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ABSTRACT: The demand for biofuels continues to increase due in part to government standards and promotion as well as the ambitious goals set by various companies and industries. Camelina is considered to be an ideal energy crop because of its low input requirements, suitability for marginal soils, and naturally competitiveness with weeds. A partial equilibrium model with a break-even price approach is used to estimate the potential supply curves for camelina in Idaho, Montana, Oregon, and Washington. The supply curves are used to determine if the 50 million gallon goal set by the "Farm to Fly" initiative can be met. Given the current price of camelina, $0.15/lb, the estimated supply of camelina in all 4 states is 1,756,076,887 lbs and 1,493,684 acres. This estimation assumes that if the wheat-camelina rotation is more profitable than the current crop rotation, then all of the acres will be converted to a wheat-camelina rotation. When a 5% adoption rate is applied to the low and the intermediate rainfall zones and a 1% to the high rainfall zones, the number of acres converted to camelina decreases to 72,213. These results suggest that given current market conditions, the supply of camelina in the

Northwest is not enough to meet the biofuel goal without an increase in yield and government promotion.

Economic Analysis of Potential Camelina Oil Crop Supplies in the Northwest U.S.

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorized release of my thesis to any reader upon request.

Lukas Stein, Author

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CONTRIBUTION OF AUTHORS

Susan Capalbo and Penelope Diebel assisted with the project idea and were involved with the design and editing. Jamie Krantz provided additional editing for this paper.

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1. Introduction

Climate change and energy independence are two important issues facing the U.S. There is a strong need for energy sources that are clean, renewable, and cost-competitive with fossil fuels. The demand for all sources of energy will continue to rise with the growth of the economy, population, and standard of living. In 2011, approximately 71% of the energy consumption in the U.S. came from fossil fuels, 9% from nuclear power, and 9% from renewable energy. The three biggest sources of renewable energy were hydropower (35%), woody biomass (22%), and biofuels (21%) (Energy Information Administration 2012). Biofuels are a type of fuel produced from biomass-organic matter derived from plants or animals as opposed to fossil fuels. The two most common sources of biofuels in the U.S. are ethanol derived from corn and biodiesel derived from soybeans. The International Energy Agency (IEA) predicts that by 2050 biofuels will provide as much as 27% of world transport fuel (Gerasimchuk et al. 2012).

The rapid growth of the biofuels industry would not have been possible without government subsidies because many biofuel producers are not cost-competitive. The IEA estimates that biofuel subsidies globally amounted to $22 billion in 2010 and could increase to $67 billion per year in 2035. The objectives of biofuel subsidies are increased energy security, reduction in greenhouse gas (GHG) emissions, environmental sustainability, rural economic development, and reduction of foreign trade deficits. However, biofuels have been the subject of serious concern due to their controversial social and environmental impacts, as well as competition with food crops for agricultural land and other production factors (Gerasimchuk et al. 2012). These concerns exist because the majority of biofuel production uses energy intensive food crops as feedstocks, such as corn and soybeans. Jaeger and Egelkraut (2011) found that U.S. produced biofuels are 14 to 31 times as costly at reducing fossil fuel use and lowering GHG emissions as alternative measures, such as raising the gas tax or promoting energy efficiency improvements. They also found that mandated U.S. corn ethanol production for 2025 reduces U.S. petroleum input use by 1.75% and would have negligible net effects on CO2 emissions (Jaeger and Egelkraut 2011). Many of the negative externalities of current biofuel production could be avoided if non-food crops, grown on marginal land with low input requirements were used instead.

The focus of this paper is on the potential supply of a new biofuel crop that has been receiving a lot of attention recently, camelina. Camelina is a part of the mustard family and is a relatively new crop to the U.S. It has been grown for millennia in parts of Europe for food, but was introduced to Montana in 2004 because it has great potential as a biofuel feedstock (Jaeger and Siegel 2008). The aviation industry has begun using biojet fuel derived from biomass sources like camelina in over 20 test flights (Geschickter and Lawrence 2010). Camelina is a promising new energy crop but the economic, environmental, and social impacts of increased camelina production must be analyzed. Policy makers and biofuel industry representatives must assess the costs and consequences of different biofuel strategies, and make well-informed decisions before investing heavily in a particular technology or crop.

1.1. Problem Statement

The aviation industry is seeking viable petroleum alternatives with a focus on camelina and other non-food energy crops. In the “Farm to Fly” initiative, the airline industry, aircraft manufacturers, the Seattle-Tacoma International Airport (Sea-Tac), and fuel production and transportation companies have agreed to produce, purchase and use approximately 50 million gallons of oilseed-derived biofuel to supply 10% of all aviation fuel delivered through Sea-Tac (Farm to Fly 2009).

