# 9

# Implications of Biofuel Feedstock Crops for the Livestock Feed Industry in Canada

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## 1. Introduction

The rapid growth of liquid biofuel production could eventually require three or four times the amount of land currently used to supply the feedstock for biofuels (FAO, 2008). The 2007 US Energy Independence and Security Act set the target for 2022 for national ethanol production at nearly four times the present production. It is predicted that this goal would result in the largest and most rapid changes in land use in history (Sinclair and Sinclair, 2010), especially when combined with the similar changes that can be expected in Canada (Klein and LeRoy, 2007).

In spite of the major impact on agriculture that can be expected from such change in land use, biofuels will satisfy a relatively small share of the fuels needed for transportation (FAO, 2008; Karman et al., 2008). Consequently, small increases in the addition of ethanol to gasoline (from 5% to 10%) have meant very large changes in crop distributions (Dufey, 2007; Fritshe et al, 2009). The adoption of 5% biodiesel in Canada could have a similar impact on land use (Dyer et al., 2010a). The increased demand for biofuel may, in turn, lead to higher retail prices for meat and dairy products because of higher livestock feed costs (Zhang and Wetzstein, 2008). Agricultural policy must take the growth of biofuels into account as part of planning for future food security.

Since anthropogenic global warming/climate change will likely be the greatest challenge to mankind in the 21st century (thanks to our addiction to oil), renewable energy supply and Greenhouse Gas (GHG) emissions are the prime justification for biofuel production (Karman et al., 2008). If properly developed, biofuels can potentially help to reduce fossil $CO_2$ emissions from transport (IEA, 2004; Klein and LeRoy, 2007; Murphy, 2008). Because of the sensitivity of the agricultural resource base to the expansion of biofuel feedstock production, the real potential reduction in GHG emissions from biofuel should take into account any related changes in land use. Such changes should include both the use of the actual land on which the biofuel feedstock was grown and any secondary, or indirect, shifts in land use (Dyer et al., 2011). In addition, land use effects may end up being as important in altering weather as changes in climate patterns associated with GHG buildup (Pielke, 2005).

While it is not clear whether the impacts on food production from increased biofuel feedstock production will always be negative, some shrinkage of resources available to produce livestock feed is expected (Auld, 2008; Klein and LeRoy, 2007). The objective of this chapter was to assess the impact from a shift in land use on the GHG emissions from the Canadian livestock industries. To achieve this goal, the actual area changes will first be identified. While the purely ecological concerns are beyond the scope of this chapter, we recognize that the reallocation of land from livestock feed to feedstock production may re-align several of Canada's agro-ecosystems. The integrity of these agro-ecosystems, particularly those that involve livestock production, will involve a range of environmental considerations, including biodiversity, soil structure or the water cycle (Vergé et al., 2011).

## 2. Background

In order to decrease dependence on foreign oil in the USA, the Bush administration introduced incentives in 2005 to stimulate the ethanol industry (Whyte, 2008). The result has been rapid growth in the grain ethanol and biodiesel industries over the last five years in both Canada and the USA. Historical trends prior to this period, therefore, provide the only realistic baseline for this assessment. Although Canada does not have the same energy security concerns as the USA, the Canadian biofuel industries are still growing (Klein et al., 2004). The growth of the US biofuel industries, particularly grain ethanol, will have inescapable economic consequences for Canadian livestock producers, regardless of how these industries develop in Canada.

An important spinoff from replacing livestock feed crops with biofuel feedstock crops is the expanded market opportunities for crop producers (IEA, 2004). Whereas most field crop producers should gain economically from the increase in grain prices, livestock farmers are expected to suffer from the rising costs of feed (FAO, 2008; Khanna et al., 2009). From 2006 to 2008, livestock feed prices nearly doubled, in part because of increasing use of corn for ethanol (GAO, 2009). Almost one-third of the US corn crop in 2008 was used for ethanol production. The amount of land available for grazing cattle has also been declining. In 2007 corn used for ethanol production in Canada increased by about 34% while corn grown for feed increased only slightly (Sawyer, 2007).

### 2.1 Biofuel industry profiles

An environmental impact assessment of biofuel feedstock production on Canadian agro-ecosystem biodiversity used case study scenarios from canola biodiesel, cellulosic ethanol, and corn ethanol (Dyer et al., 2011). Several other possible scenarios were identified in that assessment, including wheat-based ethanol in western Canada and soybean-based biodiesel in eastern Canada. Dyer et al. (2011) predicted only minor impacts from the latter two biofuel industries. Wheat used as a feedstock in western Canada is a small share of the wheat that goes into the food market and should result in very little shrinkage in the land available to support livestock in that region. Since this diversion to biofuel feedstock provides a market for low quality wheat (EIC, 2010), there should be minimal environmental impacts from the production of wheat for ethanol feedstock.

Some use of soybeans for biodiesel feedstock is already in operation in eastern Canada (McKague, 2009). But high corn prices have still tempted many Ontario farmers to stray from their usual corn/soybean crop rotation in order to raise more corn (Sawyer, 2007). A stronger market for biodiesel made from soy oil would stimulate soybean production in the corn growing regions of Canada and displace some of the expanding popularity of corn in central Canada, and thus slow the trend towards a corn monoculture. Therefore, the net impact from soy-biodiesel on the environment should be positive. Since soybean meal, the biggest fraction of this crop (Halliday, 2003; Yacentiuk, 2001), is still available as feed, the impact from soy-biodiesel on livestock feed supply would be minimal.

