

# Greenhouse Gas Intensity of an Irrigated Cropping System in Saskatchewan

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## Abstract

In response to increasing global food demands, the proportion of irrigated agricultural land within the Canadian Prairies is likely to increase. However, the implications of this with respect to the agricultural greenhouse gas (GHG) balance are not well understood. This study investigates and compares the greenhouse gas intensity of a typical irrigated and dryland cropping system in Saskatchewan, a semi-arid region of the Canadian Prairies. Compared to their dryland counterpart, irrigated cropping systems have higher GHG emissions which are a result of the energy used for pumping and larger nitrous oxide (N<sub>2</sub>O) production rates associated with higher N-fertilizer application and moist soil conditions. These emissions may be partially offset by increased carbon sequestration from the greater productivity realized through irrigation. This investigation focuses on the quantification of soil GHG emissions through chamber-based flux measurements. Factors driving these emissions have been determined through in-situ soil temperature, matric potential, and moisture measurements. The emissions associated with pumping and other crop management activities are accounted for using the Intergovernmental Panel on Climate Change (IPCC) literature and methodology. Preliminary results from the first season of study confirm that irrigated cropping systems have greater greenhouse gas intensity. Soil N<sub>2</sub>O emissions from the irrigated system were four times greater than the dryland and were the greatest source of emissions for the irrigated system. Diesel combustion used to power equipment was comparable between cropping systems. Emissions associated with pumping were notable; however, due to the wet growing season they remained smaller than could be expected most years. The information derived from this study will aid in the development of regional specific soil emission factors, improved management strategies, and will identify new approaches for mitigating emissions.

## **Introduction**

As a rising world population imposes increasing global food demands, irrigated agriculture is poised to play a more prominent role in food production. However, the effect of increased irrigated production with respect to the agricultural greenhouse gas (GHG) balance is not well understood. Particularly within the Canadian Prairies, there is potential to see large increases in the number of irrigated hectares if the environmental sustainability of these systems can be assured.

Irrigation supplements natural precipitation through the application of water, optimizing soil moisture to meet crop water requirements. Compared to their dryland (rainfed) cropping systems, typical irrigated cropping system management also involves higher fertilizer rates, additional tillage operations, and greater use of chemical for pest and weed management. Although these inputs are favorable for production increases, the emissions occurring as a result of soil conditions and from fossil fuel derived energy can be substantial. Of particular interest to producers are greenhouse gases produced as a result of soil conditions, especially nitrous oxide (N<sub>2</sub>O) emissions. The efflux of nitrous oxide from soil gas represents direct losses of soil nitrogen, an important nutrient for crop productivity. These losses directly translate to economic losses to producers via lost inputs and reduced productivity.

Emission information specific to irrigated production systems is limited, particularly in the semi-arid prairie region of Western Canada. To our knowledge, no studies have attempted to understand the emission dynamics from irrigated production within this region. A regional understanding of agricultural greenhouse gas (GHG) emissions will help develop more accurate national accounting and aid in improving irrigation management strategies. Strategies focused on mitigating these emissions will help address climatic influence and reduce economic losses for crop producers.

Our two-year study aims at quantifying and comparing the GHG intensity of a typical irrigated and dryland production system in the Canadian Prairies. This includes the quantification of soil emissions and an investigation into the soil conditions driving these emissions. The development of system specific emission budgets, incorporating soil emissions and emissions pertaining to operations, aids in identifying areas of focus for mitigation efforts. Presented below are preliminary results from the 2012 field season that were discussed in an oral presentation at the 2013 Soils and Crops conference.

## **Materials and Methods**

### *Study Site*

Located approximately 75 km south of Saskatoon, the study site consists of two neighboring quarter sections, one managed under irrigated crop production and the other under dryland production. Both fields were planted to wheat in the 2012 growing season. The soils at the site are dominantly Orthic Dark Brown Chernozem by classification with minimal topographical variation.

