Intermediate Winter Canola

Intermediate Winter Canola offers an opportunity to produce new, low carbon intensity biofuel feedstock supplies.

Executive Summary

Intermediate Winter Canola (IWC) is an additive winter crop that transforms historically fallow acres in the Mid-Southern United States, into productive land, generating new sources of revenue for growers without displacing primary summer crops. As a rotationally beneficial Brassica, IWC enhances soil health by capturing residual fertilizer inputs after corn, improving soil structure and biological activity, reducing erosion, and breaking pest and weed cycles, which in turn supports stronger yields and stability for subsequent crops. Its early harvest opens a wider and more reliable planting window for double crop soybeans or cotton, improving operational efficiency and enabling integrated nutrient management practices, such as combined phosphorus and potassium applications, that can reduce field passes, fuel use, and on-farm emissions. The crop also fits seamlessly into existing equipment and logistics, providing a scalable pathway to convert IWC oil into renewable diesel, biodiesel, and sustainable aviation fuel. Together, these agronomic, economic, and refining advantages position IWC as a high value, low carbon intensity (CI) feedstock that helps boost whole rotation profitability and strengthens the long-term sustainability of farming systems across the Mid-South.

Representatives from Chevron Corporation, Bunge Limited, & Corteva Agriscience contributed to this white paper *Last updated: March 2026*

Bunge Chevron AG RENEWABLES | CORTEVA agriscience

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Intermediate Winter Canola Introduction

In 2022, Bunge and Chevron formed Bunge Chevron Ag Renewables (BCAR) to identify and develop novel crops that can be used to produce renewable fuel feedstocks. In 2023, a commercial collaboration between BCAR and Corteva was announced with the goal of introducing proprietary winter canola hybrids. The three companies offer comprehensive expertise in various aspects of the value chain including plant breeding, grower engagement, field agronomy, crop cultivation, grain handling, oilseed processing, biofuel production, and products marketing.

This memo gives an overview of key attributes of intermediate winter canola (IWC): characteristics as a commodity, fit between current primary crops rotation, region targeted for cultivation, and use as a biofuel feedstock.

IWC Overview

IWC is a harvestable cover crop planted in the fall and harvested in the spring and is helping to meet biofuels market demand. The crop is planted as an intermediate cover crop in between the primary season crop rotations of corn and soybeans. IWC grain characteristics (e.g., size, moisture, oil content, etc. of the grain) require specialized processing at crush plants.[1] The resulting meal and oil products meet the domestic and internationally accepted specifications for canola oil and meal. Canola meal is one of the most widely traded and utilized plant protein meals globally, and widely used in dairy, poultry, swine, and aquaculture feed. Canola oil can be used as a feedstock to produce biofuels such as renewable diesel, biodiesel, and sustainable aviation fuel (SAF).

IWC is grown in the winter months, making its output additive to existing farmland production as it fits between primary crop seasons. As described below, growers can benefit from planting IWC as a cover crop for a variety of reasons, including its contributions to soil health, creating crop diversity, and reducing pest pressures.

IWC crop rotation inclusion functional benefits *(Citations omitted in table are included in subsequent sections)*	
Soil	Reduced erosion, and improved water filtration Enhanced soil biological activity that promotes nutrient cycling[2] Easily degradable straw supports faster nutritional release into the soil Increased soil organic matter

Crop Diversity	Crop diversity through a multi-year crop rotation Additional revenue source from existing cropland Beneficial yield gains for other crops in the rotation
Pest Cycles	Disruption of pest cycles enabling greater performance of all crops in the rotations.[3] Effective weed control by providing ground cover during traditionally fallow periods

Growing Region

IWC from Corteva has been adapted to grow in the Mid-South United States. (Figure 1). The region presents a significant opportunity for IWC development due to very low adoption of winter cover crops (Table 1). The region is prone to soil erosion, reduction in soil organic matter and loss of nutrients due to most of the acres being left fallow during winter. Additional areas in the southern U.S. may be adaptable to include IWC into the rotation with additional agronomy and seed breeding efforts.

Figure 1 U.S. Intermediate Winter Canola growing region developed by Bunge, Chevron, and Corteva

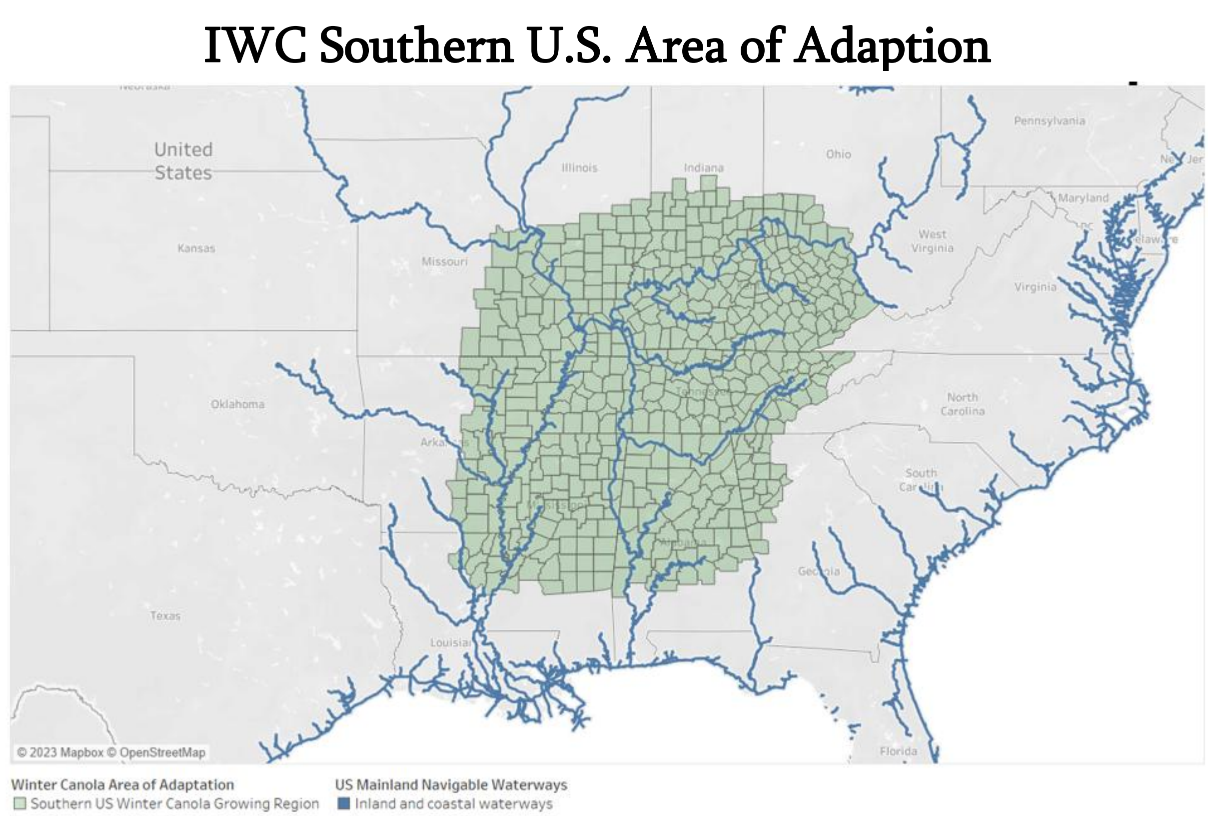

Table 1: Winter acre productivity for the Mid-South (2015-2024) demonstrating significant fallow acres and opportunity into introduce IWC sustainably into the rotation. The methodology for calculating acre productivity is described in appendix A.