When cellulosic ethanol facilities become commercially viable, they could replace older grain ethanol facilities, creating more demand for biomass (Simpson, 2009). This certainly would be the case in the US with their national ethanol production target for 2022 of 86.4 billion liters of ethanol per year from non-grain feedstock (Sinclair and Sinclair, 2010). However, the quantitative changes resulting from biomass feedstock for cellulosic ethanol are highly speculative at this stage because this industry is still in its infancy. Since biomass can be produced on almost any class of land, the only land use shift would likely involve moving cattle from higher to lower quality grazing land (Sawyer, 2008). The changing use of rangelands have not attracted as much interest with respect to GHG emissions as have impacts from cattle displaced into forested areas (Baker, 2010). However, if rangeland was used to either support biomass production or to graze too many displaced cattle, biodiversity loss from those previously-undisturbed rangeland habitats would be a greater concern than increased GHG emissions (Dyer et al., 2011).

### 2.2 Livestock GHG emissions in Canada

Agriculture and Agri-Food Canada (AAFC) researchers undertook to make an inventory of GHG emissions from livestock farms in Canada (Dyer et al., 2010b). This inventory procedure recognized that farm animal populations are limited by the area available to grow the feed grains and forage they consume. Consequently, animal-based production cannot be effectively assessed without first determining the GHG emissions from growing those crops. The land base on which those crops are grown was defined as the Livestock Crop Complex (LCC). The cost of feedstock crop production must include $N_2O$ emissions, farm inputs and farm fossil energy use (Reijnders, 2008). Therefore, manure and enteric methane emissions, nitrous oxide from nitrogen fertilizer and manure, and fossil carbon dioxide emissions associated with feed grain and forage production in the LCC were part of the AAFC methodology for the livestock GHG emissions assessment (Vergé et al., 2007).

Commodity-specific crop complexes were defined for the Canadian beef, dairy, pork and poultry industries (Vergé et al., 2007; 2008; 2009a,b). For each livestock industry, the crop type composition and amount of each crop in the respective diet defined the total crop area in each respective crop complex. This methodology also exploited the differences in diet among age-gender categories of each type of livestock (Elward et al., 2003). Historical GHG emission trends were generated from the statistical assessments for the four livestock industries (Dyer et al., 2008; Vergé et al., 2008; 2009a,b) over the 1981 to 2006 census years (5-year intervals). The whole set of required computations were assembled together in one unified spreadsheet model that can be driven by agricultural census records of livestock populations. This unified model has been used to estimate protein-based GHG emission intensities (Dyer et al., 2010c).

## 3. Methodology

Simplistic approaches are unlikely to deliver a sustainable biofuel industry or contribute to the climate change challenge (Otto, 2009). Estimating GHG emissions from livestock requires a detailed and deterministic set of estimates for those emissions prior to, or in the absence of, the growth of the biofuel industries. The same methodology must be applicable to altered livestock industries under a range of scenarios for those expected biofuel crops. The unified spreadsheet model for livestock GHG emissions in Canada (mentioned above) provided the GHG estimates used in this chapter. The 2001 livestock GHG emission estimates from this model were used as the baseline GHG emissions for the pre-Bush Administration incentives in this chapter.

The environmental impacts from livestock feed production are specific to agro-ecosystems (Vergé et al., 2011). Therefore, the effects of expanding biofuel feedstock production into areas that had previously been used to grow livestock feed will also vary by region. The only areas of the two feedstock crops (corn and canola) that will be considered are those areas that will encroach on the land dedicated to producing feed grains for livestock. Six hypothetical scenarios involving canola biodiesel and corn ethanol used in this chapter to demonstrate the biofuel feedstock and livestock feed interactions in Canada are summarized in Table 1. The expected or required volumes of ethanol or biodiesel were used to estimate the required weights of grain corn or canola to be diverted to feedstock and away from livestock. Any corresponding shrinkage in the respective livestock GHG emissions were then added to the fossil fuel savings from each respective biofuel type.

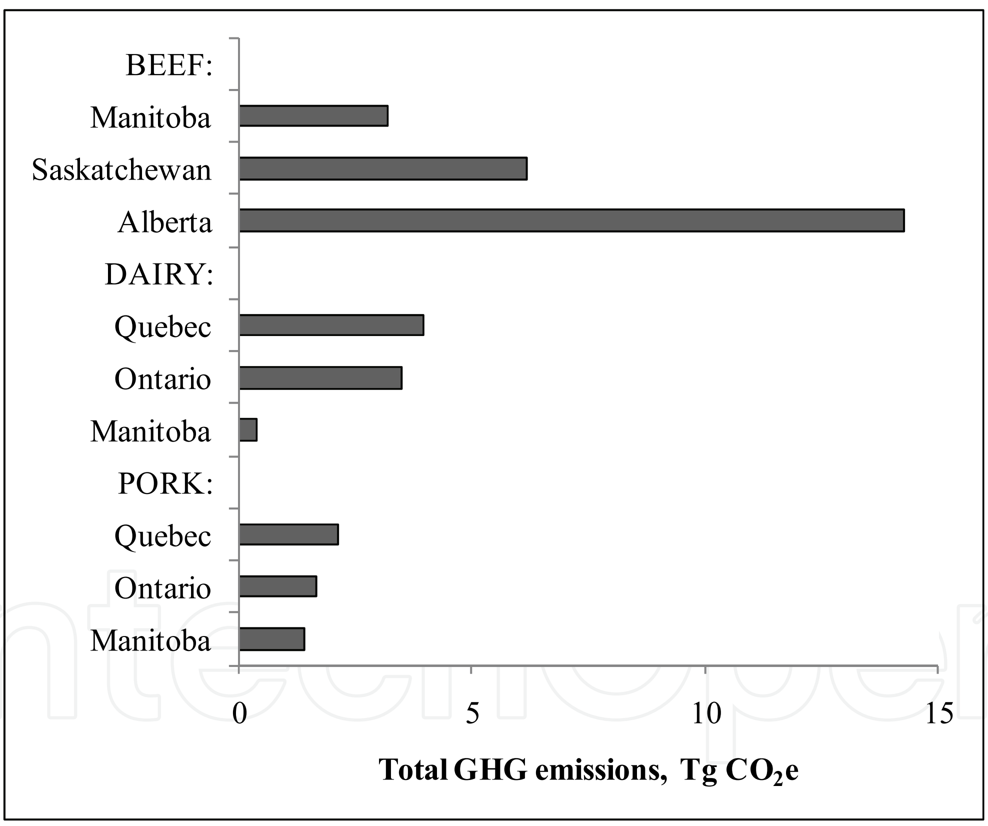


Fig. 1. Total GHG emissions from beef farms in the three Prairie Provinces and from dairy and hog (pork) farms in the three central provinces of Canada in 2001

