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Life cycle and economic assessment of Western Canadian pulse systems: The inclusion of pulses in crop rotations

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ABSTRACT

The introduction of a pulse crop into a cereal production rotation has been widely recognized for the rotational benefits resulting from nitrogen fixation and crop diversification. Pulses are the dry, edible seeds of pod-bearing plants in the legume family, such as dry pea and lentil. Both dry pea and lentil are widely grown across Western Canada and provide an important source of food and feed worldwide. In addition, these pulse crops demonstrate positive returns over and above the production of traditional crops in most situations except when their prices are low. Although the economic and environmental benefits of pulse crops have been examined in many different capacities, an examination of the rotational implications of including pulse crops in a cereal-based rotation in Western Canada has not been conducted on a life cycle basis. In this study, life cycle and economic assessments were used to examine the environmental and economic implications of including dry pea and lentil crops in an oilseed-cereal rotation in Western Canada. An analysis was performed in which dry pea or lentil replaced a spring wheat crop in a canola – spring wheat – spring wheat – spring wheat rotation. Pulses were ultimately produced for their protein content. Results suggested that introducing dry pea or lentil in the rotation reduced environmental effects in all impact categories examined (Global Warming and Resource Use: −17% to −25%; Ecosystem Quality: −1% to −24%; and Human Health: −3% to −28%). In addition, the economic benefits of this practice suggested that the farm level returns over variable costs improved for both the dry pea and lentil rotations (from $−20.43 ha^{−1}$ for the traditional rotation to $110.45 and $138.78 ha$^{−1}$, respectively, for dry pea and lentil rotation). These reductions were a result of reduced fertilizer requirements for the pulse-containing rotations (i.e. no application of nitrogen fertilizer to the pulse crop and reduced application to the succeeding cereal crop) as well as higher cereal yields. Based on these results, improved returns to producers and reduced amounts of material and energy inputs can be realized with optimized crop management that can include dry pea and/or lentil in rotation with other high yielding crops. Including pulse crops in an oilseed-cereal rotation is an effective method to enhance the economics and environmental effects of crop production.

1. Introduction

The Prairies play an important role in Canadian agriculture, providing 32 million hectares of arable land and accounting for approximately 85% of farmland. Historically, cereal-fallow rotations have been the predominant cropping system in the semiarid Canadian Prairies and northern Great Plains of the United States (US) (Grant et al., 2002; Spratt et al., 1975; Tanaka et al., 2010). The practice of monoculture cereal cropping, however, often results in pest accumulation (Bailey et al., 2000) and other related adverse effects, such as increased pesticide requirements. As a result, crop rotations have diversified to include crops that break cereal disease and insect cycles, such as pulses.

Pulses are the edible seeds from legume plants, such as dry pea, lentil, dry bean and chickpea. There are several advantages to including pulses in crop rotations, for example, pulse crops in a rotation break disease and insect cycles and have the ability to fix atmospheric nitrogen. Nitrogen fixation reduces the fertilizer requirements of the pulse crop itself, as well as the following grain crop. In addition, the inclusion of pulses in a crop rotation improves the yield and protein content of the following cereal crop.

The agronomical benefits of including pulse crops in crop rotations may result in changes to the environmental effects and economic implications of crop production by reducing the synthetic nitrogen fertilizer requirements of the rotation and by improving the rotational yield and quality of the grain. Furthermore, the

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pesticide and herbicide requirements of the rotation may decrease and the quality of the soil may improve over time.

The goal of this study was to investigate the environmental effects and economic implications of including dry pea and lentil pulse crops in an oilseed-cereal rotation. This study was performed as part of a larger study where the environmental effects and economic implications of pulse crop production and subsequent pulse grain use as animal feed, for human consumption and for ethanol production were examined.

2. Materials and methods

2.1. Life cycle assessment

Life cycle assessment (LCA) is a method of examining the environmental effects of a product, process or system across its entire life span. In this study, an International Standards Organization (ISO)–compliant (ISO 2006a, 2006b) LCA was conducted to assess the environmental effects of the inclusion of dry pea and lentil in an oilseed-cereal crop rotation. Results were based on the use of the SimaPro (version 7.1.8; PRé, 2009) LCA computer modeling system, combined with the IMPACT 2002+ midpoint method (Jolliet et al., 2003). The IMPACT 2002+ method was updated to analyze global warming over 100 years with the most up to date global warming potential (GWP) factors available (IPCC, 2007). Impact assessment categories included impacts to human health (i.e. carcinogens, non-carcinogens, respiratory inorganics, ionizing radiation, ozone layer depletion and respiratory organics), ecosystems quality (aquatic ecotoxicity, terrestrial ecotoxicity, terrestrial acidification/nutrification, land occupation, aquatic acidification and aquatic eutrophication) and global warming and resource use (i.e. non-renewable energy and mineral extraction) (Fig. 1). Further details on the impact categories are available in Appendix A.

