PROJECT DETAILS

- **Title**: The environmental footprint of canola and canola-based products (part 2)
- **Funders:** Agriculture and Agri-Food Canada, Alberta Canola, Canola Council of Canada, Manitoba Canola Growers and SaskCanola
- **Research program:** Growing Forward 2
- **Principal investigator:** Vern Baron (Agriculture and Agri-Food Canada Lacombe)
- **Collaborators/additional investigators:** Neil Harker, John O'Donovan, Brian McConkey, Reynald Lemke and Guy Lafond
- **Year completed:** 2017

Executive summary

1. The life cycle assessment (LCA) of canola production practices between 1990 and 2010 was published in Agricultural Systems and reported on in the last fiscal year, so no comments will be added to that objective. However, the results were reported in Science News From the Prairies. March 2017. Canola. Life cycle assessment of canola production. aafc.prdn-nrdp.acc@canada.ca.

2. Results from the Canola greenhouse gas intensity from a high yield high input region were summarized. This amounts to an in-field LCA. Averaged over five years canola had a decided economic advantage over barley. Average cost of production was \$463 vs \$634 ha^{-1} for barley vs. canola; gross revenue was \$765 vs. \$1417 ha^{-1} for barley vs. canola; and net revenue was \$302 vs \$783 ha^{-1} for barley vs. canola. Thus there is an economic incentive to keep canola in the rotation as frequently as possible.

3. Grain yield for barley was 4594 kg ha^{-1} compared to 3268 kg ha^{-1} for canola; late planted canola yielded 2078 kg ha^{-1}. However carbon yield in grain was 1964 kg ha^{-1}, 2150 kg ha^{-1} and 1350 kg ha^{-1} for early planted barley and canola and late planted canola respectively. Carbon in the grain is removed from the field at harvest, so annually more carbon is removed from early planted compared to late planted crops, but it was about the same amount for both early planted barley and canola. Of the total carbon profile (root, residue or straw and grain) the grain removed represented 38, 34 and 25% of the total crop production of carbon for early barley and canola and late planted canola respectively. Residue and root carbon yield was similar for early and late planted canola.

4. Nitrous oxide emission was 51% greater for early planted canola than early planted barley. This was due to higher amounts of N fertilizer used and higher contribution of N to soil from residue for canola compared to barley. Residue-N from late planted canola was significantly greater than from early planted canola and total inputs that contribute to nitrous oxide emission were greater for late planted canola than early

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planted barley even though fertilizer-N inputs were the same. Averaged over crops total available-N was made up of 50%, 31 and 19% from fertilizer, residue and roots.

5. CO_2 emission from farming activities was largely made up of those from the fabrication of farm inputs and diesel fuel used in farming operations. Diesel fuel represented 19% and inputs 78% of the farming activity category, but in total energy based CO_2 emission was approximately 30% of the total of nitrous oxide emission on a CO_2 equivalent basis.

6. Carbon sequestration can either offset greenhouse gas emissions or add to them if carbon is lost. In general the crop and its' environment gained carbon during the growing season and lost it when leaf area index was less than 1.0 and due to the removal of carbon in form of grain when harvested. The dynamics of CO_2 assimilation and respiration differed between barley and canola.

7. Greenhouse gas intensity of early planted canola and barley was similar. The carbon balance for all crops and planting dates on average was negative. The amount of carbon sequestered by the crop environment offset the emissions from nitrous oxide and CO_2 from farming operations and activities, but the CO_2 equivalent in grain or oilseed removed was always greater than the net CO_2 sequestered. The system losses in carbon were similar on average to comparable losses in soil carbon predicted by the Century model for these cropping practices.

Final report

Introduction

Canola acreage is close to 8 million ha and 90% of the production is exported. This is a large footprint nationally and globally. Sustainability is one of four market issues that impact canola market accessibility, particularly the large European biofuel market. Improving agronomic efficiency through improved and changing management practices should go hand in hand with economic stability and environmental sustainability. In this new marketing environment the environmental impacts need to be documented along the product value chain down to the farm gate on a product intensity basis (i.e. GHG emitted / kg seed produced). Yields of seed and oil per unit of input are important. This research will document impact of management change through LCA; GHG emission coefficients may be reduced through work on canola rotations and impacts of high yield production on GHG intensity tested. Often LCA analyses when conducted on an industry basis at the Country scale cannot take into account the specific production and regional efficiencies that reveal the high level of "on-farm" sustainability of Western Canadian canola production, because the analyses are based on existing literature. The current studies are the results of a combination of actual field scale inputs, seed and oil yields compared with evidence from previous studies. Therefore this study should have improved relevance at the farm level.