### *Quantification of Soil Conditions and Emissions*

Soil emissions of carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) were quantified using 20 static chambers installed in each field along a single 125 metre linear transect. Chamber bases were installed after seeding and gas samples were collected weekly for the duration of the season. Within the the expected peak emission periods (May through July), samples were collected twice per week. During each sampling event, gas samples were collected from the chamber headspace at three 15 minute intervals. Gas concentrations within each sample were determined using gas chromatography (Farrell et al., 2002 in [Ens, 2012]). Using ambient air samples a time zero gas concentration, GHG fluxes were calculated as the slope of the gas concentration verse sampling time relationship. Only fluxes calculated with a *p-value* < 0.1 were used for calculating average emissions on sampling days. Seasonal emissions were deduced using the fluxes measured from sampling days.

Measurements of soil temperature, moisture, and matric potential were made continually from seeding to soil freeze-up using sensors installed into the soil. Time domain reflectometry (TDR) probes (Campbell Scientific CS-650) were used to measure soil temperature and volumetric water content. Soil matric potential was quantified using heat dissipation probes (Campbell Scientific CS-229). Sensors were installed horizontally at a 10 cm depth at four locations along each gas sampling transect. All soil sensors were wired into dataloggers (Campbell Scientific CR-3000) to enable continuous measurement.

### *Estimation of Emission from Cropping Operations*

The emission budgeting includes those emissions or reductions occurring within the scale of the farm site. Fuel usage for all cropping activities were obtained from the cooperator. Emissions resulting from fuel combustion were calculated using the Off-Road Diesel emissions factors used in Canada's national inventory (Environment Canada, 2010a). The electricity used for irrigation operations was determined from the operating hours recorded from the pivot control box and the SaskPower energy meter. The associated greenhouse gas emissions were calculated using province specific emission factors for electricity generation (Environment Canada, 2010b).

## **Preliminary Results and Discussion**

The results presented are preliminary results from the 2012 growing season.

### *Soil N<sub>2</sub>O Emissions and Soil Moisture Conditions*

The 2012 growing season was a wetter than normal growing season with a moisture deficit of roughly 100 mm, compared to typical deficits of around 300 mm for this area. This was reflected in high soil moisture conditions throughout the spring and through to mid-July. In both the irrigated and dryland cropping systems, soil N<sub>2</sub>O emissions corresponded to the high volumetric water content and low negative matric potential present during this time (Fig. 1 and 2). Daily emission fluxes were larger and more variable in the irrigated system and were sustained later into the season as periodic irrigation events maintained conditions of high soil moisture (Fig. 2). Seasonal N<sub>2</sub>O emissions (measured from May 30<sup>th</sup> to November 6<sup>th</sup>) from the irrigated system measuring 61.36 kg N<sub>2</sub>O were much greater than the 15.02 kg N<sub>2</sub>O emitted from

the dryland system (Table 1 and 2). Nitrous oxide emissions of these magnitudes elicit warming potentials equivalent to 18254 kg CO<sub>2</sub> from the irrigated soil and 4480 kg CO<sub>2</sub> from the dryland soil (Intergovernmental Panel on Climate Change, 2007). The greater N<sub>2</sub>O emissions observed in the irrigated system are likely due to a greater nitrogen fertilizer rate, as the irrigated cropping system received a total of 110 kg/ha of N while the dryland system received 67 kg/ha.

It is important to note that, due to logistics, soil emissions were not measured prior to seeding resulting in an underestimation of seasonal N<sub>2</sub>O emissions. In addition, the soil CO<sub>2</sub> and CH<sub>4</sub> fluxes and soil temperature data collected during the 2012 season were not discussed due to time limitations.

