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A regional assessment of land, irrigation water, and greenhouse gas emissions from canola biodiesel feedstock production in California

Kiara Winans Department of Civil and Environmental Engineering, University of California, Davis, California 95616, kswinans@ucdavis.edu
Boon-Ling Yeo Energy Institute, University of California, Davis, California 95616, blyeo@ucdavis.edu
Nicholas George Department of Plant Science, University of California, Davis, California 95616, nicgeorge@ucdavis.edu
Alissa Kendall Department of Civil and Environmental Engineering, University of California, Davis, California 95616, amkendall@ucdavis.edu
Stephen Kaffka Department of Plant Science, University of California, Davis, California 95616, srkaffka@ucdavis.edu

Abstract. The objective of this research is to evaluate the effects of cropping choices on land, water use for irrigation, and greenhouse gas emissions after introducing canola (*Brassica napus* L.) cultivation for the production of 60 million gallons of biodiesel per year. Characterization of regional farm-level cropping patterns and agronomic inputs and economic data are used to model the adoption of canola in place of the diverse incumbent cropping patterns in four regions of California: Northern and Southern San Joaquin Valleys, Sacramento Valley, and Southern California, using the Bioenergy Crop Adoption Model. The life cycle assessment approach is then used to assess environmental impacts due to cultivation of canola in place of the incumbent cropping patterns in terms of: (1) land use; (2) life-cycle greenhouse gas emissions due to direct land use change (kg CO_2e ac^{-1}); (3) greenhouse gas emissions due to irrigation water (kg CO_2e ac^{-1}); and (4) life-cycle greenhouse gas emissions expressed in grams of carbon dioxide equivalent per megajoule of biodiesel. Preliminary results show the adoption price of the canola with a yield of 1.5 U.S. tons per acre is estimated to be $481 per ton of canola in 2012 dollars at which point a total of 508,400 acres appear in canola cultivation. This land area (508, 400 acres) is equivalent to approximately 89 million gallons of biodiesel from canola per year given the assumptions stated in this study. Consequentially, crops that are less profitable are replaced with canola and greenhouse gas emissions due to irrigation water are reduced while maintaining a diversified percentage of the incumbent cropping patterns, as well as canola cultivation.

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Introduction. Substitution of fossil fuels with lower carbon biofuels may reduce lifecycle greenhouse gas (GHG) emissions (Huang et al. 2013). However, understanding the effects of a decision to introduce a biofuel crop requires a consequential analysis, which can be carried out systematically by using life cycle assessment (LCA). No previous studies have considered the consequences of introducing a biofuel crop to California's regionally diverse cropping patterns which are dominated by specialty crops. In highly diversified farming regions like California where a large number of crops produced and land use varies regionally, multiple changes in cropping patterns and land use are possible when new crops introduced. These changes can be complex and have various consequences. Linking economic models with LCA methods helps evaluate changes in complex systems.

Canola (*Brassica napus* L.) is an oilseed crop grown globally for human consumption and biodiesel production (USDA ERS, 2015). In the United States, current canola production is concentrated in the Northern Plains (Montana, North Dakota, and Minnesota) and Oklahoma, Oregon, and Washington. Current demand for canola products in the United States exceeds domestic production (USDA ERS, 2015). The historic market price of canola has fluctuated over the last 30 years (1102±330 U.S. dollars per U.S. ton of crude oil) depending on market conditions (Canola Council of Canada, 2015a). There is no commercial canola production in California currently, but studies suggest it has high yield potential in the study regions (Kaffka et al., 2013; George et al., submitted, Crop Science). Regional farm-level cropping patterns, agronomic inputs, and economic data are used to model the adoption of canola in place of some incumbent crops using the Bioenergy Crop Adoption Model (BCAM) developed by Kaffka and Jenner (2011).

Environmental impacts, e.g. water use and land use GHG emissions vary due to geographic disparities that must be understood to account better for the various consequences of a production chain (Chiu et al., 2009; Stoms et al., 2012). LCA can be used to account for spatial variability of water impacts and carbon footprint of the production chain (Holma et al., 2013; Hortenhuber et al., 2014; Goglio et al., 2015). In this study, a regionally specific agro-economic model and a model of environmental effects are linked to assess crop substitution effects due to the adoption of canola (*Brassica napus* L.) for the production target of 60 million gallons (MG) of biodiesel per year. This target approximately doubles current in-state biodiesel production while helping to meet the state's Low Carbon Fuel Standard for low carbon intensity biofuels. These effects are reported for four of the main agricultural regions in California: Sacramento Valley, Northern and Southern San Joaquin Valleys, and Southern California (primarily irrigated desert areas). The environmental model uses an LCA approach to evaluate some environmental impacts due to the cultivation of canola in place of the incumbent cropping patterns. These effects include: (1) direct land use; (2) life cycle GHG emissions due to direct land use change (kg CO_2e ac^{-1}); (3) GHG emissions due to irrigation water (kg CO_2e ac^{-1}); and (4) life cycle GHG emissions expressed in grams (g) of carbon dioxide equivalent (CO_2e) per megajoule of biodiesel ($MJ_{biodiesel}$).

Research Questions. At what price would farmers be willing to displace the required acres of land currently planted in traditional crops and adopt the production of canola for producing 60 MG of biodiesel per year in the Sacramento Valley, Northern and Southern San Joaquin Valleys, and agricultural areas of Southern California?