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Objectives
1. To determine how much the farm-gate canola carbon footprint has decreased in each of the soil zones across the Prairie Provinces between the era of 1985-1990 to 2005-2010 and to determine what the drivers of this change were in terms of canola management on the farm.
2. To determine the greenhouse gas (GHG) intensity (including carbon sequestration) for canola production using best management practices in a high yield and high input region (Central Alberta) of the prairies.

Objective 1. Farm-gate Canola Footprint
The Saskatchewan Research Council (SRC) was contracted to conduct the life cycle assessment from cradle to farm gate for canola production in each of the soil zones across the Prairie Provinces between the era of 1985-1990 to 2005-2010. Considerable planning went into the definition of the objective, question to be asked and the scope of the issue. The LCA was conducted by SRC and a report written, and in accordance with ISO 14040 the LCA has been reviewed by a qualified third party, Dr. Goretty Dias Assistant Professor, University of Waterloo. After the review of Dr. Dias the report was reviewed again by the steering committee and consultants of the CCC Subsequently a manuscript was drafted. And submitted to Agricultural Systems.

Objective 2: Canola greenhouse–gas intensity from a high yield –high input region

This field scale experiment has been conducted at Lacombe, Alberta over five years.

Location: The study was conducted in three fields, each surrounding an Eddy Co-variance tower, at the Neumenko farm area of Lacombe Research Centre

Field 1. (Tower 1.) At the south end of S.W. ¼ SEC. 15-40-27-4
Field 2. (Tower 2.) At the North end of N.W. ¼ SEC. 10-40-27-4
Field 3. (Tower 3.) Approx. 400 m south of Tower 2 on NW ¼ SEC 10-40-27

Experimental design: Landscape design with pseudo-replication (sub-samples; n=6) within the sampling block around each tower.

Rotational trial (canola/barley grown from 2011 to 2016)

Soil Type and Classification and texture.

The soil was a Penhold Black chernozem with a texture that ranged from clay loam to fine sandy loam.

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Table 1. Rotations	2010	2011	2012	2013	2014	2015
			C-Footprint in Field			
Field 1	Bar. silage	E. Bar. grain	E. Canola	E. Bar. grain	E. Canola	L. Canola
Field 2	Bar. silage	E. Canola	L. Bar. grain	L. Canola	E. Bar. grain	E. Canola
Field 3	Bar. silage	L. Canola	E. Bar. grain	E. Canola	L. Bar. grain	E. Bar. grain

Early Planted Barley vs. Early Planted Canola 5 Yrs. on 3 different fields
Early Planted Canola vs. Late Planted Canola 3 Yrs. on 3 different fields
Early Planted Barley vs. Late Planted Barley 2 Yrs. on 2 different fields

Field-Scale C-Footprint for Canola and Barley

Figure 1. Clock-wise from top left: 1. Eddy co-variance system in early-planted canola; 2. Combining Metcalfe barley; 3. Emerging canola; 4. Freshly harvested canola prior to "green-seed" test.

Greenhouse gas emission

Towers are situated on the mid slope of the west facing ridge with approximately 200 m between the tower and borders. A 1-ha sampling area, close to the footprint of the tower running 50 m (actually 100 m x 100 m) square on each side of the tower. Eddy covariance equipment and the sampling blocks are identified in all three fields by August-September of 2010. Field 1 was instrumented with both Eddy and BREB in operation by early spring of 2010.