The 2001 GHG emissions from dairy, beef and hog farms as estimated by Vergé et al. (2007; 2008; 2009) were used as the baseline for the livestock-related GHG emissions in this analysis. Those GHG emission calculations were re-run for this analysis with the virtual age-gender category and total population changes required to test each of the three livestock types. Since the goal of this chapter was to compare the total $CO_2$e emissions of GHG with the avoided fossil $CO_2$ from biofuels, only the total GHG emissions are shown in Figure 1, rather than specific types of GHGs. In this application, avoided emissions refer to the net amount of fossil fuel that would not be burned as a result of the increase in biofuel energy assumed in this analysis.

### 3.1 Biofuel feedstock area and avoided fossil fuel

The starting point for the conversion of biofuel to both the feedstock area and avoided $CO_2$ emissions from fossil fuel was an assumed target energy quantity of 8 PJ. For equivalent fossil $CO_2$ emissions, energy was converted to the equivalent volumes of diesel at 36 MJ/litre and gasoline at 32 MJ/litre (Karman et al., 2008). With $CO_2$ emissions per volume of liquid fossil fuel of 2.73 and 2.36 kg/litre for diesel and gasoline, respectively (Neitzert et al., 1999), the weights of $CO_2$ emissions from the initial quantities of bioenergy from these two fuels could then be calculated.

With $CO_2$ emissions per unit of energy given by Jaques (1992) as 70.69 t/TJ for diesel and 67.98 t/TJ for gasoline, the weights of $CO_2$ from these fossil fuels could also be calculated (as a cross-check) directly from the assumed energy. The weights of $CO_2$ emissions to produce and consume a litre of fuel (Peña, 2008), expressed as an index of gasoline, provided a basis by which to derive the net avoided fossil $CO_2$ as a result of using biofuels. This index gave the fossil $CO_2$ emission cost of corn ethanol produced with natural gas as 68% of gasoline, whereas biodiesel is given as 52% of gasoline and 47% of petro-diesel. Hence the substitution value of corn ethanol for gasoline was 32% of the imbedded $CO_2$ emissions and the substitution value of biodiesel for petro-diesel was 53%.

The assumed target energy quantities were converted to the equivalent volumes of canola oil at 34 MJ/litre and ethanol at 21 MJ/litre (Karman et al., 2008). The volumetric energy of ethanol reflects the relatively low energy content per unit volume compared to gasoline (Karman et al., 2008). An average estimate of 377.5 litres of ethanol per t of grain corn was derived from three literature sources (AAFC, 2009; Bonnardeaux, 2007; Hardin, 1996). The tons of feedstock crop (F) of grain corn (*gc*) was computed as:

$$F_{gc} = V_{\mathrm{ethanol}} / 377.5 \quad (1)$$

Since canola loses 39% of its weight during oil extraction (Vergé et al., 2007), and the density for canola oil is 0.915 kg/litre (Elert, 2000), the weight in tons of feedstock crop (F) of canola seed (*cs*) was computed from the volume in litres of canola oil as:

$$F_{cs} = 0.915 \times V_{\mathrm{canola\ oil}} / 0.39 \quad (2)$$

The two biofuel byproducts, dry distillers grain (DDG) and canola meal, were added back into the respective livestock diets to offset some of the expected shrinkage from these LCC area losses. Both of these byproducts were treated as high energy grain substitutes, rather than as extra roughage for ruminants. The DDG byproduct from the ethanol processing was 31.9% of the grain corn feedstock weight (Bonnardeaux, 2007). The canola meal byproduct from the biodiesel processing was 61% of the canola feedstock weight (Vergé et al., 2007). While they are both high in protein (McKague, 2009; EIC, 2010), the dietary benefits of this protein were ignored in this analysis. These feedstock weights were factored by provincial crop yields to estimate the crop areas needed to produce these fuel volumes. The scenario tests involved the subtraction of these estimated net feedstock crop areas from the respective LCC areas.

### 3.2 Livestock scenarios for biofuel expansion

For cattle, producers may respond to less available feed grain by feeding more forage, a system that has proven to be economically viable in some countries (Casey and Holden, 2005, 2006). This strategy was the basis of Scenarios B1 to B4 for beef (described below). In Ontario and Quebec, however, virtually all arable land is in cultivation and so no land would be available to expand forage production to compensate for reduced grain corn supply (Whyte, 2008). The two Central Canada scenarios are as follows.