### *Emissions from Cropping Operations*

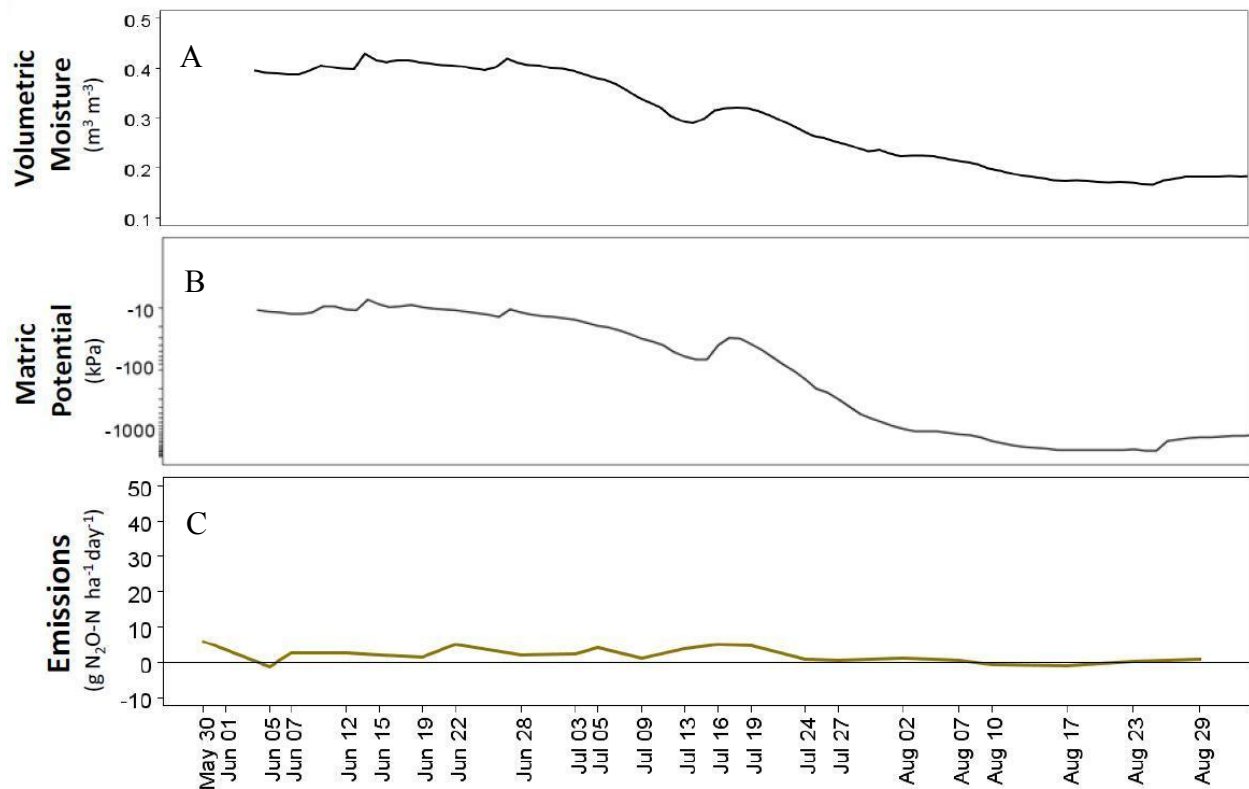
Both cropping systems were seeded to wheat in the 2012 season resulting in similar fuel usage associated with management operations. Cropping operations included a fall anhydrous application, spring seeding, herbicide application, swathing, and harvest. However, the irrigated system received two additional operations: an application of fungicide for control of fusarium head blight and a tillage operation prior to the fall anhydrous application. As a result, diesel fuel usage within the irrigated cropping system was slightly higher than the dryland system at 3639 litres and 3316 litres, respectively. This contributes emissions totaling 10898 kg CO<sub>2</sub>eq for the irrigated system and 9931 kg CO<sub>2</sub>eq for the dryland system (Intergovernmental Panel on Climate Change, 2007).