Year	Summer productive acres (millions)	Winter productive acres (millions)	Winter fallow acres (millions)	% winter fallow
2015	25.2	2.1	23.1	91.7%
2016	25.8	1.6	24.2	93.7%
2017	27.1	1.4	25.6	94.8%
2018	27.2	1.5	25.7	94.4%
2019	24.8	1.3	23.5	94.7%
2020	26.2	1.4	24.7	94.6%
2021	27.1	1.7	25.3	93.6%
2022	27.0	1.7	25.3	93.6%
2023	26.4	2.2	24.2	91.8%
2024	24.9	1.8	23.1	92.8%
Average	**26.2**	**1.7**	**24.5**	**93.5%**

Rotational Practices

IWC is positioned as a complementary crop that fits naturally into the production window between the region's primary summer crops, corn, soybeans, and cotton. As shown in Figure 2, several crop-rotation patterns are used across the region, and many of these can incorporate IWC as a ecologically-enhancing rotation option. The inclusion of IWC provides growers with additional flexibility, helps diversify the cropping system, and can improve soil health and resource efficiency. However, growers will ultimately adopt only those rotation sequences that align with their operational needs, equipment availability, labor capacity, and overall economic objectives.

IWC complements systems where winter wheat is also planted, providing growers with the potential for five crops within three years (see *Winter Canola – summer and wheat rotations 1* in Figure 2). There are numerous cropping rotations that can be adopted in the region. The key aspect is that IWC is additive within the existing rotations and that novel oilseed crops that are grown during historically unproductive periods can produce more IWC meal for feed and more oil for biofuel use on existing agricultural land. Under federal crop insurance guidelines administered by USDA's Risk Management Agency, IWC has a standard three-year rotation requirement that determines how often it can be planted on the same field for insurance coverage to be valid, allowing for a natural preservation of winter wheat practice where existing.[4]

Environmental Cropping Practices

IWC fits effectively between corn and double-crop soybeans across the Southern and Southeastern U.S. The crop establishes well when planted promptly after corn harvest and benefits from a straightforward fertility package supporting a 50-70 bushel-per-acre yield: 120 lbs. nitrogen, 40 lbs. phosphorus (P_2O_5), 35 lbs. potassium (K_2O), and 25 lbs. sulfur (*see* Appendix B for field data). To manage for potential late fall weed pressure, growers may choose to apply selective preemergence herbicides (e.g., trifluralin or cyclohexanedione). These nutrient levels align with removal-based recommendations and regional guidance established through agronomic research and on-farm experience.[5][6][7][8]

Phosphorus and potassium behave very differently from nitrogen in the soil. Unlike nitrogen, they are far less mobile and can build up over time, which means growers must think in terms of long-range nutrient management. The first step is a soil test—this is essential for understanding existing nutrient levels and preventing both over-application and under-application, either of which can undermine crop health and yield.

To ensure that IWC integrates smoothly into the broader cropping system, Corteva has, in some cases, recommended aligning phosphorus and potassium applications to meet the nutrient needs of both IWC and the subsequent soybean double-crop. For example, a combined recommendation of 80 lbs. of phosphorus and 120 lbs. of potassium for the full system can be applied upfront, with 53% of the phosphorus (42 lbs./acre) and 30% of the potassium (36 lbs./acre) attributed to IWC. These allocations are aligned with IWC removal rates.[9]

This single, combined application eliminates the need for an additional fertilizer pass before soybean planting, saving time, reducing fuel use, lowering emissions, and allowing growers to plant soybeans immediately after harvesting IWC. That earlier planting window can add valuable growing days, improving soybean productivity while increasing operational efficiency.

IWC fits well when planted as a winter crop once every three years, consistent with federal crop insurance general eligibility conditions and complimentary to winter wheat rotations that occur in small quantities across the southeast (Figure 2).

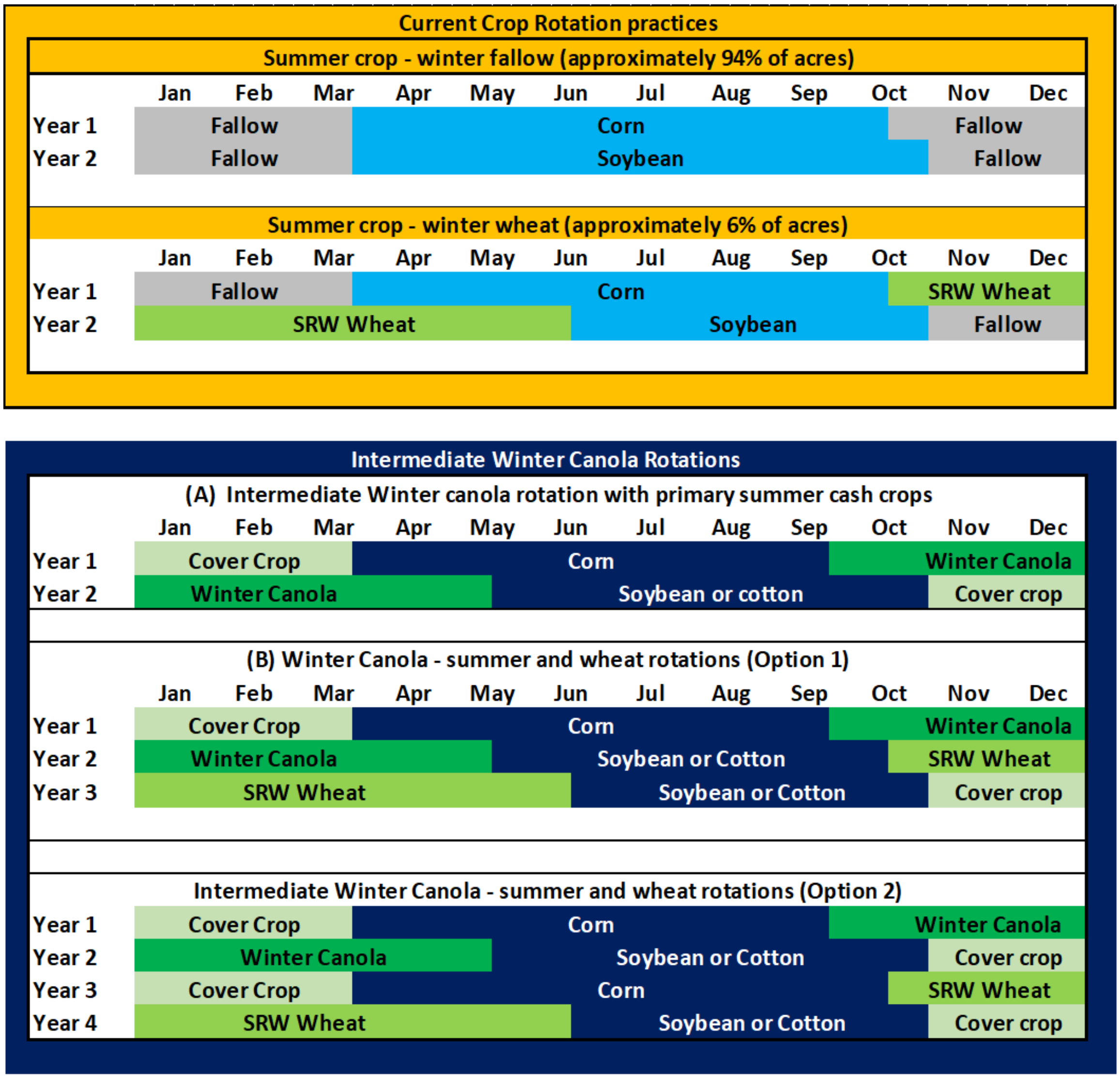

Figure 2 Crop rotation calendars. orange titled calendars indicate current grower practices in the Mid-South, while white titled calendars indicate new rotational practices with the introduction of IWC.

