Net Ecosystem Carbon Dioxide Exchange over a Temperate, Short-Season Grassland: Transition from Cereal to Perennial Forage

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North American grass lands may be part of a terrestrial carbon (C) sink that partially offsets CO_2 emission from fossil fuel use and land use change. Organic-C from grass land soils, vegetation and litter is continuously in exchange with atmospheric CO_2 through ecosystem photosynthesis and respiration. The northern edge of the terrestrial sink is estimated to be approximately 51^o N lat.

World grasslands are considered to be significant contributors to the sink, because they represent 32% of global vegetation on an area basis. Rangelands have relatively low potential C-sequestration rates per ha, but cover huge areas of the North American continent and should have a large cumulative effect on potential C-sink. Pastures have larger potential rates of C-sequestration as they are located in humid and sub-humid regions and are more responsive to management inputs. Pastures are considered to have a large upside for C-sequestration, because most are managed below production potential, so can sequester relatively large amounts of soil-C before reaching an equilibrium with atmospheric CO_2. Pasture area in USA and Canada is approximately 60 million ha. Most (90%) of the Canadian pasture land (10.0 million ha) is located in the short-season Aspen Parkland and Boreal Transition regions of the Prairie Provinces.

Net ecosystem CO_2 exchange studies were conducted on a black chernozemic soil at Lacombe, AB, Canada (52^o 26’ N: 113^o 45’ W) with land in transition from cereal to conserved forage/pasture production during the seedling year, May 15, 2002 to May 14, 2003, and first production year, May 15, 2003 to May 14, 2004. The objective was to compare annual and within year CO_2 flux on meadow bromegrass (*Bromus riparius* Rhem.) and alfalfa (*Medicaigo sativa* L.) mixture-stands, destined for crop land pasture, using the Bowen ratio / energy balance (BREB) technique year-round. The forage crop was established (seedling year) by using barley (*Hordeum vulgare* L.) as a nurse crop. Farming practices prevalent in the region were used; forage stand was direct-seeded with a nurse crop; silage and hay were removed for both years; grazing of the forage species mixture occurred in Sept. or October. Soil respiration measurements were taken at intervals during the growing season between spring thaw and freeze up.

Growing season rainfall was 76 and 72% of average in seedling and first production years, respectively. Net CO_2 uptake occurred on only 65 and 61% of the days between May 15 and Sept. 30 during seedling and first production years, respectively, partly due to dry conditions. Analyses of daily net BREB CO_2 flux indicated patterns of sequestration and respiration that followed crop growth, climate and management practices. Periods of initial growth re-growth, grazing, dormancy and transition between dormancy and growth could be identified from daily net CO_2 flux in both seedling and first production years. Maximum daily net CO_2 uptake occurred between May 15 and harvest in the seedling (6.68 g CO_2 m^2 d^{-1}) and first production years (1.68 g CO_2 m^2 d^{-1}). Maximum average net CO_2 loss (-12.7 g CO_2 m^2 d^{-1}) occurred during spring 2003 of the seedling year, but prior to the first production year. By contrast, large, CO_2 flux into the ecosystem occurred during spring 2004 for the first production year (3.30 g CO_2 m^2 d^{-1} on average). Flux out of the ecosystem followed harvest for 25 d for the seedling year (-4.88 g CO_2 m^2 d^{-1} on average) and 14 d for the first production year (-5.51 g CO_2 m^2 d^{-1} on average), and occurred during heavy grazing in the fall of the seedling year (-7.90 g CO_2 m^2 d^{-1} on average) and light grazing for the first production year (-0.80 g CO_2 m^2 d^{-1} on average). Flux was low and consistently negative (loss) during winter, Dec. 1 to Feb. 28, in both the seedling (-1.71 g CO_2 m^2 d^{-1}) and first production years (-1.51 g CO_2 m^2 d^{-1} on average).

Soil respiration (including root and soil microbial processes) accounted for 56, 46 and 39% of the variability in BREB night time respiration for dormant, re-growth and spring periods, respectively, but did not account for significant proportions of variability for initial growth and entire growing seasons (included re-growth).

A large annual CO_2 flux loss, equivalent to 200 g C m^{-2} yr^{-1}, occurred during the seedling year. A much lower annual loss, equivalent to 11 g C m^{-2} yr^{-1}, occurred during the first production year. On the basis of annual BREB CO_2 flux both the seedling year and first production year ecosystems were sources for atmospheric CO_2. In addition, removal of hay and silage from the ecosystem caused an estimated loss of an extra 200 and 180 g C m^{-2} yr^{-1} kg C ha yr^{-1} from seedling and first production year stands, respectively.

Management of crop land pasture in the Aspen Parkland of Western Canada influenced its potential as a CO_2 sink. When the number of days of net CO_2 uptake is limited by a short growing season every effort must be made to provide a continuous cover of leaf material to maximize net ecosystem uptake. Measurement of annual CO_2 flux should continue to determine if ecosystem equilibrium or status as a CO_2 sink is attained after several years and to get an estimate of variability in annual net CO_2 flux.