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Energy use and fossil CO_2 emissions for the Canadian fruit and vegetable industries

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ABSTRACT

The Fruit And Vegetable Energy (FAVE) model was developed to quantify the energy budget and fossil CO_2 emissions in this paper. The energy terms considered were fieldwork, irrigation, on-farm cooling, farm building maintenance, off-farm transport, and N fertilizer supply, with an estimate of farm machinery supply energy integrated with the farm fieldwork energy CO_2 emission intensity estimates. The 31 vegetable crops and 18 fruit crops identified in the socio-economic Canadian data base (CANSIM) were divided into six vegetable groups and five fruit groups, along with potatoes. The data provided by the 1996 Farm Energy Use Survey (FEUS) and the guidance provided by two grower focus groups were essential to the development of this model. Total energy use in Canada between 2007 and 2016 was 2.3 PJ by the vegetable industry and 2.32 PJ by the fruit industry. These included 0.77 PJ for fieldwork, 1.05 PJ for irrigation, 0.36 PJ for on-farm coolers, 0.67 PJ for farm building maintenance, 0.70 PJ for off-farm transport and 1.07 PJ for fertilizer supply. The FAVE model was used to determine the fossil CO_2 emission intensities of 12 individual crops.

Introduction

An analysis of the energy budget for the Canadian fruit and vegetable commodity groups is long overdue since energy budgets for the rest of the Canadian agricultural sector has been developed (Dyer, Kulshreshtha, McConkey, & Desjardins, 2010; Dyer, Vergé, Desjardins, Worth, & McConkey, 2010; Dyer, Desjardins, Karimi-Zindashty, & McConkey, 2011; Vergé et al., 2012). With this omission, an important means of adaptation to climate change in Canada has been overlooked. With a number of global changes underway, maintaining food supply and a diverse human diet will likely become greater challenges for the world and Canada. A warming climate may well mean that the range of climate regions capable of growing a diversity of fruits and vegetables will expand appreciably in Canada, while traditional fruit and vegetable growing countries lose their productivity through environmental degradation and climate change. The goal of this paper is to quantify the energy use and fossil CO_2 emissions budget for Canadian fruit and vegetable production, excluding the greenhouse industry (Dyer et al., 2011).

Background

Much of the foundation for the methodology and work described in this paper was based on focus group data collection from fruit and vegetable growers in Nova Scotia and South Western Ontario (Dyer, 2012a, 2012b). While the findings of those sessions were anecdotal and limited to the responses from a relatively small number of growers, they provided important general guidance to this study. The data provided by the 1996 Farm Energy Use Survey (FEUS) (Tremblay, 2000) on energy use by the fruit and vegetable industries, played a major role in this energy budget development, even though these data were only available on a Canada-wide basis. The FEUS identified five fossil fuel types, including diesel, gasoline, furnace-oil, LPG and natural gas, plus electricity, which were used either in verification or for indexing the terms in the fruit and vegetable energy budget.

The socioeconomic database for Statistics Canada (CANSIM) provided historical records of both areas and production quantities for 31 vegetable crops and 18 fruit crops, along with potatoes (CANSIM, 2017a, 2017b, 2017c). All of these fruit and vegetable crops had to be considered in order to account for all of the energy that the FEUS attributed to these two commodity groups (Tremblay, 2000). Since potatoes are considered to be a field crop, rather than a vegetable, their energy use was not accounted for in the set of energy terms that the FEUS attributed to fruits and vegetables. The records for fruit and vegetable

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crop areas are quite complete back to 1996, while the crop production records have too much missing data prior 2007 for reliable extrapolation to any years before 2000.

Methodology

To guide the development of algorithms that could take into account the characteristics of each crop type, the fruit and vegetable crops were sorted into commodity groups based on the part of the plant used as food and the way that they are harvested. The main advantage of grouping crops was that many of the algorithms required for this energy budget only needed to be adapted to crop groups, rather than to individual crops. Six commodity groups were used for the vegetable crops and five were used for the fruit crops. Potatoes were treated as a separate crop group. Table 1 shows how these crops were grouped for this paper.