The addition of IWC into the rotation offers many potential benefits for the agronomic system, including retention and capture of residual nutrients, improvement in soil organic matter, increased soil water retention and disruption of pest cycles, and improvement of outcomes for both the primary crops in the rotation and winter wheat grown during the alternative winter years.[10][11][12] Relative to winter wheat, IWC can improve subsequent crop yields, soil biology and structure, nutrient cycling, availability, and increase soil carbon sequestration. IWC is harvested earlier than many other winter crops, such as winter wheat and other winter cereals, enabling earlier planting opportunities for the next crop.

A key advantage of IWC in this rotation is its ability to capture and retain residual nutrients left after corn. The crop's overwintering root system actively takes up mobile nitrate-N and sulfate-S during a period when these nutrients are at high risk of leaching in humid Southern climates. Extension services and research programs in Kentucky, Tennessee, and Georgia consistently note canola's strong nutrient-scavenging behavior and its role in improving nutrient-use efficiency across the rotation.[13][14] IWC residues present after harvest are generally richer in nitrogen and more chemically labile than other intermediate crops.[15] Decomposition of the IWC residue occurs more rapidly and enables the substrate to be more accessible for microbial growth, enzymatic activity and metabolic inclusion for the primary crops.[2]

IWC can also provide valuable soil protection and biological activity during the otherwise fallow winter period.[16] Its living canopy and root system can reduce erosion, maintain surface structure, and support early-season nutrient cycling. IWC's modest residue load and soil-conditioning effect create a favorable environment for the next crop and reduce early-season establishment risks for soybeans.[17] In addition, USDA-NRCS conservation crop-rotation guidance includes Brassica oilseeds (including winter canola) as an accepted rotational crop that contributes to improved soil organic matter, reduced pest pressure, and extended periods of living cover, core conservation outcomes equivalent to those delivered by cover crops.[18]

By harvesting IWC in late May to early June, growers gain an early window for double crop- soybean or cotton planting. Compared with other winter crop options in the region, the earlier canola harvest improves moisture capture, specifically of early spring rains, extends the viable planting period for soy, and supports stronger soybean emergence and yield potential. Field experience in Kentucky and Tennessee shows that this earlier window, combined with the nutrient cycling benefits of canola, improves the overall profitability and seasonal stability of the -double crop- soybean system.[19] Additionally, as growers gain more experience integrating IWC into their cropping systems, several opportunities emerge to further optimize overall performance, ranging from improved agronomic practices to the deployment of elite genetics in both double cropped soybeans and IWC canola (e.g., shorter maturity- varieties), along with more precise optimization of input use.

Field data and direct emissions considerations

Extensive field testing has been conducted in the region confirming that IWC is well adapted to the region and productive for growers as part of a sustainable rotation with corn and soybeans.[20][21] Furthermore, Kansas State University has coordinated winter canola variety trials that include testing locations within the area of adaptation and demonstrate that the crop has strong winter survivability and crop productivity for over two decades.[22] Corteva Agriscience has developed proprietary winter canola hybrids genetically developed for the southern U.S. and paired with farm management support from Corteva's extensive agronomist network. The team has collected data from research and commercial sources to determine the direct emissions from the field trials (Appendix B).

Driving productivity and lower emissions in the IWC system

Introduction of IWC in the U.S. mid-south has created a present opportunity for environmentally beneficial outcomes on the farm and in the biofuel supply chain, however, there are additional opportunities to increase productivity and conserve resources to meaningfully reduce emissions associated with IWC production. By bringing together improved genetics and optimized agronomy, Corteva is positioning the system to target significantly lower emissions on a per-acre basis. The company has already developed and commercially introduced IWC hybrids stacked with enhanced pod-shatter tolerance, a trait that directly improves yield by 10–15%, increasing output per acre without requiring additional inputs. As the product pipeline turns over, all hybrids in the IWC program will eventually have pod-shatter tolerance. Complementing this, the introduction of earlier-maturity hybrids enables an earlier winter-canola harvest, widening the planting window and improving the yield potential of the subsequent double-cropped soybean. This not only strengthens overall rotation productivity but also enhances the carbon-sequestration potential of the full system. Finally, agronomic practice improvements can further elevate nitrogen-use efficiency by applying nitrogen during key growth stages when the crop most effectively absorbs it. Transitioning to two spring nitrogen applications, spaced 30 days apart after the crop breaks dormancy, has the potential to reduce total nitrogen inputs by 20–30% while maintaining topline yield. Together, these genetic and agronomic innovations reflect Corteva's ongoing commitment to continue modernizing the IWC system for higher productivity and lower environmental impact, while recognizing that agricultural practices and their environmental impacts are subject to improvement and adaptation based on new data and insights.

Biofuels Use Case Considerations

BCAR / Corteva Closed Loop Pathway Overview

The partnership of BCAR and Corteva creates a closed loop value chain, connecting the production of on-farm inputs and agronomic expertise with the logistical and processing capabilities to biofuel demand. This partnership works to align all levels of the agricultural value chain and drive the adoption and production of IWC.

The production of IWC in the southern United States (Figure 1) enables the leveraging of existing Corteva owned and third-party retail networks to distribute seed and inputs to growers. On-farm equipment to plant, fertilize, and harvest standard commodity primary crops, like soy and corn, can be used in the production of IWC. Similarly, current logistical supply chains are sufficient to offtake grain from production fields across the growing region as well as store, handle, and transport for processing.

As noted above (*see* IWC Commodity Information), the processing capacity in the U.S. is predominantly soybean based. Oilseeds like canola, sunflower, and safflower require specialized equipment to process them into oil and protein meal. Relatively few plants in the U.S. can process these types of grains and the logistical costs of reaching those facilities from IWC production areas are economically impractical. In 2021, BCAR invested in construction of a new, high-scale processing capacity at Bunge's Destrehan, Louisiana, export terminal that can handle IWC. This new plant is scheduled to begin processing IWC by 2027 and will enable IWC to be transported via barge to the U.S. Gulf for processing.

IWC oil can be used to produce biofuels like biodiesel, renewable diesel, SAF, renewable propane, and renewable naphtha. Fuel can be produced and shipped to an end use market, like California or another U.S. market. Given the comparable quality between spring canola and IWC meal and oil products, biofuels facilities that can process spring canola oil will also be able to process IWC oil to produce biofuels. Canola oil is a well-studied and commercially viable feedstock, giving it multiple outlets as the cultivation and distribution matures.

Model Design

When approaching lifecycle analysis modelling, there are characteristics that can be carried over between IWC and spring canola, including the logistical and crushing energy inputs. Crop inputs including fertilizer and oil yield are the primary differences that should be examined for the modelling of direct lifecycle emissions to ensure accurate accounting and target research as more data gathering is completed annually.

Indirect Land Use Change Considerations

Indirect land use change (iLUC) assessment of agricultural products accounts for the greenhouse gas emissions that may occur when production of a particular product displaces existing food or feed production, leading to the potential conversion of high-carbon stock lands like forests and wetlands elsewhere. When considering the iLUC associated with IWC there are some key aspects to consider.