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Daily and annual CO_2 flux is conducted in adjacent fields using the Eddy covariance method (Fluxnet-Canada Measurement Protocols 2003). Towers separated by 400 m. Field 1 has both Eddy and Bowen Ratio Energy (BREB) equipment in operation by early spring of 2010. Year 1 was used to calibrate, synchronize and evaluate corrections required among the three towers, which should be in operation by mid-summer. Soil respiration rates bi-weekly n = 6 within measurement blocks; soil N_2O flux (n = 6) (Livingston and Hutcheson 1995) snow-melt to freeze-up with annual flux determined with seasonal estimates made by linear interpolation (Lemke et al 1999).

Besides direct measurement of greenhouses gases, IPCC (2006) Tier 2 methodology was used to model emissions from various sources of energy and fossil fuels as well as N2O-N emission. Ultimately ratios of energy input and output and greenhouse gas emission per unit of harvested canola and barley seed were calculated from the aggregate of accumulated emissions and seed yields.

All energy used in manufacture and transportation of equipment (embodied), operation and maintenance (fuel and lubrication) was accounted for in all cropping activities for each crop species and cropping. Energy (MJ ha^{-1}) was converted to diesel fuel equivalent (L ha^{-1}) and then to CO_2e (kg CO_2e ha^{-1}) (Nagy 2000). Equipment used for each crop activity was referenced to Nagy (1999) and Saskatchewan Agriculture Farm Machinery Custom Rental Guide 2008–09 to determine a work rate (ha h^{-1}) for the actual equipment combination used or its' equivalent size and type. Then, for cropping activities, the equipment combination was matched to embodied fuel and lubrication energy required hourly (Nagy 1999) and a total determined for the energy required (MJ ha^{-1}) for annual crop production from pre-seeding operations to harvest. Energy used in the manufacture and transportation of seed, fertilizer and herbicides used were determined (Table A4) for each crop and feed combination in each year. The embodied energy coefficients for seed and herbicide were from Nagy (1999; 2000) and Zentner et al. (2009), and fertilizer from Snyder et al. (2009). Energy (MJ kg^{-1}) was converted to a diesel fuel equivalent (MJ L^{-1}) and then to CO_2 equivalent (kg CO_2e kg^{-1}) for the specific input (Nagy 2000). For each crop or feed all energy sources (inputs, equipment and production activities) were summed on per ha basis (kg CO_2e ha^{-1}).

Methods for calculation of N_2O generally follow the outline for defining nitrogen fractions and emission factors for crops on an ecodistrict basis as described by Rochette et al. (2008). The base emission factor for Ecodistrict 737 incorporates the factors for tillage, topography, irrigation and soil texture typical of the Bowden to Wetaskiwin farming areas of Alberta. Irrigation was not used and was not a consideration. No manure was applied to farm lands. Manure from grazing animals is not considered as part of the crop input component (Rochette et al. 2008). N mineralization was assumed be at steady-state, therefore net mineralization was equal to 0.0 and soil mineralized-N not added to the sum of crop N-inputs. Relevant information for the ecodistrict as supplied by Worth and Desjardins (Pers. Comm.) were P/PE = 0.65, Emission factor $_{soil}$ = 0.0095 kg N_2O-N kg^{-1} N.

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Fertilizer-N applied and above ground residue and root contributions were determined and summed as direct emissions. Residue and root-N were quantified using actual data for residue dry matter, root mass and N concentration or using methods and ratios for product: above ground residue: root and appropriate N concentrations supplied by Janzen et al. (2003). All residue-N and root-N was assumed to be returned to the soil each year for annual crops (Janzen et al. 2003). Indirect N_2O-N emission consisted of leaching of fertilizer-N and root and residue-N that had mineralized within the year. In this case a leaching fraction $(FRAC)_{Leach} = 0.19$ kg N ha^{-1} of N-inputs and volatilization of applied fertilizer-N of = 0.10 kg N ha^{-1} of fertilizer-N inputs. Emission factor for leaching (EF_{Leach}) was 0.0075 kg N_2O kg^{-1} N ha^{-1} and the emission factor for volatilization = 0.01kg N_2O kg^{-1} N ha^{-1}.