- Scenario D: given the lack of land for expanding forage production, no attempt was made to redefine the balance between grain and roughages (forage) in dairy cow diets to accommodate the changing crop distribution in the LCC. When the supply of feed grain in the dairy cattle diet was reallocated to feedstock, reduction of the entire population was assumed, rather than adjusting the herd for possible increased roughage consumption.
- Scenario P: no forage crops are involved in the non-ruminant hog diet. The Canadian hog population includes either breeding stock or animals destined for slaughter, with almost no differences in diet between the two categories. Therefore, reductions in the total populations were assumed for the pork industry, in response to reallocation of land in annual crops to feedstock production.

| Scenario | Required action | Animal type | Feedstock | Biofuel | Region |
|---|---|---|---|---|---|
| B | | Beef | Canola | Biodiesel | Prairie Provinces[1] |
| B1 | Send the calves and yearling slaughter animals in feedlots for slaughter. | | | | |
| B2 | Transfer calves and yearling slaughter animals in feedlots from a grain diet to the predominantly forage-based diet of replacement heifers. | | | | |
| B3 | Feed all slaughter and replacement animals the same forage-based diet as the grazing, breeding cattle. | | | | |
| B4 | Reduce the whole beef population across all age-gender categories. | | | | |
| D | | Dairy | Grain corn | Ethanol | Central Canada[2] |
| | Reduce the whole dairy population across all age-gender categories. | | | | |
| P | | Pork | Grain corn | Ethanol | Central Canada[2] |
| | Reduce the whole hog population across all age-gender categories. | | | | |

[1] Manitoba, Saskatchewan and Alberta
[2] Quebec, Ontario and Manitoba

Table 1. Scenarios used to test the effect of reallocating farmland from feed grains used in the Canadian livestock industry to feedstock crop production for biofuel

### 3.3 Scenarios for western Canadian beef

Because the Canadian beef industry is a mix of grain-based and grazing-based production systems, several farm level responses are possible from the expansion of canola feedstock areas into the beef crop complex (BCC). The Canadian beef industry is also unique in that these different production systems are typically managed independently (ranches and feedlots under different ownership), with different decision processes (Vergé et al., 2008). The four possible scenarios specific to beef (B) production (Table 1) were ranked in order of the number of beef animal categories they affected. Because of the complexity of the western Canadian beef industry, the age-gender category populations (as defined by Vergé et al. (2008)) and the mean live weights are summarized in Table 2. The grain-based differences in diet among the age-gender beef categories are illustrated in Figure 2.

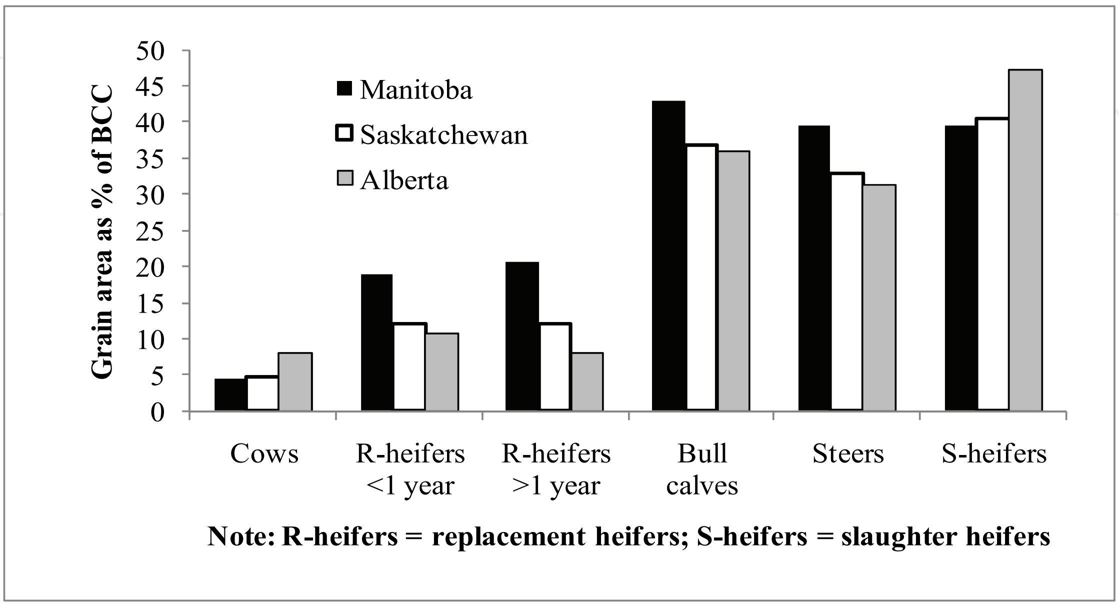


Fig. 2. The areas in feed grains as % of the Beef Crop Complex (BCC) for six age-gender categories in each prairie province of Canada in 2001

Two beef scenarios are similar to the dairy (D) and pork (P) scenarios. In scenarios B1 and B4 changes were limited to the outright removal of animals from the system, rather than reallocation of animals from one livestock category to another within the same industry. The other two scenarios (B2 and B3) were based on shifting the diet of one or more age-gender livestock categories to the diet of other categories that consume less grain. From a feed supply perspective, a number of yearling steers would be re-designated as range-fed breeding cows, for example, taking into account the difference in their respective live weights. These two scenarios required more grain area to be reallocated than the area needed to produce the desired biodiesel energy. This was because some additional area of grain is needed to meet the grain dietary components of the expanded population of the new category.

- Scenario B1: the impact would be limited to the reduction of the slaughter cattle (slaughter calves, steers and non-replacement heifers), mostly in feedlots. The assumption behind this scenario was that, with less grain or high energy feed, there would be no value in keeping these animals alive during the period they would normally be in the feedlot. Hence, they were slaughtered straight away and thus eliminated from the industry (and its carbon footprint).
- Scenario B2: instead of immediate slaughter of these animals (from Scenario 1), they would be kept on a diet equivalent to that of the replacement heifers, which is based on more forage and less grain than that of slaughter animals. Hence the impact would be broadened to include the population expansion of the replacement category by the slaughter animals. In this assumption, these animals become mainly grass-fed, rather than mainly grain-fed, beef. With respect to diet-based GHG emission calculations

(Vergé et al., 2008) they became virtual replacement heifers, with allowance for the live weight differences (Table 2).