- *Increased agricultural productivity with existing resources:* IWC is planted within the existing primary crop cycle without displacing other harvestable crops. IWC is planted on existing farmland when the land is traditionally fallow, uses existing farm equipment, and can be stored and transported within the current supply chain. This means that more products (i.e., meal and oil) are produced by IWC using existing resources, increasing farm productivity without major investment or conversion of land by growers. While oil is expected to go to the biofuel market, the meal produced can offset meal demand traditionally met through primary crop production.

- *Supply Chain traceability of a distinctive feedstock:* IWC is genetically distinct from spring canola due to its vernalization requirement, limiting the mis-categorization of IWC, despite its grain phenotypic resemblance. Due to this genetical difference, IWC grain is physically distinct from spring canola, further ensuring that the crops can be segregated. Furthermore, the growing season, geographic fit and supply chains of IWC are distinct from primary crops with little likelihood of crossover, preventing the comingling of products.

- *Minimized impact risk on performance of primary crops:* While IWC creates a new revenue stream opportunity for growers, their primary crop remains their main cash crop. Prior to adopting IWC, growers will consider the impact on the subsequent primary crops. Any material impact on the primary crop performance will naturally disincentivize adoption of IWC within the crop rotation. As shown in Figure 2, IWC immediately fits within existing crop rotations and has the capacity to add incremental product into the market. In future years, there are opportunities to further maximize performance of all crops throughout the crop rotation. IWC has been demonstrated to improve soil quality through various factors and may have positive yield benefits for the summer crops (as demonstrated by anecdotal evidence from early adopters) through long-term inclusion in a sustainable rotation.

- *Broader environmental benefits beyond no land conversion:* The inclusion of IWC within a crop rotation can provide numerous qualitative ecological benefits. Winter coverage can improve soil quality by reducing erosion and improving water retention. IWC can also be a major pollinator in early spring, months prior to flowing of primary crops, and offer protection against some plant and animal pests. These benefits are not adequately measured in equilibrium trade models, nonetheless they positively impact agricultural production systems.

For these reasons, it is our belief that IWC, and oilseed crops grown under intermediate cover crop practice, should be given the operating condition of a neutral or negative iLUC score. A neutral baseline is a good place to start as more research is completed to quantify the negative iLUC impact from IWC. There is consistent precedent supporting this approach. Current biofuel programs, such as the intermediate camelina, intermediate carinata, and intermediate pennycress pathways under the 45z Clean Fuels Production Credit,[23] the camelina and carinata pathways under the ICAO CORSIA program,[24] and the temporary Camelina feedstock pathway under the California LCFS program[25] provide neutral or negative iLUC treatment. Similarly, academic and research publications from Purdue University[26] and the ACS Sustainable Chemistry & Engineering journal provide credible justification for such application of iLUC on intermediate crops.[27]

2025 Research Paper on Winter Canola iLUC

In 2025, BCAR engaged Dr. Farzad Taheripour of Purdue University to investigate the environmental impacts, specifically iLUC and the associated greenhouse gas emissions, of producing biofuel from IWC. The paper found that an average iLUC score of -20.1 gCO_2e/MJ across 30 scenarios was attributable to IWC. This is a more than 34 gCO_2e/MJ reduction compared to standard spring canola.

The study applied the 2014 global economy database to the GTAP-BIO model and the AEZ-EF emission module to assess the iLUC implications of producing renewable diesel from the specific hybrids of IWC produced and marketed by Corteva and BCAR. This is consistent with GTAP-BIO modeling parameters under the California Low-Carbon Fuel Standard program parameters. A single production volume shock of 100 million gallons was applied across 30 scenarios that incorporated four unique variables – including yield to price elasticity, yield improvement associated with the land type, and productivity of new cropland relative to productivity of exiting cropland – to show sensitivity of the iLUC score. The study assumes that IWC is grown as a second crop on existing cropland, implying it does not require the conversion of new land and incorporates IWC production and oil / meal yields. Further, the model incorporated winter canola as a new sector that uses intermediate inputs on existing cropland.

The model considers the change in cropland, forestry, and prairie land in the U.S. and Brazil. Due to the second growing season on existing cropland and additional meal produced for animal feed markets, the study findings resulted in a decrease in emissions across all 30 scenarios, with an average decrease of 20.1 gCO_2e/MJ. Given the agronomic performance of IWC and BCAR / Corteva closed loop operating model, Dr. Taheripour's study reflects the market conditions for production of IWC oil into biofuel.

Further considerations

BCAR and Corteva remain committed to supporting ongoing research to further quantify the long-term benefits of IWC integration into agricultural systems and explore additional opportunities for positive environmental impacts.

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[1] U.S. domestic crush capacity is heavily focused on soy processing and would not be eligible to process IWC. The National Oilseed Processors Association ("NOPA") reports only six crush plants that can process Canola in the US. *See* National Oilseed Processors Association. (n.d.). NOPA Plant Locations. NOPA. Retrieved January 22, 2026, from https://www.nopa.org/about-us/nopa-plant-locations/.

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Appendix A: Method to calculate winter acre productivity

Data on counties in the Southeastern United States that are suitable for producing intermediate winter canola (IWC) were extracted from the USDA Cropland Data Layer (CDL) through the *CropScapeR* R package, which interfaces with the USDA Cropland Data Layer via the *CropScape* web service.[1] Counties were selected based on environmental conditions favorable for integrating IWC into a double-cropping rotation—specifically climate, temperature patterns, daylight duration, soil characteristics, annual precipitation, and locality to aggregation points. The R script performs all data processing and calculations described below.

For each county, harvested acreage was classified into two groups:

Summer primary crops (e.g., corn, soybeans, cotton)

Winter crops (e.g., wheat, rye)

Then "summer productive acres" (total acres planted to summer crops) and "winter productive acres" (acres planted to winter crops) we calculated. This enables the ability to estimate "winter fallow acres" and % winter fallow – or acreage that is idle during winter months.

Summer Productive Acres – Winter Productive Acres = Winter Fallow Acres

Winter Fallow Acres/ Summer Productive Acres = % Winter Fallow

State	Counties/Parishes
Alabama	Autauga, Bibb, Blount, Calhoun, Chambers, Cherokee, Chilton, Choctaw, Clay, Cleburne, Colbert, Coosa, Cullman, Dallas, DeKalb, Elmore, Etowah, Fayette, Franklin, Greene, Hale, Jackson, Jefferson, Lamar, Lauderdale, Lawrence, Lee, Limestone, Macon, Madison, Marengo, Marion, Marshall, Montgomery, Morgan, Perry, Pickens, Randolph, St. Clair, Shelby, Sumter, Talladega, Tallapoosa, Tuscaloosa, Walker, Wilcox, Winston
Arkansas	Arkansas, Ashley, Bradley, Chicot, Clay, Cleveland, Craighead, Crittenden, Cross, Desha, Drew, Fulton, Greene, Independence, Izard, Jackson, Jefferson, Lawrence, Lee, Lincoln, Lonoke, Mississippi, Monroe, Phillips, Poinsett, Prairie, Randolph, St. Francis, Sharp, White, Woodruff
Georgia	Bartow, Carroll, Catoosa, Chattooga, Cherokee, Cobb, Coweta, Dade, Douglas, Floyd, Fulton, Gordon, Haralson, Harris, Heard, Paulding, Polk, Troup, Walker, Whitfield