Camelina is considered to be an ideal energy crop because of its low input requirements, suitability for marginal soils, and naturally competitiveness with weeds (Putnam et al. 1993). However, the number of planted acres of camelina in the Northwest U.S. falls far behind these expectations. This is partly due to the fact that camelina yields have not been adequate for sustained profitability (U.S. Department of Agriculture 2011a). Approximately 1.3 to 1.6 billion lbs of camelina would be needed to achieve a 50 million gallon goal, annually. This would require approximately 900,000 to 1,800,000 planted acres depending on yield and oil content. Table 1 shows the annual camelina acreage required to meet the 50 million gallon goal given various yields and oil content.

Table 1: Annual Camelina Acreage Requirements for 50 Million Gallon Goal with Varying Productivity Assumptions[a]

Per Acre Yields (lbs)	32% Oil Content	36% Oil Content	40% Oil Content
900	1,810,516	1,609,347	1,448,413
1200	1,357,887	1,207,011	1,086,310
1500	1,086,310	965,609	869,048

[a] These estimations were calculated assuming that camelina processing recovers 70% of the oil.

1.2. Thesis Objectives

The purpose of this research is to estimate the potential supply curves for camelina in Idaho, Montana, Oregon, and Washington by considering the economic returns of camelina compared to the returns from existing cropland. By assuming farmers maximize their profits it is possible to estimate where camelina will be grown and what crops it will replace by comparing the profitability of camelina to the profitability of the land in alternate uses. This study will consider these conversions under current market conditions and under variations in yield and price. It will also determine what, if any, policy incentive changes could be instituted to have adequate production to meet the "Farm to Fly" biofuel goal. The following is a list of main objectives that this thesis will be able to achieve.

1. Determine the revenue, production costs, and profits per acre for camelina and the alternative crops for each state and rainfall zone.
2. Compare the profits per acre of the wheat-camelina rotation to the profits per acre of alternative wheat rotations.
3. Estimate the supply of camelina given the per acre profits of the wheat-camelina rotation and the per acre profits of alternative wheat rotations.

4. Estimate where camelina will be produced, how much will be produced, and what crop(s) it will replace.
5. Determine how many acres of camelina must be grown in order to meet the "Farm to Fly" biofuel goal.
6. If the supply of camelina is less than the amount demanded in the "Farm to Fly" initiative, determine what, if any, changes are necessary for farmers to realistically produce enough to meet or exceed demand. Policy incentives, market conditions, and agronomic improvements are all potential ways of increasing camelina production.

1.3. Thesis Organization

The remainder of this paper will be divided into four sections: literature review, methodology, results, and conclusion. The literature review section will provide background information on the "Farm to Fly" initiative, camelina, the camelina supply chain, and grower economics. The methodology section will describe the structure of the partial equilibrium model and the procedure used to develop the supply curve. The results section will present the findings and discuss their significance. Finally, the conclusion will summarize what was learned from the supply curves and discuss topics for future research.

2. Literature Review

In order to estimate the potential supply curves for camelina in Idaho, Montana, Oregon, and Washington and to determine the production necessary to meet the "Farm to Fly" biofuel goal it is necessary to review the "Farm to Fly" initiative, the agronomics of camelina, the camelina supply chain, and grower economics. The following sections review each topic in detail. There is limited published data because camelina is a new crop of interest. However, there is a considerable amount of unpublished field data and research performed by universities and private interest groups that will be cited in the following sections.

2.1. Background of the "Farm to Fly" Program

The U.S. government and many state governments have been promoting the increased use and production of biofuels. Federal and state renewable fuel standards (RFS) require a minimum percentage of biofuel blends in transportation fuel (U.S. Department of Energy 2009). The Energy Independence and Security Act of 2007 set a goal for the production of 36 billion gallons per year of alternative biofuels by 2022 (Schnepf and Yacobucci 2010). In addition to government promotion, both civilian and military aviation industries are beginning to use biofuels to reduce their reliance on crude oil. The Navy recently set a goal for 50% alternative energy use by 2020 (United States Department of the Navy 2010). Sustainable Oils LLC, a producer and marketer of environmentally clean and high-value camelina-based renewable fuels, has been awarded a contract by the Defense Energy Support Center (DESC) to supply 100,000 gallons of camelina-based jet fuel to the Air Force (Sustainable Oils LLC 2009).

The Boeing Company with the Defense Advanced Research Projects Agency (DARPA) funded partners has produced synthetic paraffinic kerosene that meets or exceeds certification requirements from several feedstocks (tropical oilseeds, temperate oilseeds, and algae oil). Without modifying flight equipment, the Boeing Company has completed test flights using petroleum/biofuel blends in four locations around the world utilizing aircraft equipped with four different jet engines produced by all three of the major manufacturers (Farm to Fly 2009). The Boeing Company's CEO for commercial airplanes recently stated, "Developing a sustainable aviation fuel supply now is a top priority both to ensure continued economic growth and prosperity at regional levels and to support the broader aim of achieving carbon-neutral growth across the industry by 2020" (New Net 2010).