What are the environmental impacts of introducing canola in California relative to the incumbent cropping pattern as measured by: (1) land use; (2) life cycle GHG emissions due to direct land use change (kg CO_2e ac^{-1}); (3) GHG emissions due to irrigation water (kg CO_2e ac^{-1}); and (4) life cycle GHG emissions (including differences in crop cultivation inputs) expressed in g CO_2e $MJ_{biodiesel}^{-1}$?

Investigative Method. Soil moisture data and weather data obtained from the California Irrigation Management Information System (CIMIS, 2015), the National Climatic Data Center (NCDC, 2015), and from in-field weather stations was used to assess regionally specific background conditions, i.e. for water availability. The amount of irrigation water required for each crop was based on the crop requirements considering the water availability (including estimated average winter precipitation and residual soil water) per region. The estimated amount of irrigation water for canola was determined for each growing region as follows: 0.33 ac-ft for Sacramento Valley; 0.70 ac-ft Northern and Southern San Joaquin Valley; and 1.50 ac-ft for Southern California (Table 1). Nitrogen recommendations for canola are dependent on the expected yield. At the same time, the yield of canola in California is correlated closely with either total rainfall up to crop requirements or supplemental irrigation received by the crop. Approximately 6 to 7 units of N are required for every 100 units of harvested seed (Canola Council of Canada, 2015b).

Agroeconomic model description and input data. The BCAM is an agro-economic optimization model used to assess crop and total land area per crop of a region that may be converted for use as a bioenergy crop (Kaffka and Jenner, 2011; Kaffka et al., 2014). To identify the diversity of cropping patterns planted in the study regions, long-term cropping patterns and agricultural land use were determined using data self-reported by farmers and assembled in the California Department of Pesticide Regulation's Pesticide Use Report (PUR) database, combined with historical cropland use recorded by the respective County Agricultural Commissioners. Data reported by farmers are aggregated on a one-square-mile section (640 ac.). Additional data from the National Agricultural Statistical Service was also used to help create a complete picture of actual land use or to check results based on PUR data. Analyzing this data provided an estimate of crop frequency from 2003 to 2012 by location across the study regions, which was then interpreted here as incumbent crop land use or effectively as incumbent cropping patterns. These cropping patterns are the dominant, recurring patterns of land allocated for the ten most common crops grown in a cluster or sub-region of the state, accounting for approximately 90 to 95% of actual land use and normalized for those ten crops. Information on crop production costs was acquired between years 2003–2012 and then adjusted to 2012 price levels using the Consumer Price Index (Table 1). This analysis excludes land planted in woody perennial crops, like orchards and vineyards, with the assumption that such areas are infrequently rotated to new annual crops in response to small changes in crop prices.

Regional clusters are considered to be representative cropping systems for modeling purposes when used in BCAM. Clusters may not be physically contiguous, but reflect similarities in land use patterns for crops within larger agricultural production regions. These similarities are on a diverse set of biophysical or other non-apparent factors contributing to farmers' crop choices not accounted for in this study. Thus, the diversity of incumbent crops displaced by canola and crop adoption within regionalized cropping systems is based on recent patterns of farmland use in California, resulting from farmers' collective choices.

After identifying the clusters per region, the optimization function of BCAM is used (Jenner and Kaffka, 2011; Kaffka et al., 2014; Kaffka et al., 2015), which is based on Positive Mathematical Programming (PMP) optimization principles (Howitt 1995). For purposes of testing crop introduction, the BCAM optimization approach is calibrated against the existing cropping system(s) to obtain some parameters that help to recover the marginal input costs from the observed average price (Table 1). The PMP method estimates the parameters of the production functions of each incumbent crop using the shadow prices of inputs in the base system, defined as the maximum price that farmers are willing to pay for an extra unit of inputs, i.e. land or water, for producing a crop. The PMP model then transforms these opportunity costs into parameters of a quadratic production function that preserve the core relationship information within the system as new crops are introduced. Land area values for each crop vary with a change in price, while the marginal values of the base system are held constant. The model structure allows the output price and the input costs to be varied. Once the PMP coefficients are established, incremental changes in a profit of the new (exogenous) bioenergy crops are introduced by adjusting the bioenergy crop output price over a range of price increases at specified, regular increments. New crop alternatives are tested by holding the non-linear coefficients of the existing cropping system constant while incrementally increasing the profit for the exogenous bioenergy crops, which enter in the model as a linear equation. The underlying price of adoption can be identified at the regional cluster level, keeping yield and input costs constant. Exogenous bioenergy crops are not part of the initial system and have no opportunity cost constraint. Other crop prices do not adjust endogenously in response to the new bioenergy crop, e.g., canola introduction. Here, a goal of doubling current in-state biodiesel production is used as an upper constraint on crop adoption. Storage and transportation costs to the processing facility are not included in the analysis.

Based on field data results, a canola yield of 1.5 U.S. tons per acre (t ac^{-1}) with a seed oil content of 43.5% was used for this analysis, which was assumed to lead to the production of 60 MG of biodiesel per year. This amount approximately doubles in-state biodiesel production in California. Actual canola yields can be higher than 1.5 t ac^{-1} at times. For example, field studies have shown that it is possible to get canola yield of up to 2.0 t ac^{-1} (Kaffka et al., 2014; George et al., CROP SCIENCE, submitted). The biodiesel production quantity assumption is based on a reasonable amount (i.e. 60 MG) of biodiesel that one or more existing biodiesel processing facilities in California can produce per annum.

Life cycle assessment approach.

This study applies a consequential approach to evaluating life cycle GHG emissions caused by the introduction of canola for biodiesel production in the state of California. As a consequential analysis, the study examines the existing cropping pattern and emissions attributable to this cropping pattern and then examines the change in emissions induced by canola for biodiesel production, which is represented in Figure 1.