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Illinois	Alexander, Bond, Clark, Clay, Clinton, Crawford, Edwards, Effingham, Fayette, Franklin, Gallatin, Hamilton, Hardin, Jackson, Jasper, Jefferson, Johnson, Lawrence, Madison, Marion, Massac, Monroe, Perry, Pope, Pulaski, Randolph, Richland, St. Clair, Saline, Union, Wabash, Washington, Wayne, White, Williamson
Indiana	Bartholomew, Brown, Clark, Clay, Crawford, Daviess, Dearborn, Decatur, Dubois, Floyd, Franklin, Gibson, Greene, Harrison, Jackson, Jefferson, Jennings, Johnson, Knox, Lawrence, Marion, Martin, Monroe, Morgan, Ohio, Orange, Owen, Perry, Pike, Posey, Putnam, Ripley, Scott, Shelby, Spencer, Sullivan, Switzerland, Vanderburgh, Vigo, Warrick, Washington
Kentucky	Adair, Allen, Anderson, Ballard, Barren, Bath, Bell, Boone, Bourbon, Boyle, Bracken, Breathitt, Breckinridge, Bullitt, Butler, Caldwell, Calloway, Campbell, Carlisle, Carroll, Carter, Casey, Christian, Clark, Clay, Clinton, Crittenden, Cumberland, Daviess, Edmonson, Elliott, Estill, Fayette, Fleming, Floyd, Franklin, Fulton, Gallatin, Garrard, Grant, Graves, Grayson, Green, Greenup, Hancock, Hardin, Harlan, Harrison, Hart, Henderson, Henry, Hickman, Hopkins, Jackson, Jefferson, Jessamine, Johnson, Kenton, Knott, Knox, Larue, Laurel, Lawrence, Lee, Leslie, Letcher, Lewis, Lincoln, Livingston, Logan, Lyon, McCracken, McCreary, McLean, Madison, Magoffin, Marion, Marshall, Mason, Meade, Menifee, Mercer, Metcalfe, Monroe, Montgomery, Morgan, Muhlenberg, Nelson, Nicholas, Ohio, Oldham, Owen, Owsley, Pendleton, Perry, Powell, Pulaski, Robertson, Rockcastle, Rowan, Russell, Scott, Shelby, Simpson, Spencer, Taylor, Todd, Trigg, Trimble, Union, Warren, Washington, Wayne, Webster, Whitley, Wolfe, Woodford
Louisiana	East Carroll, Franklin, Madison, Morehouse, Ouachita, Richland, Tensas, West Carroll
Mississippi	Alcorn, Attala, Benton, Bolivar, Calhoun, Carroll, Chickasaw, Choctaw, Claiborne, Clarke, Clay, Coahoma, DeSoto, Grenada, Hinds, Holmes, Humphreys, Issaquena, Itawamba, Jasper, Kemper, Lafayette, Lauderdale, Leake, Lee, Leflore, Lowndes, Madison, Marshall, Monroe, Montgomery, Neshoba, Newton, Noxubee, Oktibbeha, Panola, Pontotoc, Prentiss, Quitman, Rankin, Scott, Sharkey, Simpson, Smith, Sunflower, Tallahatchie, Tate, Tippah, Tishomingo, Tunica, Union, Warren, Washington, Webster, Winston, Yalobusha, Yazoo
Missouri	Bollinger, Butler, Cape Girardeau, Carter, Crawford, Dent, Dunklin, Franklin, Howell, Iron, Jefferson, Madison, Mississippi, New Madrid, Oregon, Pemiscot, Perry, Reynolds, Ripley, St. Charles, Ste. Genevieve, St. Francois, St. Louis, Scott, Shannon, Stoddard, Warren, Washington, Wayne, St. Louis city
Ohio	Adams, Brown, Butler, Clermont, Clinton, Hamilton, Highland, Scioto, Warren
Tennessee	Anderson, Bedford, Benton, Bledsoe, Bradley, Campbell, Cannon, Carroll, Cheatham, Chester, Claiborne, Clay, Coffee, Crockett, Cumberland, Davidson, Decatur, DeKalb, Dickson, Dyer, Fayette, Fentress, Franklin, Gibson, Giles, Grainger, Grundy, Hamilton, Hancock, Hardeman, Hardin, Haywood, Henderson, Henry, Hickman, Houston, Humphreys, Jackson, Knox, Lake, Lauderdale, Lawrence, Lewis, Lincoln, Loudon, McMinn, McNairy, Macon, Madison, Marion, Marshall, Maury, Meigs, Montgomery, Moore, Morgan, Obion, Overton, Perry, Pickett, Putnam, Rhea, Roane, Robertson, Rutherford, Scott, Sequatchie, Shelby, Smith, Stewart, Sumner, Tipton, Trousdale, Union, Van Buren, Warren, Wayne, Weakley, White, Williamson, Wilson

Appendix B: Inputs and Data to Calculate IWC Direct Emissions

Corteva and BCAR have conducted extensive field testing throughout the IWC growing region. In addition to localized trials of IWC, the partners have collected two growing seasons of commercial production data on IWC performance and growing practices. This data covers IWC production across more than 37,000 acres in five states, yielding approximately 2 million bushels of IWC grain. The production data collected over the 2023/2024 and 2024/2025 growing seasons correspond with recommended growing practices of IWC and serve as a representative sample for larger scale production of IWC. The grain produced in these growing seasons followed the closed loop supply chain model implemented by BCAR and Corteva. Grain was delivered and handled at existing locations throughout the mid-south, utilizing existing logistics and storage infrastructure.

Provided below are the weighted average inputs used to calculate the direct emissions of IWC as well as the field production data from the 2023/2024 and 2024/2025 growing seasons.

Direct Emission Weighted Averages:

Measure	Units	Input Amount[2]	Commentary
Production	thousand bushels of oilseed	227.4	
# of Years for Avg. Field Data	#	3	
Yield	bushel/acre	52.4	
Agronomic Characteristics			
Moisture Content	% (oilseed)	8%	
Harvest Index	Unitless	0.30-0.45	
Root-to-Shoot Ratio	Unitless	0.15-0.20	
Aboveground biomass N content	% (oilseed)	*Assume spring canola defaults*	
Belowground biomass N content	% (oilseed)	*Assume spring canola defaults*	
Canola Oilseed Properties			
Oil Content	% (oilseed)	44%	
Canola Crushing			
Oil Yield	lb oil/lb oilseed	*Assume spring canola defaults*	
Canola Meal Yield	lb meal/lb oilseed	*Assume spring canola defaults*	
Meal Mass	lb/lb oil	*Assume spring canola defaults*	
Meal Protein Content	%	*Assume spring canola defaults*	
Oil loss	weight%	*Assume spring canola defaults*	
Canola Oil Refining			
Refining energy use *e.g., electricity*	kWh/refined canola oil	*Assume spring canola defaults*	
Refining chemical use		*Assume spring canola defaults*	
Transportation			
Oilseed	Logistical Leg	Canola from Plantation to Stack	
	Mode	MD-Truck	
	Share	100%	
	Payload (ton)	*default*	
	One-way distance (mile)	10	
	Logistical Leg	Stack to Oil Extraction Mill	
	Mode	Barge	
	Share	100%	
Oil	Payload (ton)	*default*	
	One-way distance (mile)	550	
	Logistical Leg	Canola Oil to Diesel Plant	
	Mode	HD-Truck	
	Share	100%	

[2] The values in the column are the production-weighted averages across all fields