Vegetation: bi-weekly above ground biomass dry matter with N and C composition and yield, LAI and stage; root dry yield, litter yield with N and C composition after harvest all at predetermined sites (n=6). Combine-Grain and standing biomass yield at maturity. Grain yield, grade, dockage and estimated oil, biodiesel, meal and protein yields.
Soil Analyses each fall with detailed analyses with texture and SOC down to 60 cm**.**

Results and Discussion

Objective 1. Farm-gate Canola Footprint
A life cycle assessment was revised and reviewed by qualified expert (Life cycle assessment of Western Canadian canola crop production: 1990 versus 2010. MacWilliam et al. 2014).
A manuscript was submitted and published in Agricultural Systems.
MacWilliam, S., Sanscartier, D., Lemke, R., Wismer, W., Baron, V. 2016. Environmental Benefits of Canola Production in 2010 compared to 1990: A life cycle perspective Agricultural Systems 145: 106-115.

An examination of the environmental effects of the production of one tonne of canola in the Grey, Black, and Dark Brown/Brown soil zones was performed for the time periods 2010 and 1990 to allow for an analysis of changes between the two time periods. The 1990 analysis was limited to Alberta and was conducted based on data from the high and low 30% of canola producers, based on yield, as complete and comprehensive LCA data were not available for all of Western Canada. From the comparison of canola production in Alberta circa 1990 and 2010, three main findings were identified.
There were three main findings:

1. When looking at the influence of field inputs and practices to the environmental effects of canola production, the major contributors were the production and use of fertilizers and the use of field equipment for on-farm practices and tillage.
2. The second finding was that the environmental profile of canola production per tonne has improved since 1990. The carbon footprint of the production of one tonne of canola was reduced between 1990 and 2010.

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Table 2. Carbon footprint or effects of one tonne of canola production for three soil zones in Manitoba, Saskatchewan and Alberta for the era of 2010; overall average 523 kg CO_2eq / Mg canola for western Canada.

Soil Zone	Manitoba	Saskatchewan	Alberta
	——kg CO_2eq / Mg canola——		
Grey	628	550	594
Black	564	489	499
Brown	N/A	469	494

The Grey soil zone resulted in the highest impacts to global warming, followed by the Black and Brown

soil zones. The reasons for the decrease in GHG emissions from the Grey to Black to Brown soil zones were reduced tillage, reduced fertilizer application, and reduced field emissions.

The results of the contribution analysis showed that the largest contributor to global warming was the nitrous oxide (N2O) emissions (34-63%) released as a consequence of applying synthetic and organic nitrogen to the soil (i.e. field emissions). Other notable contributors to global warming were the GHG emissions resulting from the combustion of fossil fuels for on-farm processes and tillage (8-22%), as well as the production of synthetic fertilizers (11-34%).

GHG emissions from the production of one tonne of canola in the Grey and Black soil zones were reduced by 24 and 27%, respectively, between 1990 and 2010 (no reduction in the Brown soil zone). More specifically, the production of one tonne of canola in Alberta in 1990 resulted in 786 kg CO2eq/tonne in the Grey soil zone (2010 Alberta Grey: 594 kg CO2eq/tonne), 681 kg CO2eq/tonne in the Black soil zone (2010 Alberta Black: 499 kg CO2eq/tonne) and 500 kg CO2eq/tonne in the Brown soil zone (2010 Alberta Brown: 494 kg CO2eq/tonne). The reductions in GHG emissions between 1990 and 2010 were primarily related to the reduction of field input amounts and on-farm practices and tillage required to produce one tonne of canola. Over the past two decades, fuel use for tillage and on-farm practices and amounts of fertilizers and pesticides production and application requirements for producing each tonne of canola were reduced. As a result of reduced fertilizer requirements and more efficient use of fertilizers, N2O field emissions, which are the largest contributor to the carbon footprint of canola production, have also been reduced.

The effects of land use change (LUC) and land management change (LMC) were taken into account as a sensitivity analyses. LUCs occur when land is converted from one use (e.g. forest) to another (e.g. cropland), while LMCs represent change in the management of croplands, for example tillage and summerfallow practices. In the 2010 era this type of management change accounted for a further reduction to 330 kg CO2eq/tonne of canola seed produced.