The system boundary includes agronomic activities for cultivation and stops after crop harvest (meaning transport of harvested product and any processing of the product is excluded). Each crop is modeled with the functional unit of one acre, but the scope of analysis (and thus the reported functional unit) is the total crop cultivation emissions from the four modeled regions. The life cycle inventory (LCI) flows tracked in the model include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions. LCI datasets were obtained from the GaBi© (version 6.0) and Ecoinvent (version 3.1) databases. The economic model output data is used to indicate the crop mix. The LCIs built for each crop, i.e. the crop inputs (fertilizer, irrigation water, and on-farm fuel) are then used as inputs for the LCA model, i.e. to account for crop mix and the inputs required for cultivating each crop.

The fertilizer inputs considered for the current study include (nitrogen (N), phosphorus (P_20_5), potassium (K_20), and sulfur (S)) per crop requirements for the study area. Crop fertilizer requirement data (and the economic data) were both obtained from the cost and return studies published by the Department of Agricultural and Resource Economics at the University of California Davis (Agricultural and Resource Economics, University of California Davis, 2015). N_2O emissions from fertilized fields are calculated using the Intergovernmental Panel on Climate Change (IPCC) Tier 1 emissions factor, which defines a linear relationship between applied N and N_2O emissions (IPCC, 2006).

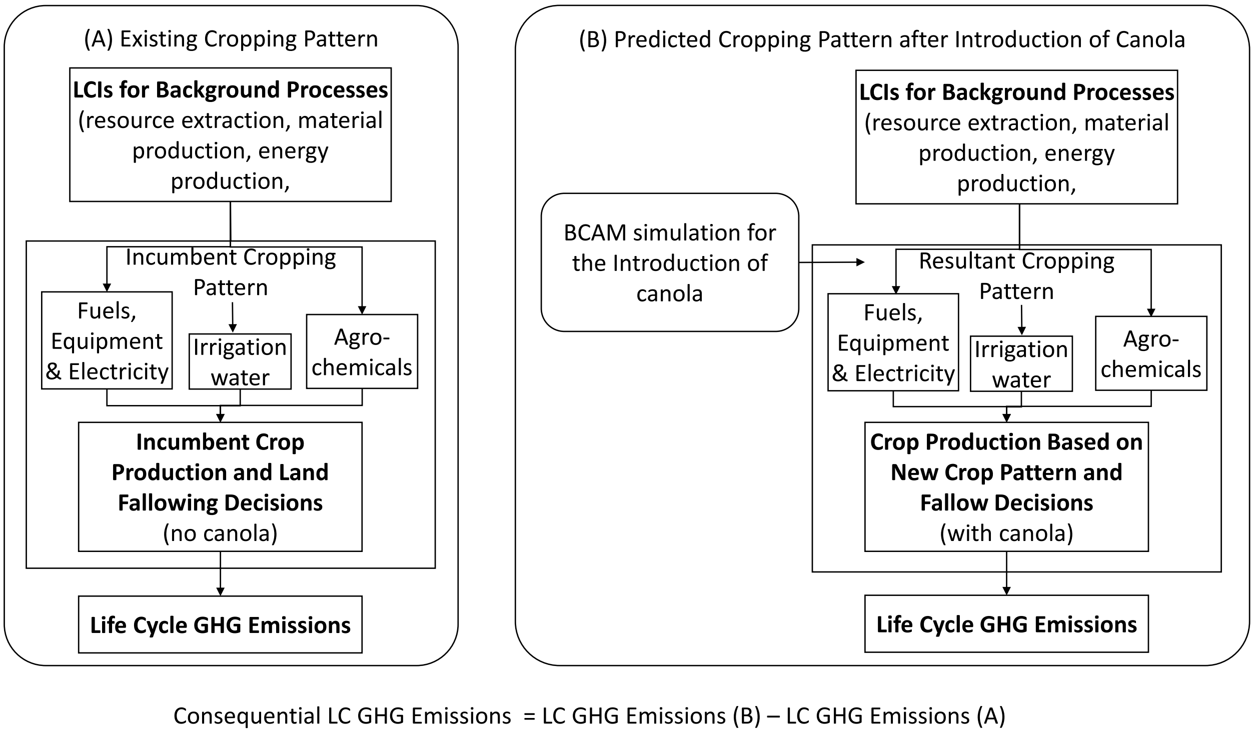

Figure 1: Consequential Assessment of Canola Production in California for Biodiesel Production.

Water inputs (acre-feet (ac-ft)) per crop are reported in Table 1 and diesel inputs per acre are assumed as a high estimate of 9 gallons of diesel used per acre for all crops.

Irrigation water emissions from electricity generation and diesel production were obtained from Kuczenski (2010a and b) and GaBi© (version 6.0). The estimated irrigation water emissions (9.36×10^{-6} kg CO_2e ac^{-1} H_2O) account for the pumped surface water delivery system including state and federal water projects (Central Valley Project and California Aqueduct, respectively). The estimated irrigation water emissions also account for gravity-fed surface water delivery from the reservoirs of the Sierra Nevada using an irrigation model developed in Kendall et al. (2015). The estimated emissions from surface water (from the total surface and ground) were 0% in Sacramento Valley, 30% in San Joaquin Valley, and 50% in Tulare Lake region. Irrigation water LCA emissions also account for groundwater depth as measured from the Department of Water Resources test wells in the year 2013. Diesel pump field emissions were obtained from CARB OFFROAD (2007), and electric, and diesel pump efficiencies were estimated at 0.50 and 0.23, respectively (Chávez et al., 2011; Martin et al., 2011).