	Payload (ton)	*Default*	
	One-way distance (mile)	100	
On-farm Energy			
Diesel	gallons/ac	*Assume spring canola defaults*	
Gasoline	gallons/bushel	n/a	
Natural gas	ft3/bushel	n/a	
Liquefied petroleum gas	gallons/bushel	n/a	
Electricity	kWh/bushel	n/a	
Crop Input application			
Nitrogen Fertilizer			
Ammonia	lbs N/bushel		
Urea	lbs N/bushel		
Ammonium Nitrate	lbs N/bushel		
Ammonium Sulfate	lbs N/bushel		
Urea-ammonium nitrate solution	lbs N/bushel		
Monoammonium Phosphate	lbs N/bushel		
Diammonium Phosphate	lbs N/bushel		
Total Nitrogen Fertilizer applied	**lbs N/bushel**	**2.35**	Maximum recommendation (not to exceed)
Phosphorus Fertilizer			
Monoammonium Phosphate	lbs P2O5/bushel		
Diammonium Phosphate	lbs P2O5/bushel	0.80	Agronomic recommendation (not to exceed rate) includes input application to IWC and subsequent spring soy crop. Multiple academic papers suggest an allocation of 53% of phosphorous to canola.
Potash Fertilizer (K2O)	lbs K2O/bushel	0.68	Agronomic recommendation (not to exceed rate) includes input application to IWC and subsequent spring soy crop. Multiple academic papers suggest an allocation of 30% of potassium to canola.
Limestone (CaCO3)	lbs/bushel	n/a	
Sulfur	lbs/bushel	0.47	Maximum recommendation (not to exceed)
Boron	lbs/bushel	0.04	Maximum recommendation (not to exceed)
Herbicide			
Atrazine	lb active ingredient/bushel	n/a	
Metolachlor	lb a.i./bushel	n/a	
Acetochlor	lb a.i./bushel	n/a	
Cyanazine	lb a.i./bushel	n/a	
Glyphosate	lb a.i./bushel	n/a	
2,4-D	lb a.i./bushel	n/a	
Dicamba	lb a.i./bushel	n/a	
Treflan	lb a.i./bushel	0.01	Maximum recommendation (not to exceed)
Clethodim	lb a.i./bushel	0.00	Maximum recommendation (not to exceed)
Others	lb a.i./bushel	n/a	
Insecticide	lb a.i./bushel	n/a	

Field production data from 2023/2024 and 2024/2025 IWC crops:

2023 / 2024 IWC Field Production Data

	State	Acres	yield lbs/ac	Nitrogen lbs/bu	Phosphorus lbs/bu	Potassium lbs/bu	Sulfur lbs/bu	Boron lbs/bu	Fertilizer Applications	Fungicide Application	Pre-plant herbicide active	fungicide Active	Insecticide	Desiccation Active
1	KY	170	2,850	2.2	0.7	0.6	0.4	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
2	KY	460	2,750	2.3	0.8	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
3	KY	130	2,900	2.2	0.7	0.6	0.4	0.03	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
4	KY	150	2,700	2.3	0.8	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
5	KY	150	2,550	2.5	0.8	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
6	KY	231	2,500	2.5	0.8	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
7	KY	198	2,000	3.0	1.1	0.9	0.6	0.05	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
8	KY	493	3,150	2.0	0.7	0.6	0.4	0.03	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
9	KY	360	2,850	2.2	0.7	0.6	0.4	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
10	KY	400	2,800	2.2	0.8	0.6	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
11	KY	420	2,450	2.6	0.9	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
12	KY	165	3,150	2.0	0.7	0.6	0.4	0.03	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
13	TN	500	2,350	2.6	0.9	0.8	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac
14	TN	360	2,950	2.1	0.7	0.6	0.4	0.03	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	none	Reglon @ 1.5 pt/ac

2024 / 2025 IWC Field Production Data

	State	Acres	yield lbs/ac	Nitrogen lbs/bu	Phosphorus lbs/bu	Potassium lbs/bu	Sulfur lbs/bu	Boron lbs/bu	Fertilizer Applications	Fungicide Application	Pre-plant herbicide active	fungicide Active	Insecticide	Desiccation Active
1	AL	575	2,050	3.0	1.0	0.9	0.6	0.05	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
2	AL	550	2,195	2.8	1.0	0.8	0.6	0.05	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
3	AL	215	2,999	2.1	0.7	0.6	0.4	0.03	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured

4	AL	600	2,010	3.1	1.1	0.9	0.6	0.05	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
5	AL	300	2,031	3.1	1.0	0.9	0.6	0.05	2 trips	None	None	None	None	not captured
6	AL	600	2,199	2.8	1.0	0.8	0.6	0.05	2 trips	None	None	None	None	not captured
7	AL	680	2,218	2.8	1.0	0.8	0.6	0.05	2 trips	None	None	None	None	not captured
8	AL	1000	2,282	2.7	0.9	0.8	0.5	0.04	2 trips	None	None	None	None	not captured
9	AL	360	1,736	3.6	1.2	1.0	0.7	0.06	2 trips	None	None	None	None	not captured
10	AL	200	1,775	3.5	1.2	1.0	0.7	0.06	2 trips	None	None	None	None	not captured
11	IL	135	2,812	2.2	0.8	0.6	0.4	0.04	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
12	IL	225	2,252	2.8	0.9	0.8	0.6	0.04	2 trips	None	None	None	None	not captured
13	IL	250	3,154	2.0	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
14	IL	480	2,445	2.6	0.9	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
15	IL	150	2,847	2.2	0.7	0.6	0.4	0.04	2 trips	None	None	None	None	not captured
16	IL	120	2,343	2.7	0.9	0.8	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
17	IL	390	2,709	2.3	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
18	IL	160	3,252	1.7	0.7	0.6	0.4	0.03	1 trip	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
19	KY	50	2,452	2.5	0.9	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
20	KY	300	3,158	2.0	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
21	KY	300	3,222	1.9	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
22	KY	250	2,489	3.0	0.9	0.7	0.5	0.04	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
23	KY	280	2,330	3.2	0.9	0.8	0.5	0.04	2 trips	None	None	None	None	not captured
24	KY	400	2,377	2.6	0.9	0.8	0.5	0.04	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
25	KY	125	2,554	2.4	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
26	KY	825	3,011	2.1	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
27	KY	350	3,071	2.0	0.7	0.6	0.4	0.03	1 trip	None	None	None	None	not captured
28	KY	400	3,130	1.7	0.7	0.6	0.4	0.03	1 trip	None	None	None	None	not captured
29	KY	800	3,218	1.9	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
30	KY	1700	1,733	3.6	1.2	1.0	0.7	0.06	2 trips	None	None	None	None	not captured
31	KY	350	2,164	2.9	1.0	0.8	0.6	0.05	2 trips	None	None	None	None	not captured
32	KY	300	2,260	2.8	0.9	0.8	0.6	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
33	KY	2400	2,625	2.4	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
34	KY	200	2,653	2.4	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured

35	KY	250	2,781	2.2	0.8	0.6	0.4	0.04	1 trip	None	None	None	None	not captured
36	KY	300	2,792	2.1	0.8	0.6	0.4	0.04	1 trip	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
37	KY	500	2,807	2.1	0.8	0.6	0.4	0.04	1 trip	None	None	None	None	not captured
38	KY	160	2,809	2.2	0.8	0.6	0.4	0.04	2 trips	None	None	None	None	not captured
39	KY	150	3,096	1.8	0.7	0.6	0.4	0.03	1 trip	None	None	None	None	not captured
40	KY	560	2,303	2.7	0.9	0.8	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
41	KY	500	2,515	2.5	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
42	KY	200	2,547	2.5	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
43	KY	300	2,683	2.3	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
44	KY	140	2,696	2.3	0.8	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
45	KY	480	2,715	2.3	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
46	KY	360	2,721	2.2	0.8	0.7	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
47	KY	425	2,723	2.3	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
48	KY	970	2,858	2.1	0.7	0.6	0.4	0.03	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
49	KY	300	2,966	2.1	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
50	KY	300	3,005	2.0	0.7	0.6	0.4	0.03	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
51	KY	250	3,066	2.0	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
52	KY	525	3,084	1.4	0.7	0.6	0.4	0.03	1 trip	None	None	None	None	not captured
53	KY	235	3,270	1.8	0.6	0.6	0.4	0.03	2 trips	2 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
54	KY	380	3,343	1.9	0.6	0.5	0.4	0.03	2 trips	None	None	None	None	not captured
55	KY	242	3,410	1.8	0.6	0.5	0.4	0.03	2 trips	None	None	None	None	not captured
56	KY	150	1,647	3.8	1.3	1.1	0.8	0.06	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
57	KY	154	2,751	2.3	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
58	KY	700	2,783	2.2	0.8	0.6	0.4	0.04	2 trips	None	None	None	None	not captured
59	KY	235	3,024	2.1	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
60	KY	250	2,095	3.0	1.0	0.9	0.6	0.05	2 trips	None	None	None	None	not captured
61	KY	125	2,208	2.8	1.0	0.8	0.6	0.05	2 trips	None	None	None	None	not captured
62	KY	230	1,930	3.2	1.1	0.9	0.6	0.05	2 trips	None	None	None	None	not captured
63	KY	446	2,840	2.2	0.7	0.6	0.4	0.04	2 trips	None	None	None	None	not captured
64	KY	400	2,874	2.2	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
65	KY	400	3,464	1.8	0.6	0.5	0.4	0.03	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured

66	KY	480	2,638	2.4	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
67	MO	147	3,059	2.7	0.7	0.6	0.4	0.03	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
68	MO	200	2,274	2.7	0.9	0.8	0.5	0.04	2 trips	None	None	None	None	not captured
69	MO	225	2,550	2.4	0.8	0.7	0.5	0.04	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
70	MO	265	2,626	2.3	0.8	0.7	0.5	0.04	2 trips	2 trip	None	picoxystrobin at 8oz/ac	None	not captured
71	TN	195	2,324	2.6	0.9	0.8	0.5	0.04	2 trips	None	None	None	None	not captured
72	TN	170	2,369	2.5	0.9	0.8	0.5	0.04	2 trips	1 trip	None	picoxystrobin at 8oz/ac	None	not captured
73	TN	300	2,360	2.6	0.9	0.8	0.5	0.04	2 trips	None	None	None	None	not captured
74	TN	50	2,374	2.5	0.9	0.8	0.5	0.04	2 trips	1 trip	Treflan at 5lbs/ac	picoxystrobin at 8oz/ac	None	not captured
75	TN	240	2,658	2.4	0.8	0.7	0.5	0.04	2 trips	2 trip	None	picoxystrobin at 8oz/ac	None	not captured
76	TN	800	2,380	2.6	0.9	0.8	0.5	0.04	2 trips	None	None	None	None	not captured
77	TN	475	2,658	2.4	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
78	TN	314	2,889	2.2	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
79	TN	300	2,530	2.5	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
80	TN	280	3,146	2.0	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
81	TN	110	2,070	3.0	1.0	0.9	0.6	0.05	2 trips	None	None	None	None	not captured
82	TN	99	2,392	2.6	0.9	0.8	0.5	0.04	2 trips	None	None	None	None	not captured
83	TN	150	2,653	2.4	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
84	TN	600	2,738	2.3	0.8	0.7	0.5	0.04	2 trips	None	None	None	None	not captured
85	TN	850	2,871	2.2	0.7	0.6	0.4	0.03	2 trips	None	None	None	None	not captured
86	TN	500	3,288	1.9	0.6	0.5	0.4	0.03	2 trips	None	None	None	None	not captured

Appendix C: Induced Land Use Change Emissions: Case of Renewable Diesel Produced from Intermediate Winter Canola Oil

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A Research Consulting Project
Supported by Bunge Chevron Ag Renewables LLC

Final Research Report
November 14, 2025

Induced Land Use Change Emissions: Case of Renewable Diesel Produced from Intermediate Winter Canola Oil

Farzad Taheripour
Research Professor

1. Introduction

Intermediate winter canola can be produced on the existing cropland as a second crop in rotation with corn and soybean or other crops in various geographical regions across the US. Therefore, as a second crop, no new cropland is needed to produce this crop. Production of intermediate winter canola as a second crop will neither increase demand for crop land nor irrigation practices. Producing intermediate winter canola provides vegetable oils that could be used for producing Renewable Diesel (RD). It also generates meal that can be used by the livestock industry as a source of protein in animal feed diets. The oil and meal contents of winter canola are about 42% and 58%, respectively. Therefore, compared with soybeans which contain about 20% oil, winter canola provides more oil and less meal. Productivity of U.S. winter canola varies by region and production technology, as intermediate winter canola has been bred to vernalize in temperate winter climates. However, producing intermediate winter canola in designated areas is expected to be about 3 metric tons per hectare. This is lower than the average productivity of US soybeans which currently varies around about 3.3 metric tons per hectare. However, as noted above, intermediate winter canola is expected to be produced as a second crop with no need for new cropland.

While production of intermediate winter canola as a second crop does not need new land, its conversion to RD could generate some savings in land use due to providing meals for the livestock industry. The new meal generated due to expansion in intermediate winter canola for producing RD could help the livestock industry to produce more products using less land. The intermediate winter canola meal could also be used as a substitute for soybean meal and drop the demand for cropland indirectly (Taheripour *et al.*, 2023). This research examines the extent to which producing RD from intermediate winter canola oil may affect Induced Land Use Changes (ILUC) at the global scale. It then calculates the ILUC emissions for this pathway. To accomplish these tasks, we introduced intermediate winter canola, intermediate winter canola oil, intermediate winter canola meal, and RD produced from intermediate winter canola oil into the latest version of the GTAP-BIO model adopted by the California Air Resources Board (CARB, 2014). The rest of this report explains the steps that we followed to estimate ILUC emissions for this RD pathway.

2. New sectors included in the GTAP-BIO Model adopted by CARB

Two new sectors were introduced into the model: Winter canola and Winter canola oil RD. The first industry uses intermediate inputs including seeds, chemicals, energy, services, and other intermediate inputs. It also uses capital (including margins gained above the operating costs) and labor to produce intermediate winter canola on the existing land as an annual second crop. Table 1 shows the cost structure of this new intermediate winter canola industry. The price of intermediate winter canola is based on the price of conventional canola in 2004, as the CARB GTAP-BIO model represents the world economy in 2004. The U.S. price of canola, and therefore intermediate winter canola, in 2004 was about $235 per metric ton.

Table 1. Cost structure for winter canola production

Major cost items	Share (%)
Winter canola seed	7.6
Chemicals including fertilizer, pesticide, …	27.7
Energy	1.6
Other costs	13.5
Labor	4.5
Capital (including margins over production costs)	45.1
Total	100.0

The second industry, winter canola oil RD, purchases intermediate winter canola, crushes the seed, and converts the extracted oils to RD following the GREET assumption for the amount required oil per gallon of RD. This sector also produces intermediate winter canola meal, and sells it to livestock industries. The livestock industry uses the meal as feed. The cost structure of this industry follows the GTAP cost structure of conventional canola oil, identified as rapeseed oil in the GTAP-BIO model. The database is modified to include production of 500,000 gallons of intermediate winter canola oil RD as an initial value. Seeding the industry with a small quantity of the product is necessary to permit simulations in GTAP-BIO. The CARB version of the GTAP-BIO model is modified to handle the new sectors and their products.