On July 21, 2010 the Air Transport Association of America (ATA) announced the official launch of the "Farm to Fly" partnership initiative with private industry, federal agencies and academia to advance a comprehensive sustainable aviation biofuels rural development plan (Consumer Energy Alliance 2010). The U.S. Department of Agriculture (USDA) joined with the ATA and the Boeing Company in a resolution to accelerate the availability of sustainable aviation biofuels in the U.S., increase domestic energy security, establish regional supply chains, and support rural development (Consumer Energy Alliance 2010).

The ATA is committed to the development and deployment of sustainable alternative fuels for use in jet aircraft. The "Farm to Fly" initiative builds on and expands the work of the Commercial Aviation Alternative Fuels Initiative (CAAFI) to hasten the availability of commercially viable, environmentally friendly alternative jet fuels. In the "Farm to Fly" initiative, the airline industry, aircraft manufacturers, Sea-Tac, and fuel production and transportation companies have agreed to produce, purchase and use approximately 50 million gallons of oilseed-derived biofuel to supply 10% of all aviation fuel delivered through Sea-Tac (Consumer Energy Alliance 2010).

The supporting goals of the "Farm to Fly" initiative are to improve regional productivity and environmental sustainability of cereal and livestock based agriculture by optimizing productivity and profitability of the current oilseed industry in the diverse agroecosystems across the Northwest. To add value to non-food mustard family oilseeds by characterizing and demonstrating valuable uses for the co-products (i.e. seed meal). Lastly, to educate farmers, industry members, and a future work force, including those from underrepresented groups, on best practices for profitable and sustainable production of biofuel feedstocks (Farm to Fly 2009). The oilseed crops that are being evaluated in the "Farm to Fly" initiative are of the Brassicaceae family (mustard family), more specifically camelina.

2.2. Background of Camelina

Camelina is an ideal energy crop for several reasons. After processing, camelina oil can be used as a replacement for conventional jet fuel. Camelina is not a food crop and can be grown on marginal farmland with relatively low inputs and no irrigation. Camelina and other mustard crops have the potential to improve the overall sustainability and productivity of the cropping systems in the Northwest (Consumer Energy Alliance 2010). Finally, life cycle assessment of camelina-based biodiesel found that camelina grown in rotation with wheat or as a double crop reduces GHG emissions and fossil fuel use by 40 to 60% when compared to petroleum diesel (Krohn and Fripp 2012).

2.2.1. Agronomic History

Camelina Sativa, also known as Gold of Pleasure, False Flax, and German Sesame, is thought to have originated in Central Asia. There is evidence of cultivation dating back as early as 600 BC in the Rhine River Valley. It is a member of the Brassicaceae family, which includes rapeseed and mustard. However, camelina does not cross-pollinate with canola, mustard, and other vegetable seeds (McVay and Lamb 2007). Camelina is a fine seed, which can make it more difficult to harvest and press as well as aggregate in bulk. The seeds were originally crushed and boiled to release oil for food, medicinal use, lamp oil, and animal feed. It is unique among vegetable oils because it is high in both vitamin E and omega-3 ALA essential fatty acid. (Dobre and Jurcone 2011).

Camelina was introduced to Montana in 2004 and is now grown in nine states and four Canadian provinces. Since camelina is such a new crop to the U.S., very little crop improvement or agronomic work has been done. However, a major effort is under way in Montana, Oregon, Washington, Idaho, and Alberta, Canada, to produce camelina on a large scale under dryland conditions (Hunter and Roth 2010).

Camelina is typically grown as an early summer annual oilseed crop, but can be grown as a winter annual in milder climates. It is a short-season crop typically taking 85 to 100 days. It germinates at low temperature and seedlings are very frost tolerant. No seedling damage has been seen at temperatures as low as -11° C in Montana. The plant performs well on marginal lands and may be better suited to dryland regions than most other oilseed crops (Hunter and Roth 2010). Historically, dryland farm ground produced a crop every other year with a winter wheat / fallow rotation. Now many dryland farms are producing two crops in three years with a winter wheat / summer crop (corn, sunflower, or millet) / fallow rotation. Spring camelina has the opportunity to be produced during the fallow period of any winter wheat based crop rotation allowing this region to produce a crop every year (Enjalbert and Johnson 2011).

