Can Grasslands be Managed as CO_2 Sinks?

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As the discussion about climate change increases so has the discussion about the possibility of reducing or offsetting greenhouse gas emissions by natural plant and soil processes. In green house gas accounting, atmospheric CO_2 concentration is not increasing at a rate equivalent to estimated annual green house gas emission caused by burning of fossil fuels and by land use change (e.g. deforestation). This short-fall in the greenhouse gas balance sheet is an indication that CO_2 is actively being taken out of the atmosphere in large quantities through photosynthesis. The only biological entities large enough to do this are the, forests, grass and crop lands of North America. This is the "Missing Sink". About 70 to 80% of the sink is estimated to be south of the 51^{st} parallel. Thus Canadian farm land is likely part of the sink.

The role that grasslands play in the sink activity is important if the sink is to be managed for atmospheric CO_2 reduction. Agricultural scientists are interested in the sink phenomenon, because in the long run it may play a role in environmental and climatic stability and because it might be economically important to agriculture through carbon (C) – offsets within the agricultural sector and with other industrial sectors.

Carbon is stored in soils and plant material growing on them and in oceans and the atmosphere. Carbon is in continuous exchange among these stores in the form of CO_2. If the exchange is mostly in the direction of one of these stores, so that it is increasing at the expense of another, it is a sink. If it is losing C to a sink, it is a source. Under a given set of climatic and management circumstances there is a point at which the sink is full. After a significant management (e.g. zero tillage) or climatic change (e.g. long term above average rainfall), which increases crop productivity or reduces soil organic matter degradation new upper levels (sink capacities) are attained. It may take 20 to 30 years to attain the new sink level. Over the intervening period the sink grows slowly.

Grass and croplands which are already well managed are likely operating close to their potential sink size and although are exchanging CO_2 with the atmosphere in both directions are likely already at equilibrium with the atmosphere. This means that they gain about as much CO_2 as they lose on a long term basis. Equilibrium is a responsible goal, as it means grasslands are sustainable for soil-C. In order to determine if any particular grassland may have potential to grow as a sink it is important to figure out how grassland sinks work. All CO_2 uptake into an ecosystem occurs as a result of photosynthesis during the growing season. Photosynthesis is countered by respiration, resulting in CO_2 emission from the living crop canopy and roots and by microbial respiration which degrade soil organic matter, litter and vegetative residues which exist above ground.

Grasslands cover 32% of the global surface and exist under different and dynamic climatic, soil and land form types. Therefore they are a huge number of small ecosystems working independently. Grasslands can be grouped into range and pasture lands as well as perennial crops as pasture and conserved forage in rotation with crop land. Range lands are extensive covering huge areas in the US and Canada. They are generally located in drier regions and are therefore not as responsive to management improvement. Never the less their large acreage means that slight improvements for C-sequestration may have a large impact on climate change. Permanent and crop land pastures in moister areas are responsive to more intensive management, increase productivity and therefore may have higher C sequestration rates than rangeland. Even though tame grasslands represent a much lower area than rangeland they may be just as significant in overall C sequestration.

Micrometeorological studies carried out by the US Agricultural Service Rangeland Carbon Dioxide Project documented ecosystem CO_2 exchange for various grasslands in the Great Plains region. These studies were conducted primarily on rangeland and provided insights into processes that affect C sequestration. Most of the research was conducted during the growing season. The studies indicated that grassland ecosystems acted as small sinks during the growing season. However, few studies were conducted year round. Those that were conducted annually indicated that the dormant period, including winter were periods of CO_2 loss. Thus managing the non-growing season may be as important as the growing season.

Conversion of cropland to perennial pasture is one means of increasing C sequestration rates by farmland. This topic was studied at Lacombe Research Station by investigating CO_2 exchange continuously during perennial crop establishment in the seedling year and during the first production year.

It is important to recognize that we have a short, cold and dry growing season in western Canada. Respiration processes by the crop and or soil occur continuously throughout the year. CO_2 is released and must be re assimilated by the ecosystem when the crop canopy is growing. Net uptake of CO_2 may occur during 80 to 100 days; net losses of CO_2 may occur during the rest of the year. The period when most photosynthetic uptake occurs is the period of initial growth from spring until mid summer, or until hay or silage harvest or grazing occurs. Thus it is important to ensure that canopy growth occurs as early as possible in the spring and as long as possible.

Choosing species that initiate growth early in the spring are advantageous. Spring is a period when soils are moist, warming and microbial respiration is peaking. If a green crop canopy is not available to take up CO_2, huge losses of C may occur, especially following dry years. Management procedures that ensure vigorous spring growth are important. These are procedures that ensure large and vigorous tillers with adequate carbohydrate reserves in the spring. Overgrazing of pastures in the fall and harvest during periods critical to winter survival are issues to overcome.

Extending the growing season is important. The period after cutting and grazing is a period of CO_2 loss as respiration is required to re establish the crop canopy. Choice of species with good regrowth capability should ensure that crop canopies are established rapidly and that net uptake is re established. Species that grow into the fall and that maintain green leaf area duration may shorten the dormant or non growing period. Leaving some green leaf area after grazing or harvest may assist in more rapid re establishment of CO_2 uptake.

The dormant period is extended by drought and heat. There is variation among species for drought and heat tolerance. The choice of species is highly specific to climatic regions as there is a fine line between drought and winter survival, tendency to become dormant and lack of productivity. In areas with intermittent drought species which retain green leaf area are important. Species such as Kentucky bluegrass, which are highly sensitive to heat and drought should be avoided. Species such as alfalfa and meadow bromegrass have the ability to maintain growth under warm and drier conditions. Species such as crested wheat grass go dormant rapidly as well and are efficient in conserving moisture. Crested wheatgrass may still be suited to semi arid areas as it grows well in the spring. Considerable research needs to be done to sort out these species x climate x dormancy interactions and their implications to C sequestration.

The seedling year normally coincides with low productivity for forage stands. A nurse crop may be required to maintain meaningful productivity and economic yield. However, any delay of canopy development by the nurse crop or cutting and grazing the seedling forage stand may predispose the land to excessive losses of CO_2 during warm moist autumn seasons and during the following spring as the seedling forage stand re establishes a canopy large enough to carry out photosynthesis.

Grassland technology normally thought of as beneficial to production may or may not coincide for C sequestration. Grasslands can be managed as CO_2 sinks, but as in other cropping systems there are weak points which must be overcome. Determining these weak points through studying and analysing CO_2 exchange of the forage establishment system has given us some clues about managing for C- sequestration.