3. Also, reductions in the environmental effects were a result of increased yields and plant biomass from

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enhanced genetics and the adoption of HT and hybrid canola, as well improved crop production management practices. This is because the environmental effects of crop production are a function of input to yield. Notable improvements to management practices include the shift from conventional tillage to conservation tillage, the increase in direct seeding practices, and improved weed management strategies such as the reduced use of chemical weed control.

Objective 2: Canola greenhouse–gas intensity from a high yield –high input region

Production

Table 3 gives an indication of production costs and revenues for a single year.
Table 3. Production costs and revenue for early seeded barley and canola and late seeded canola in 2015

		Crop/system		
Component	Units	E. barley	Early canola	Late canola
Equipment cost				
Fixed	$ ha^{-1}	101.62	97.58	88.39
Operating	$ ha^{-1}	71.76	69.10	63.30
Total	$ ha^{-1}	173.38	166.68	151.69
Fuel consumption [z]	L ha^{-1}	32.9	31.7	29.2
Crop inputs [z]	$ ha^{-1}	262.31	505.67	392.25
Labor	$ ha^{-1}	28.67	27.87	25.47
Production total [z]	$ ha^{-1}	464.36	700.22	569.41
	$ kg^{-1} product	0.133b	0.315a	0.349a
Gross revenue	$ ha^{-1}	653.22b	986.37a	723.46b
Net revenue	$ ha^{-1}	188.86b	286.15a	154.05b

[z] no replicate variability
[y] Differences were calculated by multiplying the standard error of a mean difference by the value of t at the appropriate degrees of freedom.
[x] Barley priced at $180.00 T^{-1}; Canola at $441 T^{-1};

On average production and economics favoured early planted over late planted canola and early over late planted canola. Averaged over 5 years cost of production for early planted barley and early planted canola was $463 ha^{-1} vs. $634 ha^{-1}, gross revenue $765 vs $1417 $ ha^{-1} and net revenue $302 vs $783 ha^{-1}, respectively. Grain dry matter yield averaged 4,594 kg ha^{-1} and 3268 kg ha^{-1} for barley and canola, respectively. In the 3 years that late planted canola was compared with early planted canola, the late canola yielded 2,078 kg ha^{-1} compared to 3268 kg ha^{-1} and net revenue was $287 ha^{-1} vs $806 ha^{-1}. On average production and economics favoured early planted over late planted canola and early over late planted canola.

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Table 4. Oil, protein, nitrogen (N) carbon (C) carbohydrate and fiber and energy composition of the grain or seed portion for early planted canola and barley and late planted canola averaged over three years

Crop	Oil	Protein	N	C	Carb/fiber	Energy
		%				Mcal kg^{-1}
Early barley	1.90	12.52	2.0	42.9	82.58	4.32
Early canola	48.88	22.01	3.5	65.8	25.11	6.84
Late canola	47.14	23.63	3.8	65.5	25.23	6.77
LSD	0.83	0.51	0.1	1.06	0.88	0.04

Table 4 shows the higher oil, N, C and lower carbohydrate content of canola seed compared to barley grain. Energy content of canola seed was about 36.6% higher than barley as a result of the higher protein and oil. Carbon content of canola seed was 1.5 times higher than barley, which plays a role in carbon balance of the crop production system. There was very little difference in composition between early and late canola crops.

Greenhouse gas emission

Nitrous oxide

Table 5. Emissions[z] of nitrous oxide (N_2O) from soil, crop residues and fertilizer resulting from production of barley and canola crops averaged over 5 years calculated using IPCC (2006) methodology for Canada

	Direct	Indirect			CO_2e^y of
		Volatilization	Leaching	N_2O-N total	N_2O total
	kg ha^{-1}				
Early Barley	2.9	0.3	0.4	3.5	1036
Early canola	4.4	0.4	0.5	5.3	1565
LSD	0.36	0.03	0.04	0.42	124

[z] Fractions subject to emission and emission factors used were: Direct – 0.0095 kg N/kg N = 0.014 kg N_2O / kg N. Volatilization – fraction volatilized = 0.1. EF_v = 0.01 kg N / kg N. Combined factor =0.001 x 44/28 = 0.00157 kg N_2O / kg N. Fraction leached = 0.19. EF_L = 0.0075 Combined factor = 0.19 x 0.0075 x 44/28 = 0.0024 kg N_2O / kg N.