2.2.2. Weed, Disease, and Insect Resistance

Camelina has very low requirements for weed control because it is naturally competitive with weeds. Since camelina is cold tolerant, early plantings of camelina have resulted in minimal weed competition (Hunter and Roth 2010). In one three-year trial, camelina was not injured by trifluralin, an herbicide, incorporated either in the fall or spring (Putnam et al. 1993). The herbicidal effect of camelina is short-lived and relatively weak and does not affect the next year's crop. Early seeding of spring camelina into clean fields usually results in minimal weed problems. The competitiveness of camelina with annual weeds means it could possibly be grown both without tillage and without preemergence weed control. Both represent significant costs of production and environmental risk factors. Currently there is only one herbicide labeled for use with camelina, Poast®, a post-emergence grass control product (Enjalbert and Johnson 2011). Poast® has not been used in many of the camelina performance, yield, and fertility trials because it is a new product. It received the camelina label in 2008 (Hunter and Roth 2010).

Not only is camelina naturally competitive with weeds, but also it is resistant to numerous insects and diseases. Few or no insects appear to cause damage to camelina. Flea beetles and common aphids, which can be pests in canola and mustards, do not seem to bother camelina. Downy mildew is a concern and has been found in some experimental trials. No downy mildew has been observed east of the Continental Divide (Hunter and Roth 2010). White mold has not been observed in camelina in Montana, but growers should monitor for white mold, as it is a disease common to Brassicas such as canola and members of the sunflower and legume families. White mold is typically found in areas with higher annual precipitation. Camelina is also highly resistant to blackleg, a major disease of canola and other Brassica crops (Hunter and Roth 2010).

2.2.3. Water Utilization

For dryland farmers in semi-arid regions, water scarcity is a key factor in determining crop agronomics. As a result, the issue of soil moisture depletion is a primary concern. For a crop to be economically viable it must perform well in low-moisture situations. For subsequent crops to perform well it must not drain deep soil of moisture content. A study done by the Central Great Plains USDA Agricultural Research

Station in Akron, CO compares the water yield response curve of leading oilseeds. It shows that soybean is the most responsive to water. Soybean yields increase in a linear fashion, starting from near zero at zero inches of rain to 3,500+ lbs/acre at 25 inches of water (during the growing season) (Nielsen 2008). Note, however, that soybean oil content, at 18% to 20%, is much lower than for competing oilseeds. Oil content is highest for safflower and sunflower (between 40% and 47%), however these are deep-rooted species, which deplete deeper soil of much needed moisture content damaging long-term water balance. This makes them impractical for semi-arid farming in the Pacific Northwest (Nielsen 2008).

The camelina yield response line is to the left of canola[1] and its rate of change (slope) is smaller. The two intersect at approximately 1,750 lbs per acre at approximately 17 inches of water use. This study shows that camelina has a comparative water use advantage in the 5 to 16 inch range. Note that, according to the study, both camelina and canola have similar oil content of between 37% and 45%. Taking moisture availability and use into consideration, camelina has distinct economic and agronomic advantages over canola for dryland farming, especially as a replacement for summer fallow, and as a way to rehabilitate lands that have fallen out of production (Nielsen 2008). Yields, however, pose a key issue, especially in light of the USDA camelina crop report in Montana, with yields below 600 lbs per acre in 2007 and 2008 (U.S. Department of Agriculture 2011a).

[1] This means camelina has a higher seed yield for any given amount of water use below 17 inches

2.2.4. Fertility Requirements

A study was conducted in Montana by the Western Triangle Agriculture Research Center (WTARC) to determine the effect of nitrogen (N), phosphorous (P), and sulfur (S) fertilizers on camelina seed yield and oil content. The study concluded that camelina has generally low fertility requirements. When 35 to 40 lbs of N was applied, yields ranging from 1,200 to 1,500 lbs per acre were expected. When 40 to 50 lbs of N was applied per acre, higher yields were expected. In addition, a recommendation for 25 to 30 lbs of P per acre and 20 lbs of S per acre may be justified in some situations. Ammonium sulfate (21-0-0-24S) at 100 lbs per acre could supply the S needs and provide 21 lbs N per acre. They concluded that camelina needs about 70 to 90 lbs of N per acre for optimum seed yield and oil content, it will likely respond to P fertilizer when P soil tests are 12 parts per million (ppm) or less, and camelina did not respond to S fertilization (Jackson 2008**)**.

The results of the WTARC study were similar to the fertility trials conducted in four locations during the 2008, 2009, and 2010 cropping seasons in regions of Idaho, Oregon, and Washington. In this study, camelina was grown in low, intermediate, and high rainfall sites to understand the growth relationship with applied N. Camelina responded differently to applied N at these sites based upon rainfall and available N in the soil. The low rainfall site had very little response to N fertilization. However, as annual precipitation increased, so did camelina’s response to applied N. They concluded that camelina requires about 10 lbs N per acre per 220 lbs of grain yield and it does not respond to S fertilization (Wysocki et al. 2011).