All GHG emissions were converted to CO_2e and the only impact assessment method applied was the 100-year global warming potential (GWP_{100}) based on values reported in the IPCC Fifth Assessment Report (IPCC, 2014). To convert the canola (seed oil content of 43.5%) to gCO_2e

per MJ, conversion factors of 207.34 U.S. gallon oil equivalent, and 123.50 MJ per U.S. gallon (low heating value) and 133.10 MJ per U.S. gallon (high heating value) were used (Hofstrand, 2008).

Agroeconomic model results. The price of canola needed to encourage sufficient feedstock production to double in-state biodiesel production was estimated to be \$481 per ton of canola in 2012 dollars, at which price a total of 508,400 acres appears in diverse regions of the state for canola production. This area exceeds the land needed (345,000 ac) to produce the 60 MG of biodiesel from canola per year due to the competitive profit relationship between wheat and canola in which small price advantages lead to displacement. Regional clusters and incumbent crops identified in the study and total land area before and after canola planting, i.e. area displaced are indicated in Tables 2–5. Of the total land area (~4 million acres) assessed within the four regions in California, the total land area of incumbent crops displaced due to canola production is 508,400acres (~13% of the total land area assessed). Percent incumbent crops replaced is highest in Southern San Joaquin Valley (37%) followed by Sacramento (25%), Northern San Joaquin Valley (21%), and Southern California (15%). In all regions, the primary crop replaced is wheat (Tables 2–5). This outcome results primarily from the favorable economic assumptions made for the cost of production of canola compared to wheat, and indicates that depending on relative price assumptions that may vary from year to year, wheat and canola production are alternatives to each other. In some cases, there were small increases in other crops, depending on the region. Economic model outcomes from this study suggest that adding a canola biodiesel crop sustains or increases the economic resiliency of farming in the diverse areas of the state.

Sensitivity analysis of changes in canola yield and price were evaluated. At the price \$481 per ton of canola in 2012 dollars and canola yield increase to 2.0 t ac^{-1}, canola crop is adopted immediately, limiting the number of incumbent crops planted following canola adoption. If the price of canola needed to encourage sufficient feedstock production to double in-state biodiesel production is reduced to be \$361 per ton of canola in 2012 dollars, a total of 357,810 acres appears in diverse regions of the state for canola production. Further sensitivity analysis of factors like canola yield and canola price are needed and will provide decision makers with a more comprehensive understanding of some of the economic and environmental consequences of adopting canola in California.

Life cycle assessment results. Calculated life cycle GHG emissions accounted for inputs (fertilizer, irrigation water, and equipment operation) per crop per acre and amounted to 591 ± 309 kg CO_2e (Figure 2). The GHG emissions calculated from incumbent crops before and after canola planting are compared per region (Figure 3). For all regions (combined) the GHG emissions due to agronomic inputs for land use increased by 587 kg CO_2e ac^{-1} after canola planting. Calculated life cycle GHG emissions for irrigation per crop amounted to 0.00002 ± 0.00001 kg CO_2e (Figure 4). The GHG emissions attributed to irrigation overall decreased by 0.36 kg CO_2e after canola planting. Calculated emissions for canola production (not including processing) amounted to 20.65–22.26 gCO_2e per $MJ_{biodiesel}$.