[y] Conversion factor for N_2O to CO_2e is 298.

Averaged over five years canola emitted significantly more nitrous oxide than barley, mostly due to the direct emission from fertilizer-N. When late planted canola was compared with early planted canola and barley both canola treatments emitted more nitrous oxide than barley and early canola more than late canola. On average, 50% of N available for emission was derived from fertilizer-N (Table 6) and in early canola it

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represented 55%. However, late canola had more residue-N than the other treatments, with residue –N representing 39% of the late planted canola total available N. Averaged over crops (Table 6) total available-N was made up of 50%, 31 and 19% from fertilizer, residue and roots.

Table 6. Sources of N contribution to nitrous oxide emission averaged over three years for early planted barley and canola and late planted canola

	Fertilizer-N	Residue N	Root N	Total available N
	kg ha^{-1}			
Early Barley	80.5	44.4	36.8	161.7
Early Canola	112.1	54.5	36.4	203.1
Late Canola	81.4	71.3	29.6	182.3
LSD	5.8	6.0	NS	9.4

Emissions from Energy or fossil fuel sources

Energy from fuel and that required to produce inputs, such as fertilizer, herbicides and seed packaging represented at least 95% of the energy expenditure for crop production whether barley or canola (Table 7). Thus because of more fertilizer inputs for early canola there were significantly greater energy inputs and significantly greater greenhouse gas emission (Table 7). Approximately 19% more energy in diesel fuel was used for barley than canola, mostly due to a higher work rate required when combining barley compared to canola. More time and energy is required when combining barley compared to canola. However, when early planted canola and barley were compared over five years greenhouse gas emission from energy based sources was 511 and 426 kg CO_{2e} ha^{-1}, respectively with canola significantly the higher.

Table 7. Energy consumption and greenhouse gas emissions associated with energy used in crop production

Crop	Energy from sources associated with crop production					Total energy emission
	Equipment			Crop inputs[z]	Total[y]	
	Fuel	Lubricants	Embodied			
	MJ ha^{-1}					kg CO_2e ha^{-1}
Barley	1595	6.2	226	5434	7326	438
Early canola	1337	5.3	194	6492	8040	481
Late canola	1254	5.0	184	5107	6559	394
LSD	57	0.2	7.2	534	574	19.7

[z] includes fertilizer, seed and herbicide
[y] includes storage energy of 15.6 MJ T^{-1}

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Averaged over five years the total greenhouse gas emission from N_2O and energy based sources was 1458 and 2073 kg CO_{2e} ha^{-1} for early planted barley and canola, respectively. Averaged over three years when late planted canola was grown total emission were lower from barley than canola even though late planted canola used approximately the same amount of fertilizer-N as early planted barley. Emissions were higher in canola than barely because of greater N_20 emission (Table 6). Energy based emission for early planted barley and canola represented 29 and 25% of total emissions respectively, averaged over five years.

Carbon Balance

During the three years when early planted barley and canola and late planted canola occurred together they yielded 5106, 3487 and 2078 kg ha^{-1} of dry matter, respectively. Each was significantly different from the other. However when carbon content of the grain or seed was taken into account (Table 4) carbon yield in grain for the early planted canola and barley was similar and late planted canola significantly lower (Table 8). Carbon content of canola grain was approximately 65% compared to 43% for barley grain. By contrast residue carbon for both canola treatments was greater than barley. These trends followed through to the five year averages for early planted barely and canola. The total carbon for root and residue by canola were higher than that for barley.