The total electricity used for pumping water and moving the pivot measured 6024 kWh in 2012, equating to 4317 kg CO<sub>2</sub>eq. Considering the wetter than normal growing, irrigation demands were low resulting in relatively low electricity usage. Average yearly irrigation demand is greater by three fold (Irrigation Crop Diversification Corporation, 2012).

### *Greenhouse Gas Intensity*

Based on the preliminary results, greater greenhouse emissions were associated with the irrigated cropping system in 2012. Total emissions represented in CO<sub>2</sub> equivalents were 33469 kg from the irrigated system, compared to 14411 kg from the dryland system. As mentioned previous, the greater soil N<sub>2</sub>O emissions and electricity usage were the major factors contributing to greater emissions. However, differences in productivity must be accounted for when comparing these two systems. The dryland wheat yield was typical to slightly higher than average at 2390 kg per ha (Saskatchewan Ministry of Agriculture, 2013), while the irrigated wheat yield of 3230 kg per ha was lower than average (Irrigation Crop Diversification Corporation, 2012). Overall greenhouse gas intensity (GHGI) was greater for the irrigated production system at 0.228 kg CO<sub>2</sub>eq per ha compared to the dryland system at 0.104 kg CO<sub>2</sub>eq per ha.

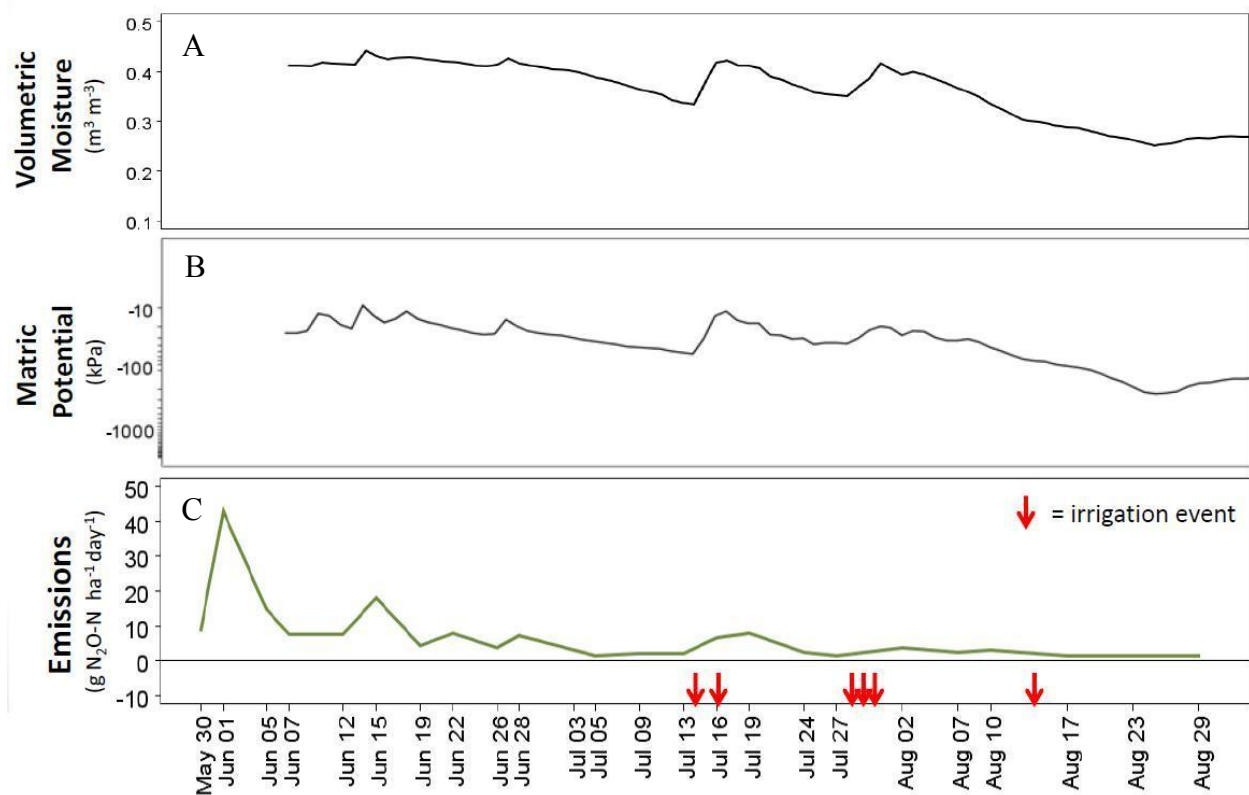
As mentioned previously, soil CO<sub>2</sub> and CH<sub>4</sub> fluxes remain to be incorporated into the GHG budget for each cropping system. Soil carbon dynamics may have a large influence on the GHGI as agricultural cropping systems may act as sinks for atmospheric carbon dioxide through carbon storage as soil organic carbon (SOC) (Snyder, Bruulsema, Jensen, & Fixen, 2009). In this regard, the enhanced productivity of irrigated cropping systems may contribute to greater GHG reductions through greater amounts of residual biomass (Liebig et al., 2005; Smith et al., 2008).