Like the energy budgets for farm fieldwork (Dyer & Desjardins, 2003), greenhouses (Dyer et al., 2011) and barnyards (Dyer, Vergé, Desjardins, & Worth, 2017), household (non-farm) energy use had to be accounted for on fruit and vegetable farms. The FEUS data set identified 24% of the energy use on fruit and vegetable farms as household (non-farm) energy use (Tremblay, 2000). Due to confidentiality limitations, the FEUS could only provide one household energy term for each commodity type. Therefore, the same household energy use value was used to adjust all of the energy types from the FEUS to quantify the farm to non-farm difference. An adjustment for household use of diesel fuel would not be applicable because of the very limited use of diesel fuel in family or personal vehicles. Hence, the household share of the other energy terms used for fruit and vegetable production was recalculated. Subtracting the diesel fuel energy from the total farm energy use before recalculating the non-farm to farm ratio increased this ratio to 38%.

The producer focus group discussions (Dyer, 2012a, 2012b) defined the set of energy budget terms for the fruit and vegetable energy use budget in this paper. These terms included field operations, nitrogen (N) fertilizer supply, irrigation, the cooling of produce during on-farm storage, building maintenance and off-farm transport (by farm-owned vehicles). Algorithms that were independent of the FEUS data could be derived for the first four of these terms. Irrigation and cooling of produce were not included in the energy budgets of livestock or field crop agriculture, and represented new challenges for defining the farm energy budgets of fruit and vegetable farms in Canada. Independent algorithms for energy use rates for building maintenance and off-farm transport were not possible (Dyer et al., 2017). Instead, these two terms were indexed directly from the 1996 FEUS (Tremblay, 2000), as has been done in previous farm energy use budgets for Canada (Dyer & Desjardins, 2009; Dyer, Desjardins, & McConkey, 2014). The relationship between the six energy budget terms and the fuel and energy types identified in the FEUS, and their impact on the algorithms is shown in Fig. 1. The integration of these algorithms for these energy terms over the 12 crop commodity groups (Table 1) resulted in the Fruit And Vegetable Energy (FAVE) budget model. This model also accounts for the related fossil CO_2 emissions.

Energy use and CO_2 emissions algorithms

To disaggregate Canada-wide estimates for each of these six energy terms, a weighted average of the coefficients was based on 2015 vegetable production areas in The Atlantic Provinces, Quebec, Ontario and British Columbia. With only 12% of the fruit and vegetable farms located in the Prairies (Statistics Canada, 2016), these farms were ignored. Only vegetable areas (AAFC, 2016) were used in these weightings because, being primarily annual crops, vegetable production statistics are much more reliant on yearly field operations than are most fruit crops in Canada. In any case, the provincial distribution of fruit and vegetable farms are quite similar (AAFC, 2016).

Field operations and farm machinery

The field operations for fruit and vegetable production were seed bed preparation tillage, seeding, cultivating for weeds, spraying, carting the produce from the field to on-farm storage sites and harvesting. Coefficients for fossil CO_2 emissions and energy use were derived directly from output generated by the Fossil Fuel Farm Fieldwork Energy and Emissions (F4E2) model (Dyer & Desjardins, 2003, 2005; Dyer et al., 2014). These coefficients, which are on an area basis (ha), assumed a mineral soil and diesel tractor fuel. The inputs and calculations for F4E2 were described in the original paper for this model (Dyer & Desjardins, 2003).

Table 1
lists of vegetable and fruit crops (identified by their common or market names) included in the study and their categorization into commodity groups.

	Vegetables						Fruits				
#	Commodity groups	Crops	#	Commodity groups	Crops	#	Commodity groups	Crops	#	Commodity groups	Crops
1	Roots & tubers		4	Pulses		1	Apples		3	Bush berries	
		Beets			Beans	2	Stone fruits				Blueberries
		Carrots			Peas			Apricots			Cranberries
		Garlic	5	Leaves & stems				Cherries	4	Thorn berries	
		Leeks			Lettuce			(sweet & sour)			Raspberries
		Onions			Parsley			Nectarines			Saskatoon berries
		Parsnips			Spinach			Peaches			Strawberries
		Shallots			Asparagus			Pears	5	Grapes	
		& green onions			Celery			Plums & prunes			
		Radishes			Rhubarb						
		Rutabagas	6	Heads							
		& turnips			Broccoli						
2	Sweet corn				Brussel						
3	Fruit (tissue)				-Sprouts						
		Cucumbers			Cabbage						
		Melons			Cauliflower						
		Pumpkins									
		Squash									
		& zucchinis									
		Tomatoes									
		Peppers									
		Watermelon									