2.2.5. Yield

Camelina seeds are small with a typical seed weight around 400,000 seeds per lb with a range of 225,000 to 550,000 seeds per lb. Camelina has yield potential similar to that of many other members of the Brassica family. Studies at the University of Idaho (UI) in 2005 and 2006, near Moscow, ID in a 24-inch rainfall zone, indicate a yield advantage for camelina compared to canola and mustard. While the yields of other Brassicas have been significantly increased in recent decades through plant breeding and agronomic improvements, the potential of camelina remains unexploited (Hunter and Roth 2010).

Under dryland conditions in Montana, camelina is expected to yield 1,800 to 2,000 lbs of seed per acre in areas with 16 to 18 inches of precipitation and 900 to 1,700 lbs per acre with 13 to 15 inches of rainfall. In Idaho, seed yields of 1,700 to 2,200 lbs per acre have been reported in the 20 to 24 inch rainfall area. Under irrigation, seed yields of 2,400 lbs per acre have been reported. Three years of yield data at Moscow, ID show a seed yield potential of 2,100 to 2,400 lbs per acre with 25 inches of rainfall (Hunter and Roth 2010). Yield data at Pendleton, OR in a 14-inch rainfall zone reported 1,300 to 1,500 lbs per acre when planted in March. November and January had the lowest yields at 300 and 700 lbs per acre. These results are similar to the past two seasons. In Corvallis, OR planting camelina between November 1st and March 1st produces the best seed yields of 1200 lbs per acre or greater. Yield data at Lind, WA in an 11-inch rainfall zone show that the March 1st planting date corresponded with the highest yield of 1,023 lbs per acre. A trial at Pullman, WA in a 21-inch rainfall zone showed a significant N fertilizer response. Camelina yielded 880, 1215, 1700, 1920, 2185, and 2380 lbs per acre from 0, 20, 40, 60, 80, 100 lbs of N per acre respectively (Fretz 2009).

2.3. Camelina Supply Chain

Camelina faces many economic and logistical obstacles after it leaves the farm. These obstacles include costs and capacity constraints for feedstock processing, transportation, storage challenges, and a lack of efficient distribution infrastructure for finished products. Presently, the U.S. biodiesel market lacks sophisticated infrastructure and concerns about the contamination of petroleum products (specifically jet fuel) from transporting biodiesel has hampered market growth. However, it is likely that camelina-based fuels will be integrated into the existing fuel infrastructure with the help of federal and state mandates for renewable fuels, increasing demand from the aviation industry, and new biofuel processing technologies (Geschickter and Lawrence 2010).

In order for camelina to reach its full potential as an aviation fuel feedstock, camelina-based biojet fuel must be “drop-in” compatible with the existing fuel delivery and storage infrastructure, and most importantly, the existing aviation fleet. Drop-in fuels are substitutes for conventional jet fuel that are completely interchangeable and compatible with conventional jet fuel. The primary technological pathway used to turn camelina seed into drop-in biojet involves hydroprocessing, a process that first uses hydrotreatment to deoxygenate the oil and then uses hydroisomerization to create normal and isoparaffinic hydrocarbons that fill the distillation range of Jet A (standard U.S. jet fuel). An oxygen-free fuel that fills the distillation range of Jet A and is created from the hydroprocessing of plant oils or animal fats is termed "HRJ". HRJ shares similar characteristics to Fischer-Tropsch pathways and both are referred to as "Bio-SPK" fuels (International Air Transport Association 2008).

Bio-derived synthetic paraffinic kerosene (Bio-SPK), a biojet fuel derived from biomass sources like camelina either via Fischer-Tropsch or hydroprocessing, has been used in over 20 test flights. Tests indicate that camelina-derived HRJ performs as well as or better than typical petroleum-based Jet A. The Boeing Company tests have shown that camelina-derived HRJ has a freeze point of -63.5° C, lower than jatropha SPK at -57° C, and petroleum Jet A-1 (standard jet fuel for the rest of the world) at -47° C. The tests further indicate that Bio-SPK fuel blends have no adverse effects on the engines or their components, and that the fuels have greater energy content by mass than typical petroleum-derived jet fuel. This translates into the potential for higher mileage (per volume and weight) from Bio-SPK fuel than for petroleum jet fuel (Kinder and Rahmes 2009).

On July 1 2001, American Society for Testing and Materials (ASTM) announced the approval of renewable fuels to be blended with conventional commercial and military jet fuel. Through the new provisions, up to 50% bioderived synthetic blending components can be added to conventional jet fuel. This means that at a 50% blend, Bio-SPK jet fuel made from non-food feedstocks like camelina can be a drop-in replacement for jet fuel. Furthermore, it requires no changes to fleet technology or the fuel storage and delivery infrastructure (ASTM International 2011).