- Scenario B3: both slaughter and replacement beef cattle are transferred to a predominantly forage-based diet. The components of this grazing-based diet would be defined by the prairie beef ranch where the breeding cows are maintained. Hence the cattle being transferred (slaughter calves, steers, replacement and non-replacement heifers, and bull calves) are treated as virtual grazing, breeding beef cows, with corrections for live weight differences (Table 2).
- Scenario B4: the impact of less high energy feed being available to the feedlot industry would be felt throughout the whole beef production system. The assumption behind this scenario was that beef producers have become sufficiently dependent on marketing their product through a high feed energy finishing process (the feedlot) that, without sufficient feedlot capacity, the unfinished beef would not be economically viable, and so the impact would be felt throughout the entire industry.

| | Breeding stock | | Replacemant heifers | | Bull | For slaughter | | Calves |
|---|---|---|---|---|---|---|---|---|
| | Bulls | Cows | > 1 year | < 1 year | calves | Steers | Heifers | < 3 months |
| Provinces | Head of beef cattle x $10^3$ | | | | | | | |
| Manitoba | 25 | 545 | 114 | 132 | 85 | 120 | 89 | 116 |
| Saskatchewan | 60 | 1,200 | 254 | 284 | 174 | 216 | 68 | 234 |
| Alberta | 104 | 2,028 | 1,083 | 621 | 372 | 438 | 760 | 497 |
| | Live weight, kg/head | | | | | | | |
| Manitoba | 765 | 671 | 490 | 319 | 319 | 356 | 451 | 153 |
| Saskatchewan | 712 | 601 | 467 | 317 | 317 | 371 | 443 | 150 |
| Alberta | 666 | 609 | 539 | 315 | 315 | 386 | 505 | 142 |

Table 2. Populations and live weights of beef cattle by age-gender categories in the three Prarie provinces of Canada in 2001

In Scenarios B2 and B3 it was assumed that the expansion of the grass-fed slaughter animals would be based on land capable of growing perennial forage but not annual grains or oilseeds. While this is typically marginal land, it is not necessarily publically-owned rangeland. In Canada, the only significant quantities of such land would be in the western provinces. This assumption brings new land into production (albeit under permanent cover) and potentially raises the net GHG emissions from beef production. It also raises the possibility of non-GHG related impacts on the land being brought into production (IRGC, 2008; Vergé et al., 2011). Because this land would probably be managed as improved pasture or hay, the chemical inputs and introduced forage crops could threaten biodiversity (Dyer et al., 2011).

### 3.4 Area reallocation calculations

Adjustment of the category populations called for in the respective scenarios was achieved through the ratio of the net feedstock area ($A_{nc}$) to the baseline areas of annual crops. The net converted (*nc*) area for feedstock (*fs*) was adjusted for the land freed from feed production by the biofuel byproduct (*bf*) (IEA, 2004) as follows:

$$A_{nc} = A_{fs} - A_{bf} \tag{3}$$

where
$A_{fs}$ = area to grow the biofuel feedstock crop
$A_{bf}$ = area required to grow the feed equivalent to the weight of feed byproduct
The ratio of the net converted feedstock area to the BCC feed grain areas (AR) of the beef categories being displaced was calculated as a fraction of the BCC:

$$AR = A_{nc} / \sum^{c} A_{beef,c} \tag{4}$$

Thus the reduced ($r$) beef population ($P_{r,c}$) for each age-gender category ($c$) was computed as:

$$P_{r,c} = P_{bl,c} \times AR \tag{5}$$

where
$P_{bl,c}$ = the baseline ($bl$) population (P) in each beef animal category ($c$).
Based on the changed beef populations, the areas in forage (mainly perennial grass, alfalfa and hay) were recalculated by re-running the unified livestock GHG emissions model with these re-aligned beef cattle populations.

## 4. Results and discussion

### 4.1 Overview of Canadian agricultural land use

Table 3 shows three levels of area data on an east-west basis. The crop areas needed to feed Canadian livestock (beef and dairy cattle, swine and poultry) are shown as the first level in Table 3. To put these LCC areas into context, they are compared to the national crop areas as reported in the 2001 agricultural census. Any areas in each crop type that do not supply livestock feed were excluded from the LCC (Dyer et al., 2010b). In the second level, only the types of crops used in animal diets (as identified in the LCC) are included, but the entire areas planted for those crops in Canada are given, regardless of whether they are used to feed livestock. In the third level, all types of field crops were taken into account, and the entire area planted to each of those crops is included. The crop types were grouped as either grains (including oilseeds) or forages.

On a national basis, forages represented more than 60% of the LCC. The largest portion of the LCC was in the western provinces (70% of the total). In eastern Canada, areas were evenly distributed between grains and forages. This was very different in the west, where the area for forages (9.3 Mha) was twice as high as the area for grain (4.4 Mha). Table 3 illustrated that most of the cultivated crop types correspond to those used for animal feed. The difference between Level 2 and Level 3 was only 3.25 Mha. Since forages were grown exclusively for animal feed, all of this difference was accounted for by the grain crops. In the west, grains and oilseeds represented about 70% of all crop lands, whereas there was almost no difference between grains and forages in the east.

Table 3 also illustrates that the LCC represented almost half the total Canadian crop land. The grain portion of the LCC represented about one fourth of the total grain and oilseed areas. The small difference in forage areas between Levels 2 and 3 was due to sheep and horses not being included in the LCC (Dyer et al., 2010b). About 80% of grain areas in the east were used for animal feed (2.84 Mha compared to 3.53 Mha). In the west, feed grains only accounted for 17% (4.38 Mha compared to 25.04 Mha) of the western grain areas.

| Regions | Grains & oilseeds | Forages | Total |
|---|---|---|---|
| | Mha | | |
| | Crop areas included in the LCC[1] | | |
| East[2] | 2.8 | 2.6 | 5.5 |
| West[3] | 4.4 | 9.3 | 13.7 |
| Canada | 7.2 | 11.9 | 19.2 |
| | All areas for only those crops in the LCC | | |
| East | 3.3 | 2.8 | 6.0 |
| West | 22.0 | 9.6 | 31.6 |
| Canada | 25.3 | 12.4 | 37.7 |
| | All areas for all Canadian crops | | |
| East | 3.5 | 2.8 | 6.3 |
| West | 25.0 | 9.6 | 34.6 |
| Canada | 28.6 | 12.4 | 40.9 |