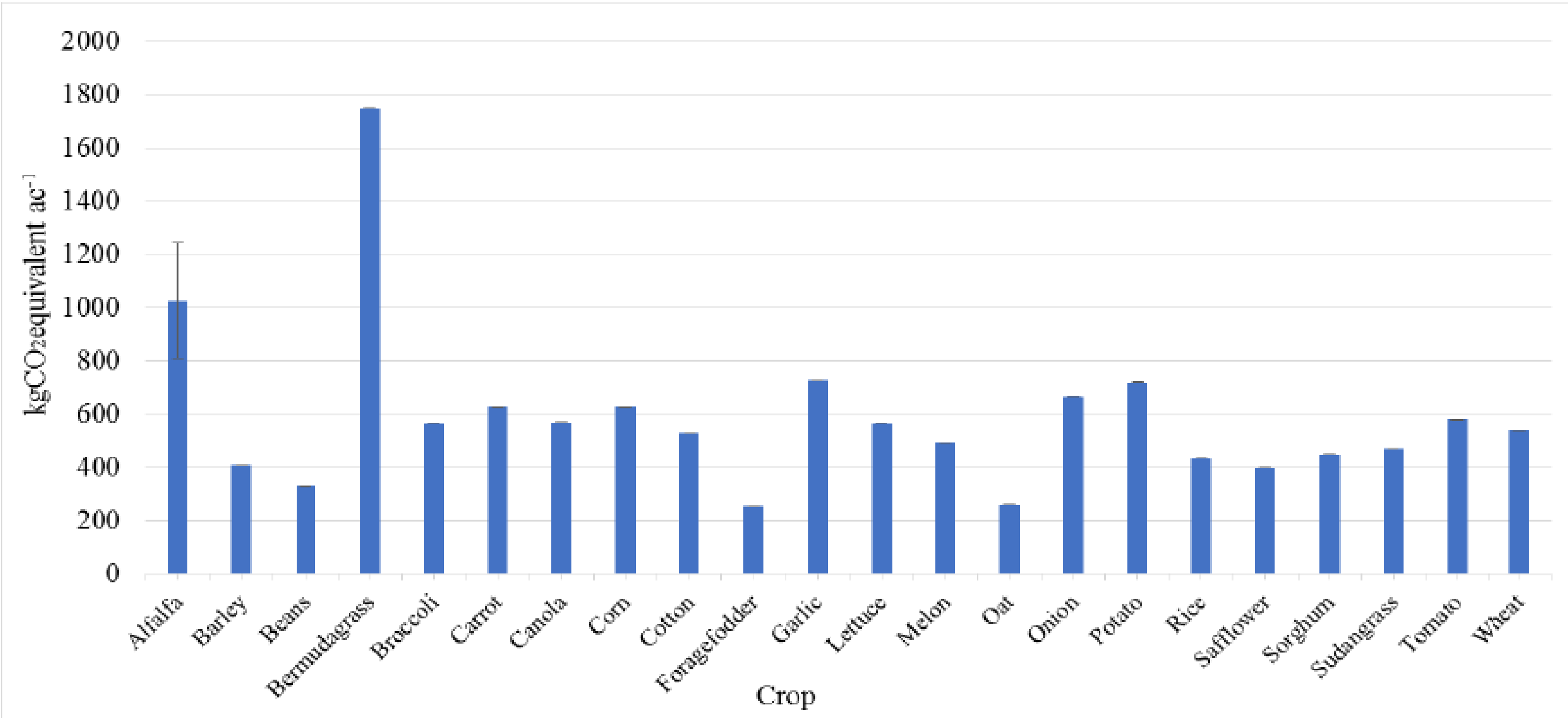

Figure 2: **Greenhouse gas emissions (kgCO_2e per acre) per crop.** GHG emissions considering fertilizer and water (ac-ft) and diesel inputs per acre accounted for separately for each crop (Table 1).

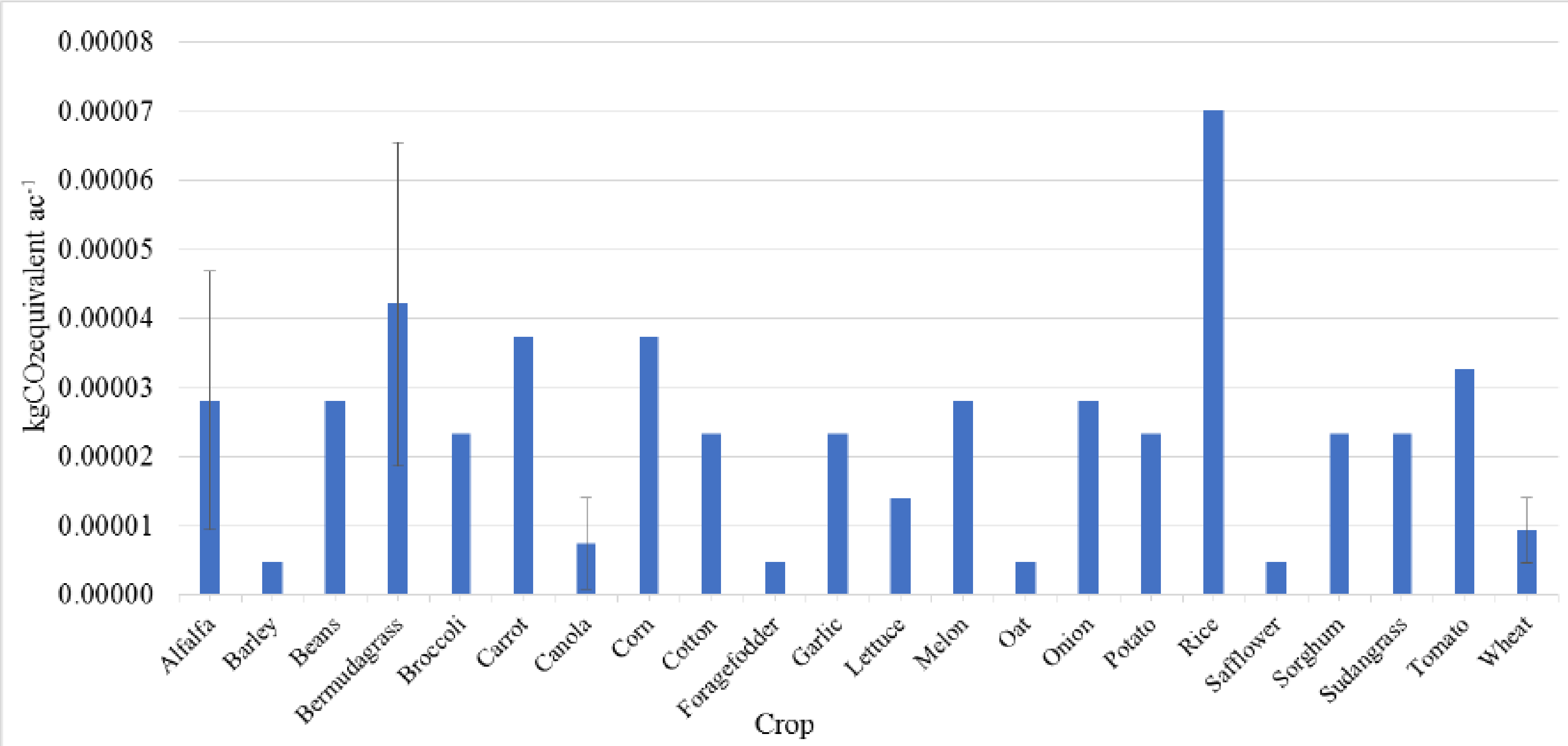

Figure 4: Greenhouse gas emissions $kgCO_2e$ per acre for irrigation. GHG emissions for incumbent crops and canola considering irrigation emissions from electricity generation and diesel production, and for the pumped surface water delivery systems as well as gravity fed surface water.