This certification opens the U.S. component of the worldwide annual jet fuel market to biojet fuel. Airbus SAS, an aircraft manufacturer, estimates that fuel from plant-derived sources may account for 30% of airlines' consumption by 2030. Airbus SAS and the Boeing Company, which together manufacture about 80% of the world's passenger planes, are planning to set up biofuel production chains across the world (Downing 2011). Since camelina-based biojet fuel is drop-in compatible with existing storage, handling, and fueling infrastructure, it is likely that the market will expand more rapidly than it has for E85 ethanol (motor fuel blends of 85% ethanol and 15% gasoline). Also, the integration of Bio-SPK into the existing aviation fuel infrastructure should be far easier than it has been for E85 gasoline or biodiesel because airports have concentrated distribution, storage, and supply networks (Geschickter and Lawrence 2010).

Supply chains for camelina-based biodiesel and biojet will need to incorporate animal feed end markets in order for camelina to realize its full potential. The value of camelina meal, a byproduct of the oil extraction process, is a key economic driver of market growth. The Food and Drug Administration (FDA) has not yet approved the unrestricted use of camelina or its byproducts as a commercial feed ingredient, which will limit camelina's market in the near-term. Private efforts to gain FDA approval for the unrestricted use of camelina meal as a feed ingredient are ongoing and will require additional research. The FDA has approved camelina concentrations of no more than 10% in beef cattle fed in confinement, broiler chickens and laying hens. The FDA has also allowed the use of camelina meal as a feed ingredient in swine rations of no more than 2% (Church 2012).

Camelina is also a potential source for bioplastics. Recently, Metabolix, Inc., a bioscience company focused on developing clean sustainable solutions to the plastics, chemicals and energy industries, was awarded $203,000 in research funding by the Saskatchewan Ministry of Agriculture through its Agriculture Development Fund (ADF). The company will use the funding to accelerate its ongoing research and development of oilseed crops, specifically camelina, as a potential source for bioplastics and other petroleum substitutes. Camelina is a viable production vehicle for PHA polymers, and Metabolix has produced PHA polymers from the oilseed itself. This funding will help support the company's research and development into very low cost production sources for PHA polymers (Metabolix Oilseeds, Inc. 2011).

PHAs are naturally occurring polymers that are particularly well suited to large-scale, industrial crop-based production as they are totally compatible with the natural environment. PHAs also offer the opportunity for broad replacement of current petroleum-based plastics. PHA production from camelina offers diversification from volatile food and feed markets in addition to creating significant new investment opportunities and highly skilled technical jobs. High value bioplastic is produced in addition to existing oil and meal (Global Energy Division 2010). This adds significant revenue and value to camelina, improving potential economic returns to producers.

2.4. Grower Economics

In order for camelina-based fuels to be successful without subsidies they must be profitable at price points set by conventional petroleum fuels. The success of camelina is highly dependent on the emergence of a supply chain that economically links remote growing regions with regional biodiesel and aviation fuel end markets, and strong local markets for camelina meal byproducts. Camelina must also compare favorably to other cropping systems before growers will devote acreage to it (Geschickter and Lawrence 2010).

In general as the price and volatility of petroleum increases, the price and corresponding demand for camelina will benefit. Higher petroleum prices indirectly raise the cost of producing and delivering crops because fuel and electricity for planting, harvesting, tillage, drying, and irrigation account for a significant amount of farm operating costs. Also, the price of fertilizer is closely tied to the cost of energy, since fertilizer is a highly energy intensive product. Brandess (2012) estimated the relationship between the price of diesel fuel and the price of N fertilizer. He found that for every dollar increase in the price of diesel fuel, the price of N fertilizer increases by $120.82 per ton. As petroleum prices increase, camelina’s lower fertilizer and water use requirements will make camelina a more favorable crop when compared to other crops that need more fertilizer and water to produce (Geschickter and Lawrence 2010).

2.4.1. Comparison to Other Crops

Camelina has many positive characteristics that make it a potentially valuable energy crop. However, widespread adoption of camelina has not happened due to the low price and yields when compared to other crops. Many advocates of camelina point out that camelina’s lower production costs should provide higher returns than other crops.

Biomass Advisors compared the costs and profitability of camelina in Eastern Montana to crops grown in rotation with wheat (Geschickter and Lawrence 2010). They adopted an economic model originally developed at Montana State University (MSU). Based on this study, both the MSU and the Geschickter and Lawrence models underestimate the production costs of camelina. The variable cost estimate for camelina is $80.27 per acre, with 23.5 lbs of N per acre and a yield of 1,350 lbs per acre. These estimations are 36% to 41% lower than the production costs estimates used in this study (see Appendix A for a camelina profitability comparison to other crops).