[1] Livestoc Crop Complex for beef, dairy, hogs and poultry
[2] Atlantic Provinces, Quebec and Ontario
[3] Manitoba, Saskatchewan, Alberta and British Columbia

Table 3. Overview of the use of arable land in Canada, as recorded in the 2001 agricultural census in relation livestock

### 4.2 Reallocations of livestock areas to biofuel feedstock

Table 2 shows the complexity of the Canadian beef industry, particularly when the differences in the way replacement stock and animals destined for slaughter are taken into account. This complexity was a critical factor in the response by beef farmers to changes in feed grain areas and the need for four test scenarios for this industry. The largest share of the provincial beef populations was in the breeding categories (replacement heifers and cows). These animals were also the heaviest. The Alberta beef cattle population is almost twice as high as the Saskatchewan population which is more than twice as high as the Manitoba population. There were appreciable differences among the age-gender categories with respect to both population and live weights.

Only the six categories that were involved in the four beef cattle scenarios are shown in Figure 2. All grains, pulses and oilseeds in the beef diet were grouped together as feed grains. The dependence on grain consumption shown in Figure 2 varies noticeably among the age-gender categories. The percent of the total area supporting the cattle (the BCC) on which feed grain was grown in 2001 demonstrates that, among the cows and replacement heifers, only a small share of their diet was in grains. In comparison, the diet for the cattle destined for slaughter required that almost half of the areas that feed slaughter animals be in grain production. Grain consumption by the breeding cows was much less than by the replacement stock. The differences in diet among the age-gender categories were quite consistent across the three provinces.

Table 4 shows that the baseline area (in the LCC prior to any area reallocation for ethanol feedstock) for hog and dairy farms was much higher than the areas being reallocated to corn ethanol feedstock production. The small area for corn for feedstock use in Manitoba reflects the relatively low acreages of this crop in Manitoba in 2001. The changes in area shown for forage are due to a reduction in areas of forage required for dairy cattle as a result of reduced feed grain and shrinkage of the dairy population. In the Ontario and Manitoba dairy industries, the areas in forage only moderately exceeded the areas in feed grains, but in Quebec the forage area was more than twice the area in feed grains. The areas in feed grain to support the hog farms was about the same in all three central Canadian provinces, while feed grain areas for dairy suggest a much smaller dairy industry in Manitoba than in the other two provinces.

| | Corn ethanol[1] | Feed grain baseline | | Forage for dairy | |
|---|---|---|---|---|---|
| | | hogs | dairy | baseline | changes |
| Provinces | | Mha | | | |
| Quebec | 42 | 582 | 238 | 597 | 48 |
| Ontario | 66 | 574 | 421 | 551 | 57 |
| Manitoba | 5 | 605 | 57 | 87 | 11 |

[1] are also equal to changes in feed grain areas for hog and dairy farms

Table 4. Areas required to support the Canadian pork (hog) and dairy industries and the changes in those areas in order to increase corn production for 8 PJ of bio-ethanol energy supply

For the beef industry, the feed grain areas shown for scenarios B1 and B4 in Table 5 were equal to the areas reallocated to canola feedstock areas for this analysis. This was a necessary condition of this analysis for these two scenarios. For the two scenarios in which beef cattle were transferred to other age-gender categories (B2 and B3), the area changes shown in Table 5 for categories of the animals being transferred were appreciably greater than the areas of expanded canola. However, the net change in feed grain area was still equal to the area reallocated to canola expansion. The difference between the feed grain area changes shown for B2 and B3 (Table 5), and the expanded canola area reflected the consumption of at least some feed grain by cattle transferred to the replacement or breeding stock diets (Figure 2).

| | Beef diet baseline | Scenarios for beef production | | | |
|---|---|---|---|---|---|
| | | B1 | B2 | B3 | B4 |
| Provinces | | Mha, feed grains | | | |
| Manitoba | 223 | 56 | 89 | 62 | 56 |
| Saskatchewan | 380 | 144 | 187 | 191 | 144 |
| Alberta | 1,106 | 99 | 115 | 141 | 99 |
| | | Mha, forages | | | |
| Manitoba | 1,108 | 86 | 0 | 0 | 279 |
| Saskatchewan | 2,652 | 266 | 20 | -356 | 925 |
| Alberta | 4,371 | 130 | 1 | -134 | 1,113 |

Table 5. Areas required to support the Canadian beef production and the changes in those areas in order to increase canola production for 8 TJ of biodiesel energy suply

For scenarios B1 and B4, Table 5 showed reductions in the forage areas that were greater than the feed grain areas for expanded canola. Scenario B2 showed no appreciable reduction in forage areas, whereas for B3, the transfer of the slaughter animals to the diet of the breeding animals in Saskatchewan and Alberta actually required increases. In this case, the area changes are shown as negative quantities because they represent forage area that had to be taken from other uses instead of being freed for other uses. The decreased forage areas in B1 were from one and a half to twice as high as the expanded canola areas, while the decreased forage areas in B4 were 4 to 10 times as high as the expanded canola areas.