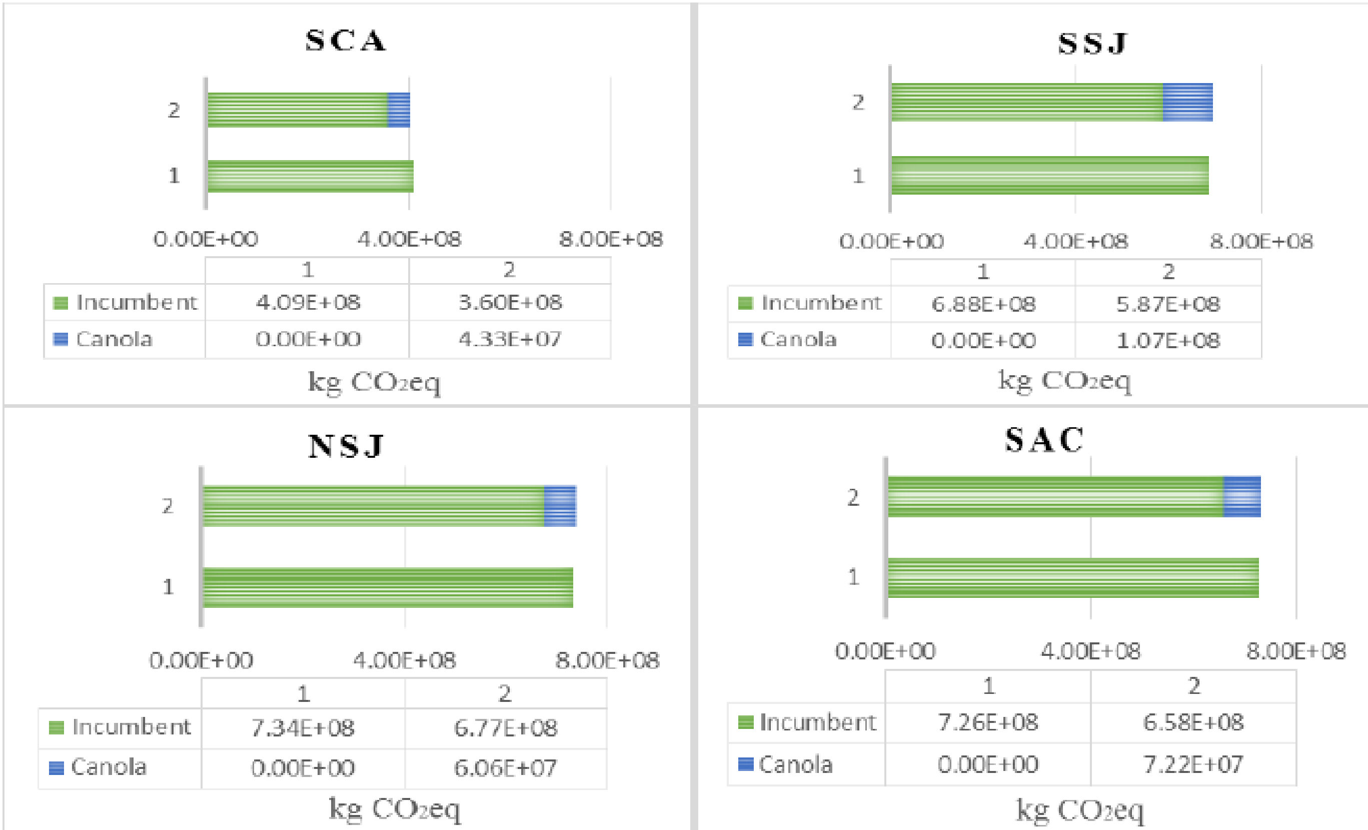

Figure 5: **Greenhouse gas (GHG) emissions before and after canola planting.** GHG emissions for incumbent crops (1) before canola, and (2) after canola planting considering emissions from fertilizer and water (ac-ft) and diesel inputs to agronomic operations per crop. Northern San Joaquin (NSJ) and Southern San Joaquin (SSJ) Valleys, Sacramento (SAC) Valley, and Southern California (SCA).