When more accurate costs and yields are used, camelina's profitability decreases dramatically but is still favorable to many other crops. Appendix A compares the costs and profitability of camelina in Idaho, Montana, Oregon, and Washington using data obtained from the National Agricultural Statistics Service (NASS) (National Agricultural Statistical Service 2012), various yield trials (Fretz 2009; Jackson and Miller 2006; Karow et al. 2010; Montana State University 2006a, 2006b, 2008, 2009a, 2009b, 2010a, 2010b; Schillinger et al. 2012; Wichman 2008) preformed in each state, and a series of enterprise budgets. The results also make favorable comparisons between camelina and other crops even with higher costs of production and lower yields.

3. Methodology

In order to estimate the supply of camelina in Idaho, Montana, Oregon, and Washington a partial equilibrium model was developed that uses a break-even price approach. This method is more limited than the general equilibrium model approach, but nevertheless, provides useful insights regarding camelina crop quantities and associated prices. The partial equilibrium model requires inputs regarding the number of acres suitable for camelina production, camelina production costs and yields, and the profitability of the land in alternate uses (Walsh 2000). A series of enterprise budgets was developed to estimate the production costs of camelina and the alternate cropping systems. The enterprise budgets and the yield estimates were used to compare the profitability of camelina to the profitability of land in alternate uses. By comparing the per acre profits of camelina and the alternate uses, one could estimate the amount of camelina that will be grown on eligible land in Idaho, Montana, Oregon, and Washington. The following three sub-sections will describe the modeling procedure, how and why the partial equilibrium was used to estimate the supply of camelina, and the limitations to the partial equilibrium model.

3.1. Modeling Procedure

There are various economic tools that can be used to compute supply curves for agricultural commodities. Econometric and mathematical programming models are two tools that have been used in the past. Extensive historical data is needed to accurately estimate supply curves using econometrics. Unfortunately, there is very little farm level data available for camelina since it is a relatively new crop to the U.S. Mathematical programming models have been used widely for simulating decision making at farm level, regional level or sectoral level (Chen and Önal 2012). In order to develop a mathematical programming model, detailed micro-level data or historical data is also needed. For these reasons, econometric and mathematical programming models are not suitable for this study. Instead of running an econometric or mathematical programming model, a partial equilibrium model with a break-even price approach will be used. A similar partial equilibrium approach has been used in the U.S. to estimate interim national supply curves for switchgrass, hybrid polar, and willow (Walsh 2000).

3.2. Modeling Structure

The following subsections will describe the land base suitable for camelina production, the method used to allocate camelina yields across state and rainfall zone, the approach used to estimate the cost of producing camelina by state and rainfall zone, and how the profitability of land in alternate uses was calculated. This information will be used to estimate the camelina prices and corresponding quantities needed to create the supply curves by state. Figure 1 summarizes the major components of the partial equilibrium model.