### 4.3 Changes in GHG emissions from feedstock expansion

Figure 1 presents the total provincial GHG emissions from the three livestock industries considered in this analysis. The largest GHG emitters were the Alberta and Saskatchewan beef industries, followed by the Manitoba beef industry and the Quebec and Ontario dairy industries. The Manitoba dairy industry was the lowest GHG source. These GHG emissions are primarily $N_2O$ and $CH_4$ (Desjardins et al., 2010).

| | Tg $CO_2$e | | | | | Gg $CO_2$e/PJ{biofuel} | | |
|---|---|---|---|---|---|---|---|---|
| | Corn | Farm-related | | Ethanol plus farm | | Corn | Ethanol plus farm | |
| Provinces | ethanol | Dairy | Pork | Dairy | Pork | Ethanol | Dairy | Pork |
| Quebec | 0.069 | 0.635 | 0.149 | 0.704 | 0.218 | 24 | 240 | 74 |
| Ontario | 0.114 | 0.517 | 0.188 | 0.631 | 0.302 | 24 | 130 | 62 |
| Manitoba | 0.005 | 0.029 | 0.008 | 0.035 | 0.013 | 24 | 153 | 58 |

Table 6. Avoided $CO_2$ and farm-related greenhouse gas (GHG) emissions, and the intensities of avoided emissions as a result of displacing dairy and pork production with corn for bio-ethanol feedstock in the three central provinces of Canada in 2001

The results for hog and dairy farms are both shown in Table 6 because the only scenario involved in the two ethanol feedstock expansion tests was a decrease in the entire population. The avoided GHG emissions from the changes in both the pork and dairy production systems far exceeded the avoided fossil $CO_2$ emissions resulting directly from the corn ethanol energy. This difference was most evident in Quebec where the dairy diet was more heavily dependent on forages. The last three columns of Table 6 use the intensity of avoided GHG emissions to put these comparisons on a basis that can be extrapolated to larger quantities of biofuel energy.

Table 7 shows that the enhancement of avoided GHG emissions was much less certain for the beef industry than for the pork and dairy industries. In the B4 scenario (5$^{th}$ column) where the whole population was reduced (just as with pork and dairy), the savings in emissions were overwhelming in comparison to the directly avoided $CO_2$ emissions by bio-ethanol. This was because of the greater dependence of beef over dairy on forages. Under Scenario B1 (2$^{nd}$ column of Table 7), feedlots would be the most affected activity of the beef industry since most of the cattle in these two age-gender categories are finished for market in feedlots in Canada. Even in this scenario, which involved the elimination of the high feed grain based finishing of slaughter animals without any increase in grazing, the avoided on-farm GHG emissions exceeded the directly avoided $CO_2$ emissions by bio-ethanol by several times.

In scenarios B2 and B3 (the 3$^{rd}$ and 4$^{th}$ columns of Table 7), the opposite trend is evident. This was because the transfer of beef cattle into more forage based diets meant that the consumption of forages by the beef cattle population increased more than the grain consumption was decreased. The effect of dietary changes from one age-gender category to another on crop distributions in the BCC was evident in Figure 2. These dietary differences meant that, under scenarios B2 and B3, total cattle numbers would have to undergo little change. With greater use of forage (and a higher roughage share in the diet) enteric methane emissions would increase rapidly (Desjardins et al., 2010). Although the B1, B2 and B3 scenarios were considered much more realistic than B4, the latter scenario provided a useful perspective and boundary condition on the set of possible responses by the beef industry.

| | Canola biodiesel | Scenarios for beef production | | | |
|---|---|---|---|---|---|
| | | B1 | B2 | B3 | B4 |
| | Tg of avoided | Tg $CO_2$e | | | |
| Provinces | fossil $CO_2$ | Farm-related GHG emissions | | | |
| Manitoba | 0.067 | 0.245 | -0.080 | 0.138 | 1.574 |
| Saskatchewan | 0.143 | 0.538 | -0.098 | -0.565 | 4.219 |
| Alberta | 0.111 | 0.315 | -0.151 | -0.358 | 7.118 |
| | | Total GHG emissions | | | |
| Manitoba | - | 0.312 | -0.012 | 0.206 | 1.642 |
| Saskatchewan | - | 0.681 | 0.045 | -0.422 | 4.363 |
| Alberta | - | 0.426 | -0.040 | -0.247 | 7.229 |
| | Gg $CO_2$e/PJ{biodiesel} | | | | |
| Manitoba | 40 | 186 | -7 | 123 | 980 |
| Saskatchewan | 40 | 191 | 13 | -118 | 1,224 |
| Alberta | 40 | 154 | -15 | -90 | 2,620 |

Table 7. Avoided $CO_2$ and farm-related greenhouse gas (GHG) emissions, and the intensity of avoided emissions as a result of displacing beef production with canola for biodiesel feedstock in the Prarie Provinces of Canada in 2001

## 5. Summary and conclusions

This analysis provides a good understanding of the interaction between livestock farming and feedstock production for biofuels in Canada. It has shown that target levels of liquid biofuel energy translate directly into cropland reallocations. It demonstrated that where dislocation of livestock is a possible outcome of the expansion of biofuel feedstock production, the carbon footprint will extend beyond the cultivation of the feedstock crop. Given how much of Canada's arable land is in the LCC (Table 3), this extended carbon footprint should be a major consideration in the Canadian biofuel development strategy.

This analysis also revealed the dependence of the ultimate value of biofuels as a GHG reduction tool on previous or alternative uses of the land targeted for feedstock production. For the expansion of feedstock crops into land that supports non-ruminant livestock (poultry or pork), the impact would be straight forward since there is no significant fall-back on grazing. For ruminants however, these interactions are highly complex, even when considered on the one-dimensional basis of GHG emissions taken in this analysis.

It is also important to understand what livestock-feedstock interactions will mean to other environmental issues (Dufey, 2007; Karman et al., 2008; Vergé et al., 2011). The environmental impact assessment of biofuel feedstock production on habitat and biodiversity in Canada raised several issues that are relevant to biofuel-livestock interactions addressed in this chapter (Dyer et al., 2011). That study found that many of the impacts on biodiversity will be the result of decisions made by farmers that are not profiting directly from feedstock crops, but wish to continue farming livestock. This is particularly true of the so-called cow-calf, or ranch, operations and how they respond to any reductions in the grain-based feedlot operations.