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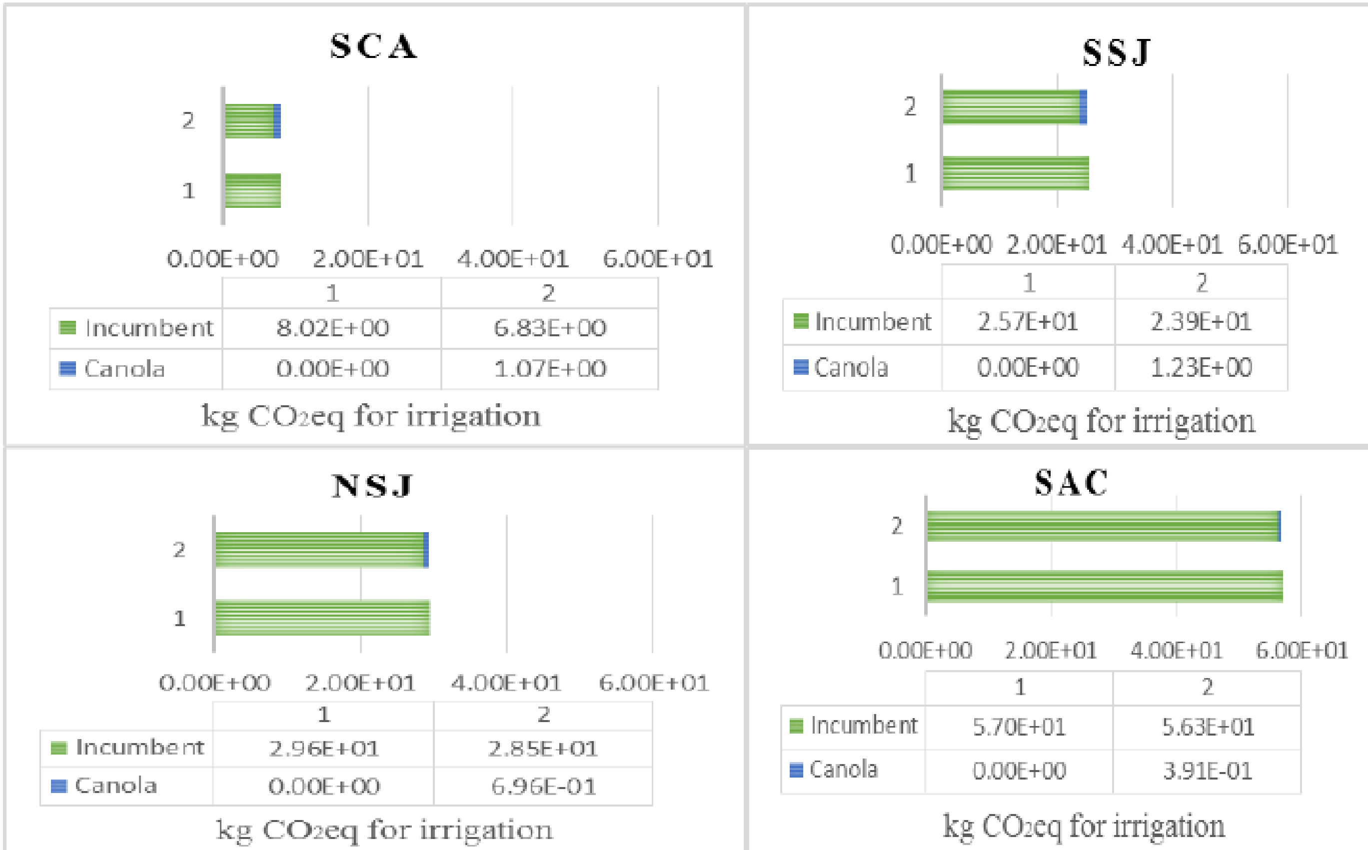

Figure 6: **Greenhouse gas (GHG) emissions for irrigation before and after canola planting.** GHG emissions for incumbent crops (1) before canola, and (2) after canola planting considering emissions from electricity generation and diesel production, and for the pumped surface water delivery systems as well as gravity fed surface water. Northern San Joaquin (NSJ) and Southern San Joaquin (SSJ) Valleys, Sacramento (SAC) Valley, and Southern California (SCA).

Conclusions. Canola and diversified incumbent cropping system production are optimized to increase economic profit at the adoption price of $481 per ton of canola in 2012 dollars. The GHG emissions are attributed to irrigation reduced 0.36 kg CO_2e while maintaining diversified cropping pattern that includes both the majority of land uses in incumbent crops as well as canola, which varies depending on the region. The overall net increase in GHG emissions is calculated to be 587 kg CO_2e ac^{-1} to grow canola to produce the total 60 MG biodiesel per year, without accounting for the benefits of producing canola meal protein, a valuable co-product used as feed for dairy cows. For by-products such canola protein meal, approximately 50% of seed yield or everything left over after the oil is removed. This by-product is not accounted for in the current study, yet is a factor that would favor canola production and should be considered in future work.

Overall, calculated emissions for canola production (not including processing) amounted to 20.65–22.26 gCO_2e per $MJ_{biodiesel}$. If compared to the average for gasoline ~96.5 gCO_2e/MJ_{EtOH} and a corn ethanol pathway ~32 gCO_2e/MJ_{EtOH}, it makes sense environmentally to plant canola in California. Still, some of the crops assessed in this study have additional environmental benefits that need to be considered further, in particular in cases where crops may contribute to soil quality improvements like C sequestration, water, and nutrient use efficiency, or wildlife and pollinator benefits (Stoms et al., 2012).

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Table 1. Yield, economic information, and water input data for crop production in California based on cost and return studies published by the Department of Agricultural and Resource Economics at the University of California Davis

Crop	Yield (U.S. t^{-1})	Price (U.S. $\$^{-1}$)	Cost (U.S. $\$ t^{-1}$)	Water (ac-ft)	Price & Yield Data Year	Cost Data Year
Alfalfa	6.90	211.00	661.00	1.00–5.00*	2012	2012
Barley	1.32	248.75	166.00	0.00	2012	1995
Beans	1.13	980.00	1048.00	3.00	2012	2013
Broccoli	6.60	1040.00	6630.00	2.50	2007	2007
Bermudagrass	5.30	157.24	802.81	2.5–5.00*	2012	2012
Carrot	17.36	480.36	6883.00	4.00	2012	2004
Canola	1.50	480.00	720.00	0.33–1.50*	2007	2007
Corn	5.18	252.00	1258.00	4.00	2012	2012
Cotton	0.83	2060.00	1321.00	2.50	2012	2012
Forage fodder	2.60	148.61	371.96	0.50	2007	2007
Garlic	6.90	820.00	4834.00	2.50	1992	1992
Lettuce	15.75	667.00	9451.00	1.50	2009	2009
Melon	16.68	517.00	5672.00	5.00	2003	2004
Oat	2.60	148.61	371.96	0.00	2007	2007
Onion	20.32	228.34	2406.80	3.00	2012	2011
Potato	20.00	140.00	2555.00	2.50	2007	2007
Rice	4.055	300.00	734.00	7.50	2007	2007
Safflower	1.05	420.00	330.00	0.50	2012	2011
Sorghum	5.00	155.07	704.14	2.50	2007	2007
Sudangrass	5.30	157.24	802.81	2.50	2007	2007
Tomato	48.99	70.00	2354.00	3.50	2007	2007
Wheat	2.73	156.00	875.00	0.50–1.50*	2012	2013