Table 8. carbon yield of seed residue and root and total C profile for early planted canola and barley and late planted canola averaged over three years

	Grain/Seed	Residue	Root	Total C
	kg ha^{-1}			
Early Barley	2191	2581	811	5582
Early Canola	2290	3443	741	6474
Late Canola	1350	3341	615	5305
LSD	188	281	60	466

The annual net ecosystem exchange (NEE) averaged over the years when late canola was planted indicated that all crops were CO_2 sinks where there was a net sequestration of C (Table 9). However when NEE was corrected for grain or seed removed (net biome) there was a biome loss for all crop treatments. In all cases however the amount of CO_2 equivalent removed from the ecosystem from grain and oilseed is greater than the NEE. Even though the NEE gain was relatively high and higher for early than late planted canola (Table 9) all crops were sources for C emission. In terms of C-sequestration the net biome loss indicated that early barley and late planted canola lost significantly more C (672 kg C ha^{-1} and 562 kg C ha^{-1}) than early planted canola compared to early planted canola (206 kg C ha^{-1}). The annual NEE flux was highly variable over years. When early barley and canola were averaged over five years NEE was similar (average -5448 kg CO_2 ha^{-1}), grain removal similar (average 7544 kg CO_2 ha^{-1}), but biome loss was 1492 and 2701 kg CO_2 ha^{-1} for early planted barley and canola respectively. This is equivalent to C-losses of 407 and 738 kg C ha^{-1} loss for early planted barley and canola respectively. Thus all cropping systems were net sources for C. The Century model

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estimates that cropland recently broken from grassland, with a high organic matter content as used in this research, loses approximately 0.5 Mg C ha^{-1} yr^{-1} (National Inventory Report 2011) due to respiration of organic matter.

Year to year variability was highest for NEE compared to N_2O and energy due to farm activity, because the latter were impacted by inputs which were more stable from year to year. NEE seemed to be impacted by the duration of net CO_2 uptake between early planted barley and canola, where during the three years in which late planted canola was compared average days of net uptake were 76, 100 and 84 days. Also when weather conditions permitted canola was more likely to take advantage of the extra growing days than barley.

Table 9. Carbon dioxide equivalent gain (negative) or loss for net ecosystem exchange (NEE), harvested grain and net biome gain or loss after grain removal for early and late planted canola and barley and late planted canola averaged over three years.

	NEE flux	Harvested grain	Net Biome
		kg CO_2eha^{-1}	
Early Barley	-5773.3	8033.2	2259.9
Early Canola	-7638.7	8396.2	757.6
Late Canola	-2890.0	4948.1	2058.2
LSD	2623	690	690

Greenhouse Gas Intensity

The greenhouse gas intensity or carbon footprint takes into account the net emission of nitrous oxide, CO_2 from energy sources and loss or gain of carbon dioxide or carbon from the system due to cropping practices. Averaged over three years early canola and barley had offsetting greenhouse gas emission, C-sequestration and yield but had essentially equal carbon foot prints.

The NEE indicates that on a CO_2 equivalent basis the emission of N_2O and energy from farm activities is readily offset by ecosystem CO_2 sequestration (Table 10). However, as stated previously (Table 9) the amount of CO_2 removed from the ecosystem in grain is greater than the NEE.

For the calculation of greenhouse gas intensity barley grain yield was high (5106 kg ha^{-1}) during these years and as a divisor made up for a difference in NEE between barley and early canola. In the case of early planted canola the high NEE was offset by relatively high N_2O emission and removal of grain, which was high in carbon content (65%). In addition the early canola grain yield on a dry matter basis was 3488 kg ha^{-1} so did not have as large an impact as a divisor as the barley yield in lowering the greenhouse gas intensity. Late planted canola the combination of low NEE and low grain yield resulted in a relatively high greenhouse gas intensity.

Find more information on this project and many other relevant canola studies on the Canola Research Hub.
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Table 10. Summary of greenhouse gas emissions, grain removed and greenhouse gas intensity for early and late planted canola and late planted barley averaged over three years.

	N_2O	Energy	NEE	Grain removed	Intensity
	kg CO_2e ha^{-1}				kg CO_2e kg $grain^{-1}$
Early barley	1045	438	-5773	8033	0.73
Early canola	1303	481	-7639	8396	0.73
Late canola	1196	393	-2890	4948	1.76
LSD	68	19.7	2623	690	

Greenhouse gas intensity = (N_2O + energy +NEE +grain removed as kg CO_2 e ha^{-1}) / grain dry matter yield (kg ha^{-1}).

On the basis of the greenhouse gas intensity for the three years early planted barley and canola were similar, while late planted canola about 2.5 times larger due to lower grain yield even though overall emissions were lower than the early planted counterparts.

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