The results of this study were intended to provide objective and transparent information to the public on the effects of growing and using pulse crops as well as to guide future research. The LCA was reviewed by an external, third-party reviewer.

3. Production systems

The potential environmental effects of including pulse crops into an oilseed-cereal crop rotation were quantified by examining a canola – spring wheat – spring wheat – spring wheat crop rotation (herein referred to as the oilseed-cereal rotation) in comparison to a canola – spring wheat – dry pea – spring wheat crop rotation (herein referred to as the dry pea rotation) and to a canola – spring wheat – lentil – spring wheat crop rotation (herein referred to as the lentil rotation). Canadian Western Red Spring wheat (*Triticum aestivum* L.) and canola (*Brassica napus* L.) were selected as the cereal and oilseed crops, while yellow pea (*Pisum sativum* L.) and large green lentil (*Lens culinaris* Medik) were selected as the pulse crops. The rotations examined are shown in Table 1.

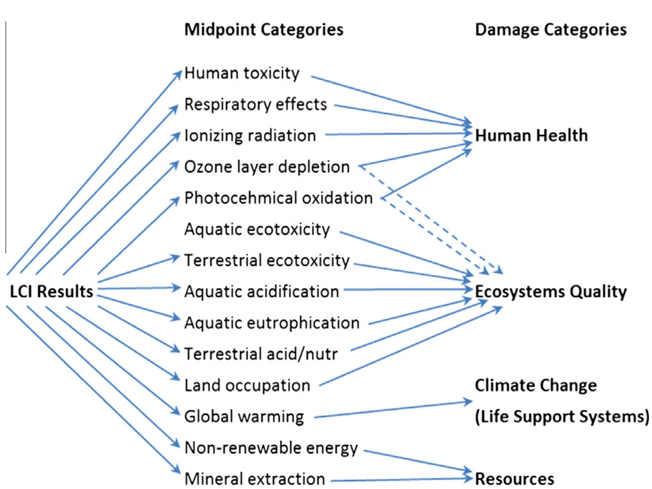

Fig. 1. Midpoint and endpoint categories of the IMPACT 2002+ impact assessment method. *Source*: Jolliet et al. (2003).

Pulse crops have historically replaced summerfallow in rotation (Nagy, 2001); however, summerfallow has been on the decline in Western Canada for several years (Carlyle, 1997). Therefore, when included in current agricultural rotations, pulse crops are most likely to replace a cereal crop such as spring wheat (SPG, 2000). As such, it was assumed that lentil and dry pea replaced a cereal crop in rotation.

The majority of existing published literature has examined either the ability of pulses to break disease and pest cycles, or to reduce the nitrogen requirement of a succeeding crop. In both situations, pulse crops were most often examined succeeding and preceding spring wheat crops, respectively. Therefore, the cereal-oilseed rotation selected was canola – spring wheat – spring wheat – spring wheat (herein referred to as the oilseed-cereal rotation). Although three spring wheat crops may not commonly be grown in succession in Western Canada, the selected rotation ensured that the LCA was based on the best available field data. To fully understand the impacts of including pulse crops in crop rotations, further analyses where additional crop rotations under various management practices are considered should be conducted.

4. Functional unit

The function of the crop production system was to produce grain for human consumption. A comparable functional unit must, therefore, represent an equal amount of grain and pulse in terms of both yield and nutritive value. As both pulse and cereal grains are sources of protein (Whitney and Rolfes, 2005), protein was selected as the unit of comparison in terms of nutritive value. A protein content of 14% was selected as it was the average protein content in wheat (all varieties) when all methods of farming and crop rotations were included (Edwards et al., 2009). The functional unit was one tonne of 14% protein-corrected grain (1 t 14% protein-corrected grain).

5. System boundaries

The system boundaries for the crop production systems began with the production of inputs required for producing the grains. The end point of the analysis was the grain elevator, where grain was stored and ready for use. Fig. 2 provides a flowchart of the general scope of activities included in the crop production system.

Fuel use associated with transportation of agriculture equipment to and from the field was excluded from the analysis as it was shown to be negligible when compared to the total fuel requirements of crop production (e.g. combine harvesting).

Table 1
Crop rotation systems examined in the life cycle assessment.

Growing season	Oilseed-cereal rotation	Dry pea rotation	Lentil rotation
1	Canola	Canola	Canola
2	Wheat	Wheat	Wheat
3	Wheat	Dry pea	Lentil
4	Wheat	Wheat	Wheat