**Figure 1.** Average daily soil volumetric moisture (A, n=4), soil matric potential (B, n=4), and soil N<sub>2</sub>O emissions (C, n=20) for the dryland field during the 2012 growing season. Dates listed on the x-axis represent gas sampling days.

**Table 1.** Greenhouse gas emissions and total greenhouse gas intensity of the dryland cropping system during the 2012 growing season.

	<b>CO<sub>2</sub></b>	<b>CH<sub>4</sub></b>	<b>N<sub>2</sub>O</b>	<b>CO<sub>2</sub> equivalent</b>	<b>GHG intensity</b>
<b>Source</b>	kg	kg	kg	kg	kg CO <sub>2</sub> eq per kg yield
<b>Soil</b>			15.03	4 480	0.032
<b>Diesel Combustion</b>	8 832	0.50	3.65	9 931	0.072
<b>Total (CO<sub>2</sub> eq)</b>	8 832	12	5 567	14 411	0.104



**Figure 2.** Average daily soil volumetric moisture (A, n=4), soil matric potential (B, n=4), and soil N<sub>2</sub>O emissions (C, n=20) for the irrigated field during the 2012 growing season. Dates listed on the x-axis represent gas sampling days.

**Table 2.** Greenhouse gas emissions and total greenhouse gas intensity of the irrigated cropping system during the 2012 growing season.

	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub> equivalent	GHG intensity
Source	kg	kg	kg	kg	kg CO <sub>2</sub> eq per kg yield
Soil			61.26	18 254	0.124
Diesel Combustion	9 691	0.55	4.00	10 898	0.074
Electricity Production	4 277	0.18	0.12	4 317	0.029
<b>Total (CO<sub>2</sub> eq)</b>	<b>13 968</b>	<b>18</b>	<b>19 483</b>	<b>33 469</b>	<b>0.228</b>

## **Conclusions and Next Steps**

Preliminary results from the first season of study confirm that irrigated cropping systems have a greater greenhouse gas intensity compared to their dryland counterparts. Soil N<sub>2</sub>O emissions from the irrigated system were four times greater than the dryland and were the greatest source of emissions for the irrigated system. Emissions from on-site diesel combustion were comparable between cropping systems. The emissions associated with electricity usage for irrigation activities were notable but, due to a wet growing season, remained smaller than could be expected most years. The next steps in the project will focus on improving cropping system GHGI estimations through the incorporation of soil carbon dynamics. Within the irrigated system in particular there is potential for substantial GHG reductions through carbon storage as SOC. Data collection will continue through the 2013 growing season, the final season of the two year study. The information derived from this study will aid in the development of regional specific soil emission factors, improved management strategies, and will identify new approaches for mitigating emissions.

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