*Water requirements for irrigation vary depending on region, increasing from north to south of California, e.g., for canola, from Sacramento Valley (0.33 ac-ft) to Northern & Southern San Joaquin Valley (0.70 ac-ft) and to Southern California (1.50 ac-ft).

Table 2. Output data from the Bioenergy Crop Adoption Model (BCAM) for Southern California

Incumbent crop	Acres before canola	Acres planted in canola*	Acres remaining in incumbent crop	% Land Use Change
alfalfa	228033	20	228013	0.01%
barley	843	1	842	0.18%
beans	1034	5	1029	0.45%
bermudagrass	18255	6939	11316	38.01%
broccoli	16452	22	16430	0.14%
carrot	23678	4	23674	0.02%
corn	14258	-49	14307	-0.34%
cotton	20580	12	20568	0.06%
foragefodder	3960	83	3878	2.09%
garlic	416	0	416	0.04%
lettuce	52047	17	52030	0.03%
melon	13069	-1	13070	-0.01%
oat	2574	72	2502	2.79%
onion	21738	3	21735	0.01%
potato	6783	8	6774	0.12%
rice	18	0	18	-0.03%
safflower	711	1	710	0.09%
sorghum	1440	6	1434	0.45%
sudangrass	13314	7108	6205	53.39%
tomato	581	0	581	0.02%
wheat	61739	61739	0	100.00%

*Negative values means acres increased.

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Table 3. Output data from the Bioenergy Crop Adoption Model (BCAM) for Southern San Joaquin Valley

Incumbent crop	Acres before canola	Acres planted in canola*	Acres remaining in incumbent crop	% Land Use Change
alfalfa	206940	35	206905	0.02%
barley	4281	20	4261	0.46%
beans	6701	19	6682	0.28%
bermudagrass	593	2	591	0.28%
broccoli	2418	0	2418	0.01%
carrot	37911	13	37898	0.03%
corn	186089	2054	184036	1.10%
cotton	261585	15	261570	0.01%
foragefodder	854	32	822	3.76%
garlic	7678	0	7678	0.00%
lettuce	2863	1	2862	0.03%
melon	2354	1	2353	0.03%
oat	16431	854	15577	5.20%
onion	12096	1	12095	0.01%
potato	24403	2	24401	0.01%
safflower	16814	90	16723	0.54%
sorghum	13618	4	13614	0.03%
sudangrass	2247	40	2207	1.79%
tomato	43119	13	43106	0.03%
wheat	208245	184000	24245	88.36%

*Negative values means acres increased.

Table 4. Output data from the Bioenergy Crop Adoption Model (BCAM) for Northern San Joaquin Valley

Incumbent crop	Acres before canola	Acres planted in canola*	Acres remaining in incumbent crop	% Land Use Change
alfalfa	211069	35	211034	0.02%
barley	11274	52	11222	0.46%
beans	23730	67	23663	0.28%
broccoli	8331	1	8330	0.01%
carrot	2168	1	2167	0.03%
corn	187194	2035	185159	1.09%
cotton	241000	14	240987	0.01%
foragefodder	2833	118	2715	4.17%
garlic	20454	1	20454	0.00%
lettuce	32294	9	32285	0.03%
melon	31912	9	31904	0.03%
oat	67997	3535	64462	5.20%
onion	20484	2	20482	0.01%
potato	9225	1	9224	0.01%
rice	7886	26	7860	0.33%
safflower	5243	28	5215	0.54%
sorghum	1290	0	1290	0.03%
sudangrass	2440	105	2335	4.28%
tomato	162928	50	162877	0.03%
wheat	100193	100193	0	100.00%

*Negative values means acres increased.

Table 5. **Output data from the Bioenergy Crop Adoption Model (BCAM) for Sacramento Valley**

Incumbent crop	Acres before canola	Acres planted in canola*	Acres remaining in incumbent crop	% Land Use Change
alfalfa	186292	31	186261	0.02%
barley	5633	26	5607	0.46%
beans	26331	73	26258	0.28%
broccoli	555	0	555	0.01%
carrot	1054	0	1054	0.03%
corn	122600	1449	121151	1.18%
cotton	5574	0	5574	0.00%
foragefodder	8725	368	8357	4.21%
garlic	1165	0	1165	0.00%
lettuce	1080	0	1080	0.03%
melon	6855	2	6853	0.03%
oat	29302	1523	27778	5.20%
onion	4868	0	4868	0.01%
potato	3242	0	3242	0.01%
rice	629004	2006	626998	0.32%
safflower	16564	89	16475	0.54%
sorghum	6022	2	6020	0.03%
sudangrass	5070	59	5011	1.17%
tomato	124097	38	124059	0.03%
wheat	120865	120865	0	100.00%

*Negative values means acres increased.

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