* to *y* is:

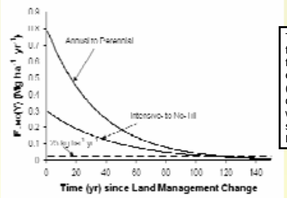
$$F_y = \frac{\Delta SOC_{LMC\max} \times \left[\exp(-k \times (y-1)) - \exp(-k \times y)\right]}{y-(y-1)} \quad (4)$$



Century simulations for base and substituted crop and management mix



Parameters for equation (3) estimated from the difference between simulated SOC for base and substituted runs.



The factors from equation (4) decrease with time since LMC

Regional Average C change Factors

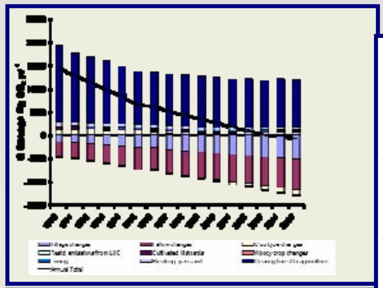
- The approach provides a good representation of the combinations of agricultural practices and initial soil C level that exist at regional (reporting zone) scale but unlikely to be good representation for a particular SLC polygon. Therefore, mean factors were derived for entire reporting zone and applied to individual soil components in SLC polygons.

Example C Change Factors

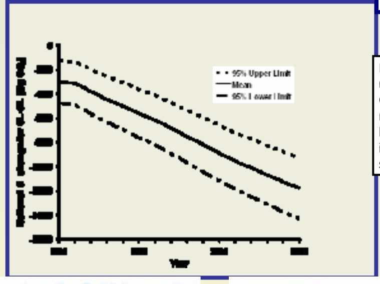
Region	Land Management Change	ΔSOC_{LMCmax} (Mg ha^{-1})	k (yr^{-1})	Avg. 20-yr factor (Mg ha^{-1} yr^{-1})
East-Central	CT to NT	5.0	0.0250	0.10
	Inc. perennials	38.2	0.0247	0.74
Subhumid Prairies	CT to NT	6.5	0.0286	0.14
	Dec. bare fallow	13.1	0.0305	0.30
	Inc. perennials	29.4	0.0233	0.55
Semiarid Prairies	CT to NT	4.9	0.0261	0.10
	Dec. bare fallow	13.1	0.0305	0.30
	Inc. perennials	26.1	0.0281	0.56

Inventory Results

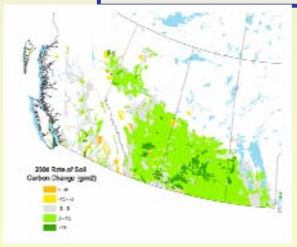
- Emissions from clearing forests to make more agricultural land have often exceeded the sink from increasing SOC
  - Reducing this is greatest opportunity to increase sink
- Compared with 1990, Canadian agricultural soils have become and increasing net CO_2 sink because of both decreasing sources and increasing sinks.
  - Net sink less than 2% of total national emissions
- National sink mainly from reducing bare fallow and tillage in western Canada



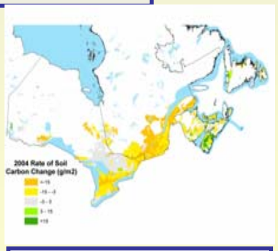
Clearing forests for agriculture, reducing tillage intensity, reducing bare fallow have the largest effects on C emissions (positive values) and C sinks (negative values).



Excluding land-use changes, Canada's mineral soils have been an increasing sink since 1990.



Most of the prairies of western Canada have been a C sink in recent years because of decreasing area of bare fallow, decreasing tillage intensity, and switching from annual crops to more pasture and forage.



Most of the eastern Canada is a C source in recent years because of switching from pasture and forage to annual crops with only modest reduction in tillage intensity to counteract this source (bare fallow is unimportant in eastern Canada).

Summary

- Canada's agricultural C inventory is data intensive
- Canada's soil is an increasing sink from 1990 to 2005
- Greatest opportunity to increase sink comes from
  - Decreasing the clearing of forests to produce new agricultural land
  - Switching from annual crops to perennial crops
  - Reducing bare fallow
  - Reducing tillage
- Improvements to inventory will come primarily from improving agricultural activity data

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