What this set of tests came down to for ruminants is that farmers can respond to reduced feed grain supply in two ways: by reducing their livestock numbers or by returning to a more roughage-based diet with more forage and less grain. The general case for eastern dairy farmers was for farm land on which to expand forage production to be a limiting factor (Whyte, 2008). In this case, simply reducing the herd size was the most plausible option, given the limited land resources. The type of beef operations most likely to be affected are the feedlots because, with a limited land base, they are the most vulnerable to feed grain price increases. The greater availability of land on which to expand forage production in the Prairie Provinces, along with the complexity of the beef population (Table 2) and large feedlot industry makes it difficult to predict how beef producers will react to expanded canola production.

Displacement of ruminants by biofuel feedstock is an effective GHG reduction strategy if the populations of those displaced animals are actually reduced. However, when they are simply transferred to the more forage-based diet, the enhanced benefit from reduced enteric methane emissions is either cancelled out or reversed (Table 7). Feeding beef cattle more forage and less grain in response to expanded canola is more likely if the canola biodiesel industry opts for vertical integration (ownership of the feedstock production) and exclusion of the beef farmers. The numbers of beef producers who would choose to reduce their herds to grow canola for biodiesel, compared to the numbers that would feed their cattle more forage, depends on giving them the opportunity to sell their canola to the biodiesel processing plants as an alternative income to cattle. Although this only applies on an appreciable scale to the beef industry, beef is Canada's largest livestock commodity and is the largest source of livestock GHG emissions (Figure 1).

Increased canola production in western Canada can displace wheat as well as feed grains. If the byproduct from the entire western Canadian canola industry were to be used as livestock feed, the canola meal byproduct may be sufficient to support an increased livestock population (cattle or hogs). However, since the market for canola as a source of healthy cooking oil is competitive with food quality wheat, only part of the expansion of canola area in western Canada should be attributed to biodiesel feedstock. To the extent that canola expansion would be into food-quality wheat, rather than into the LCC, the canola meal byproduct would be available to livestock. However, none of the reductions in GHG emissions from the existing cattle populations could be credited to the expanded canola production unless the cattle transferred to a more canola meal-based diet (with less forage) were displaced, or came, from the existing cattle populations.

This assessment was critically dependent on the set of livestock GHG emission inventory models developed by Vergé et al. (2007; 2008; 2009a,b). Given the magnitude of GHG emissions from the Canadian livestock industries (Figure 1), any future assessments of biofuel feedstock production in Canada should also make use of this methodology. Caution is needed in interpreting or applying these test results because the responses to the conversion of crop land to feedstock production were based on assumed decisions by the farm operators. The ultimate value of biofuels as a GHG reduction tool depended on previous or alternative uses of that land that were beyond the scope of these livestock GHG emission models. What is really critical from a policy perspective is that those farmers operate independently from the decision makers who purchase the biofuel feedstock crops. It would therefore be useful to assess the social and economic pressures that drive these decisions.

This chapter has not dealt with the changes in soil carbon as a result of land use changes. This term would depend on the use to which the land removed from forage production was put. If it was seeded with other feed grains or annual crops, then some soil carbon would be lost (Davidson and Ackerman, 1993). If, however, it was used for grazing, then this may serve to reduce pasture stocking rates, and lower the dependence on rangeland for grazing beef cattle. Lower stocking rates will mean healthier turf, whether in improved pasture or rangeland, which is likely to result in an overall increase in soil carbon. Another looming possibility is the developing cellulosic ethanol industry which could exert pressure on ruminant livestock farming from the forage supply side (rather than feed grains) while at the same time, maintaining perennial ground cover, and soil carbon levels. This is not to say that changes in soil carbon will not make a difference in this extended carbon footprint for biofuels. But it is equally unlikely that those changes would always fully compensate for changes in enteric methane. Therefore, even without taking soil carbon into account, the implications of including livestock industries in biofuel GHG calculations should not be ignored. However, incorporating soil carbon sequestration is a future challenge for the set of livestock GHG emission models used in this chapter.

The final caveat to the GHG mitigation benefits of the livestock displacement described in this chapter is that Canadian agriculture would produce less meat. In North America and Europe, the loss of some meat is not a major threat to the human diet. Nutritionally, there might be health benefits for many consumers if they were encouraged by higher meat prices to consume more vegetables and whole grains, and less red meat. In the developing world, however, dietary protein is often a limitation to improved health, and will be more so as human populations continue to grow. As many of these countries achieve higher incomes, the demand for meat will increase and other sources will be sought. Nevertheless, the assumption that displaced livestock will mean lower GHG emissions attributed to biofuel production may not apply to countries that are protein deficient or where the demand for meat is growing.

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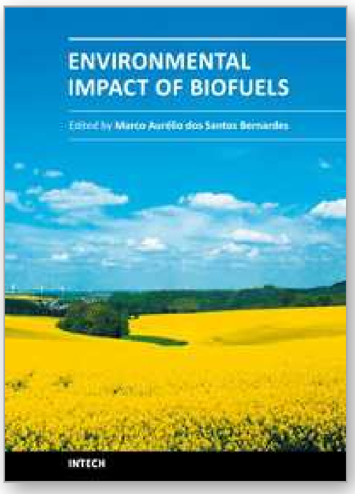


**Environmental Impact of Biofuels**

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This book aspires to be a comprehensive summary of current biofuels issues and thereby contribute to the understanding of this important topic. Readers will find themes including biofuels development efforts, their implications for the food industry, current and future biofuels crops, the successful Brazilian ethanol program, insights of the first, second, third and fourth biofuel generations, advanced biofuel production techniques, related waste treatment, emissions and environmental impacts, water consumption, produced allergens and toxins. Additionally, the biofuel policy discussion is expected to be continuing in the foreseeable future and the reading of the biofuels features dealt with in this book, are recommended for anyone interested in understanding this diverse and developing theme.

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