3. Examined Simulations

ILUC emissions for intermediate winter canola RD will be estimated for a shock size of 100 million gallons expansion in this biofuel under various model parameters that CARB has considered for other biofuel pathways. The GTAP-BIO baseline parameters for ILUC calculation are: YDEL[1]=0.25; PAEL[2] for U.S. = 0.4; PAEL for Brazil = 0.2, and ETA[3] = Standard GTAP values. These parameter values have been considered as central values. CARB defined a distribution for each of these parameters. Table 2 represents the implemented parameters by CARB.

Table 2. Parameter values used by CARB in December 2014

Parameter		December 2014
YDEL		0.05, 0.1, 0.175, 0.25, 0.35
ETA		80%, 100%, 120%
PAEL	U.S.	0.2, 0.4
	Brazil	0.1, 0.2

The possible mixes of these parameters are 30 cases, as shown in Table 3. For each case listed in this table a simulation has been made.

Table 3. Summary of scenario parameter values adopted by CARB

Scenario	YPE	PAEL_BR	PAEL_US	TEM
1	0.05	0.1	0.2	Baseline TEM
2	0.05	0.2	0.4	Baseline TEM
3	0.1	0.1	0.2	Baseline TEM
4	0.1	0.2	0.4	Baseline TEM
5	0.175	0.1	0.2	Baseline TEM
6	0.175	0.2	0.4	Baseline TEM
7	0.25	0.1	0.2	Baseline TEM
8	0.25	0.2	0.4	Baseline TEM
9	0.35	0.1	0.2	Baseline TEM
10	0.35	0.2	0.4	Baseline TEM
11	0.05	0.1	0.2	120% TEM Baseline
12	0.05	0.2	0.4	120% TEM Baseline
13	0.1	0.1	0.2	120% TEM Baseline
14	0.1	0.2	0.4	120% TEM Baseline
15	0.175	0.1	0.2	120% TEM Baseline
16	0.175	0.2	0.4	120% TEM Baseline
17	0.25	0.1	0.2	120% TEM Baseline
18	0.25	0.2	0.4	120% TEM Baseline
19	0.35	0.1	0.2	120% TEM Baseline
20	0.35	0.2	0.4	120% TEM Baseline

[1] YDEL represents yield to price elasticity
[2] PAEL represents rate of yield improvement associated with the land type of cropland-pasture.
[3] ETA represents productivity of new cropland relative to productivity of exiting cropland

21	0.05	0.1	0.2	80% TEM Baseline
22	0.05	0.2	0.4	80% TEM Baseline
23	0.1	0.1	0.2	80% TEM Baseline
24	0.1	0.2	0.4	80% TEM Baseline
25	0.175	0.1	0.2	80% TEM Baseline
26	0.175	0.2	0.4	80% TEM Baseline
27	0.25	0.1	0.2	80% TEM Baseline
28	0.25	0.2	0.4	80% TEM Baseline
29	0.35	0.1	0.2	80% TEM Baseline
30	0.35	0.2	0.4	80% TEM Baseline

4. Results

Table 4 summarizes the land use changes and their corresponding ILUC emission values for the examined 30 cases. The CARB AEZ-EF model has been used to convert the GTAP-BIO results to ILUC emissions.

Table 4. Estimates of land converted predicted and ILUC results for the 30 scenario runs for intermediate winter canola renewable diesel

Scenario	World-Wide Land Converted (ha)			Land Converted in Brazil (ha)			ILUC (gCO2/MJ)
	Forest	Pasture	Cropland-Pasture	Forest	Pasture	Cropland-Pasture	
1	10,595	14,371	29,172	928	823	20,313	-27.5
2	9,456	15,694	29,884	801	1,112	20,864	-25.8
3	9,276	11,340	26,526	883	743	18,732	-23.6
4	8,263	12,509	27,176	727	945	19,236	-22.2
5	7,814	8,285	23,631	776	642	16,966	-19.5
6	6,904	9,323	24,207	626	848	17,427	-18.1
7	6,692	6,021	21,515	727	549	15,655	-16.7
8	5,886	7,017	22,036	558	754	16,069	-15.5
9	5,781	4,324	19,403	615	451	14,320	-14.4
10	5,095	5,119	19,868	505	642	14,695	-13.4
11	9,028	11,529	29,425	818	654	20,398	-24.2
12	7,726	12,929	30,132	604	916	20,950	-22.5
13	7,868	9,140	26,740	713	590	18,797	-20.8
14	6,818	10,328	27,382	560	782	19,311	-19.2
15	8,263	6,321	23,807	670	505	17,032	-17.3
16	7,814	7,412	24,391	503	718	17,488	-16.2
17	6,904	4,554	21,674	589	412	15,712	-15.1
18	6,692	5,585	22,199	409	609	16,129	-13.9
19	5,886	3,081	19,535	503	358	14,368	-12.9
20	5,781	3,914	20,015	390	526	14,752	-12.0
21	5,095	18,175	28,843	1,165	1,121	20,210	-32.6
22	9,028	19,570	29,525	1,006	1,388	20,752	-30.9
23	7,726	14,535	26,233	1,092	1,011	18,633	-27.7

24	10,279	15,796	26,839	945	1,266	19,129	-26.3
25	9,477	10,678	23,381	941	791	16,889	-22.9
26	8,564	11,918	23,945	812	1,119	17,336	-21.6
27	8,276	8,379	21,297	898	689	15,586	-19.4
28	7,415	9,323	21,799	759	918	15,988	-18.4
29	6,946	5,925	19,192	794	622	14,244	-16.2
30	6,280	6,713	19,656	661	779	14,621	-15.4
					Average ILUC (gCO2/MJ)		-20.1

The results presented in Table 4 indicate that production of RD from intermediate winter canola grown as second crop reduces demand for cropland, which increases areas of forest, pasture, and cropland-pasture. In general, the results confirm that, other factors being equal, increases in values of PAEL, YDE (or YDEL) and TEM (or ETA) lead to smaller savings in the demand for cropland in most cases with some changes in the mix of savings in forest, pasture, and cropland pasture.

Table 4 represents the ILUC emissions for each case as well. In general, the results confirm that, other factors being equal, increases in values of PAEL, YDE (or YDEL), and TEM (or ETA) lead to smaller emissions savings. Overall, Table 4 shows that an increase in RD produced from intermediate winter canola as a second crop by 100 million gallons leads to a saving in land use emissions by 20.1 gCO2/MJ on average.

In conclusion, this research has examined the effects of a limited shock size of 100 million gallons of RD produced from intermediate winter canola as a second crop. This level of shock generates minor land use changes with insignificant impacts on the commodity prices and profitability of agricultural activities in the U.S. or at the global scale. This research also assumes that intermediate winter canola produced as a second crop will be used only for RD production @and will not be used to produce edible oil. This research also assumes that producing intermediate winter canola as a second crop in rotation with other crops will not affect productivities of other crops. Finally, it is important to note that the CARB GTAP-BIO model has not been updated over time and its simulation results could be different for the results obtained from the newer versions of this model that operate based on the newer databases.

References

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