Life cycle assessment of Pacific Northwest canola-based biodiesel

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The production of canola and other brassica-based oilseeds has long been promoted as a strategy for diversifying cereal-based cropping systems in the inland Pacific Northwest (PNW). As can be observed in Figure 1, canola has great potential as a rotational crop for wheat production in the region. However, success has been limited by the lack of a viable regional processing infrastructure for crushing the seed. Recent policy-driven interests in renewable energy and carbon mitigation have contributed new resources and enthusiasm for production of oilseeds, in particular the strategy of regionally produced biofuels that can help meet a low carbon fuel standard (LCFS). The U.S. Environmental Protection Agency (EPA) has developed an estimated value for an LCFS for canola-based biodiesel based on midwestern production data, but many producers are concerned that the existing EPA estimate is not an adequate representation of production conditions in the PNW. The PNW enjoys a highly diverse landscape and climatic system with a variety of agroecological zones under which different cropping systems (crop type, varieties, agronomic management, etc.) have evolved. The consequence of this heterogeneity is that there is no single set of expected production inputs and outputs that is universally applicable across the region, and therefore a lifecycle assessment (LCA) for a crop produced in the PNW should account for the range of production issues in the region. The brassica oilseed crops (canola, mustard, and camelina) have an even greater degree of heterogeneity due to the fact that their commercial introduction to the PNW is recent and they do not have the same history of varietal and agronomic development as wheat. Our team used the CropSyst model to simulate yield, carbon sequestration, nitrous oxide emissions, carbon footprint, water dynamics, and land use impacts for canola production in the inland PNW as a basis for providing the EPA with a regionally appropriate estimate for the LCFS for canola-based biodiesel.

IMPACT

Canola has great potential as a rotational crop for wheat production in the inland Pacific Northwest. This study provides the first regionwide lifecycle assessment of the production of canola for use as a feedstock for biodiesel.

Tables 1 and 2 show the baseline and alternative rotations simulated in this study.

Highlighted findings from the simulation

- Crop rotations with canola differ considerably in their production inputs and potential yields across the inland PNW, indicating the need for a more detailed subregional analysis of the potential impacts of feedstock production in the region.
- Crop simulations do partially capture a "rotation effect" that supports the claim that shifting to canola production should not be treated as a 1:1 land substitution for current grain production. Our analysis indicates that the displaced food value ranges from -10% to -31%, depending on location and crop rotation.
- Because current crop simulations do not fully capture the "rotation effect" observed by farmers and reported in experiments, there may be additional, positive impacts on yield, input costs, land substitution, and other lifecycle factors that require further quantification.
- Estimated average yields across the PNW were the equivalent of 66 gallons of biodiesel per acre for spring canola and 71 gallons for winter canola, with substantial spatial and temporal variability.
- Simulated alternative crop rotations containing canola do not result in a significant change in soil carbon sequestration or nitrous oxide emission relative to current cropping systems. The net change in total production-related greenhouse gas emissions of the alternative canola rotation over the conventional rotation is also not significantly different.

Table 1. *Baseline crop rotations for each location.*

Location	Annual Precipitation (inches)	Crop rotation
Lind, WA	10.0	WW – SF
Moro, OR	11.5	WW – SF
Davenport, WA	14.1	WW – SW – SF
St. John, WA	17.2	WW – SW – SF
Moscow, ID	27.4	WW – SW – SW

WW = winter wheat; SW = spring wheat; SF = summer fallow.

Table 2. *Alternative crop rotations for each location.*

Location	Annual Precipitation (inches)	Crop rotation
Lind, WA	10.0	WW – SF – WC – SF
Moro, OR	11.5	WW – SF – WC – SF
Davenport, WA	14.1	WW – SW – SF – WC – SW – SF
St. John, WA	17.2	WW – SW – SF – WC – SW – SF
Moscow, ID	27.4	WW – SC – SW

WW = winter wheat; SW = spring wheat; WC = winter canola; SC = spring canola; SF = summer fallow

- Our analysis indicates that relative to petroleum diesel, use of canola feedstock in biodiesel production reduces lifecycle greenhouse gas emissions by 66% and 67%, respectively, for spring and winter canola.
- Canola biodiesel produces 3.4 and 3.5 units of energy per unit of energy spent during processing for spring canola and winter canola, respectively.

Summary and conclusions

Simulated crop rotations with canola were observed to have a small, generally positive impact on wheat yields. While the introduction of canola would displace some acreage of the dominant cereal grains produced in the region, the ultimate displacement effect on a mass food value basis ranged from losses of only 10% to 31%, depending on location and rotation in these simulations. This is much lower than the assumed 1:1 displacement on an acreage basis. Accounting for the observed "rotational effect" of disease and weed suppression not captured in model simulations may push this trade-off closer to a net-zero displacement effect. Therefore, land use displacement or "food for fuel" concerns should not be significant for PNW canola production.

Overall nitrous oxide emissions were slightly lower for the alternative canola rotation than for the conventional wheat rotation, but the difference is too small to be significant. Soil carbon sequestration of the alternative rotation ranged from 768 to - 887 pounds of carbon dioxide (CO_2) per acre (862 to -996 kilograms of carbon dioxide (CO_2) per hectare) annually and is also not significantly different from the conventional wheat rotation. As seen in conventional rotations from earlier studies, the generation of nitrous oxide generally outweighs the potential benefit of increased soil carbon sequestration. The net change in total production-related greenhouse gas emissions of the alternative canola rotation over the conventional rotation ranges from 45 to - 68 pounds of CO_2 per acre (50 to -76 kilograms of CO_2 per hectare) annually, but again is not significantly different.

From a crop production standpoint, the carbon footprint implications of shifting to alternative rotations that include canola relative to a conventional wheat rotation, while different depending on location and system, are small in comparison to the impacts of reducing tillage in wheat production systems, as indicated by earlier crop simulation studies. The potential agronomic and environmental benefits created by adding canola (or other oilseeds), especially when that addition facilitates adoption of no-till or reduced tillage, are likely far greater in significance than the carbon footprint implications of the canola rotations.

Figure 1. *Coauthor Bill Pan (left) assessing a field of canola. Photo by Karen Sowers.*