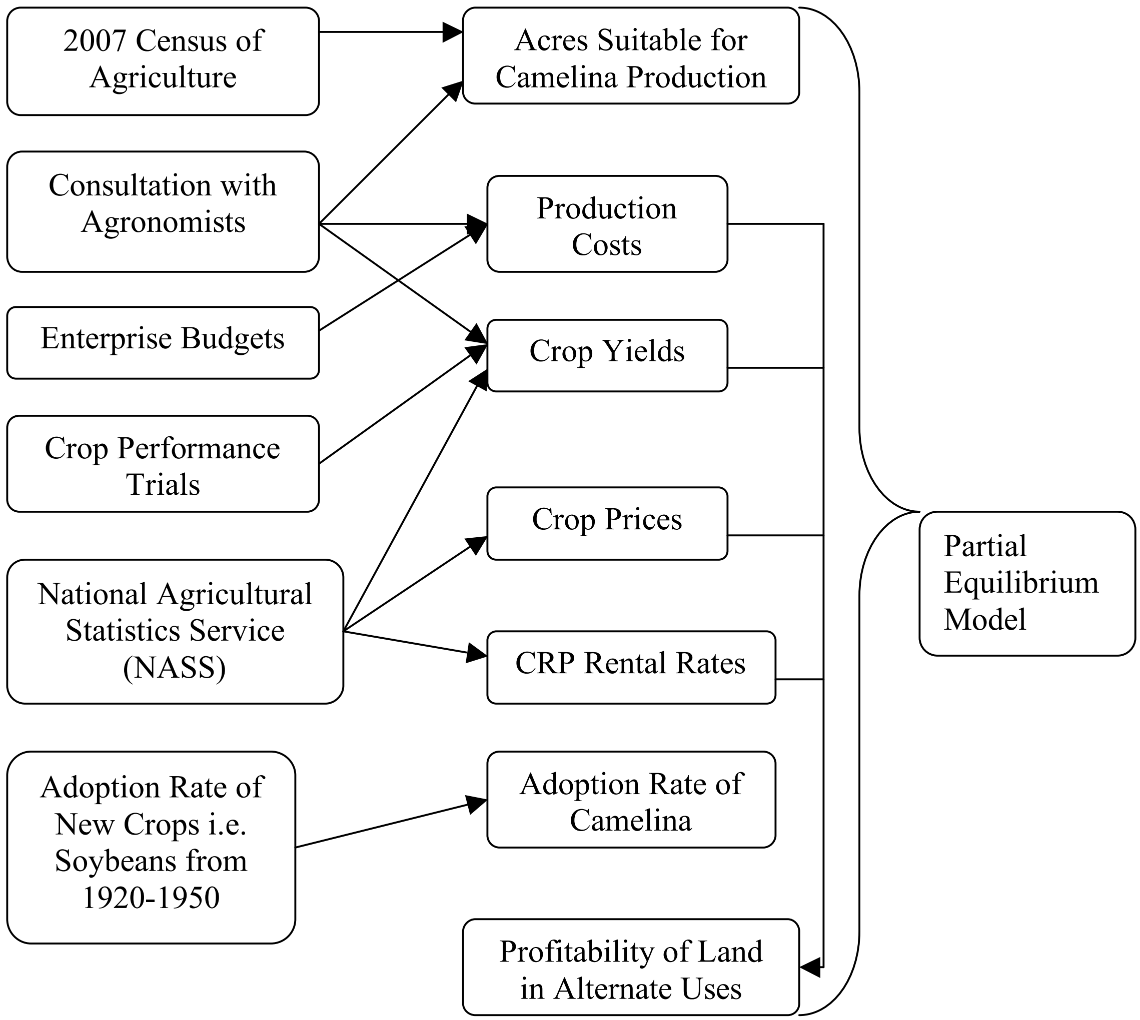

Figure 1: Major Components of the Partial Equilibrium Model

3.2.1. Acres Suitable for Camelina Production

Camelina is a fast growing crop that germinates at low temperatures and performs well on marginal lands. It is typically grown as an early summer annual oilseed crop but shows promise as a low-input rotation crop that can replace summer fallow in any winter wheat based crop rotation (Ehrensing and Guy 2008). MSU trials and companion work at Washington State University (WSU) and Oregon State University (OSU) have focused on developing camelina's potential in eastern Washington, eastern Oregon, and Montana (Montana State University 2010b; Karow et al. 2010). Agricultural land considered potentially suitable for camelina production includes all agricultural cropland. However, camelina is most likely to be grown as a rotation crop with winter wheat. For this reason the acres included in the partial equilibrium model are comprised of winter wheat, fallow, and crops that are grown in rotation with winter wheat.

The rotation crops included in the analysis are barley, canola, dry edible peas, lentils, mustard, and flax. The acreage for these crops was obtained from NASS (National Agricultural Statistical Service 2012) then separated by state (Idaho, Montana, Oregon, and Washington) and rainfall zone (low- less than 15", intermediate- 15 to 20", high- more than 20"). County level data was available every year for winter wheat and barley, but for the other crops data was only available for years when the U.S. Census of Agriculture (Census) was released. A 5-year average was calculated for winter wheat and barley. For the other crops, the 2007 Census data was used (U.S. Department of Agriculture 2009a, 2009b, 2009c, 2009d). Appendix B contains the acreage data used in the partial equilibrium model.

The NASS and Census data contain county estimates for each state. In order to separate the Census data by rainfall zone, each county was assigned to a rainfall zone. This was accomplished by creating a precipitation map using a Geographic Information System (GIS) dataset developed by the PRISM Climate Group (PRISM Climate Group 2012). The map was created using ArcMap version 10.1 (Environmental Systems Resource Institute 2010) and the PRISM dataset containing the 30-year precipitation averages. State and county borders were then inserted so each county could be assigned to the appropriate rainfall zone (see Figure 2 for a precipitation map of the Northwest U.S.).

After each county was allocated to the appropriate rainfall zone, certain counties were excluded from the analysis. Counties that were located further than 100 miles from the closest refinery capable of using camelina as a feedstock were excluded. These counties were excluded because the higher transportation costs would decrease the profitability of camelina. After speaking with an oilseed agronomist at OSU (T. Chastain, personal communication, October 2011) and a camelina industry representative (T. Endicott, personal communication, February 2012), counties that received more than 2 inches of rainfall from April to June were removed as well. These counties were excluded because camelina is not tolerant of over saturated soil and heavy rains during later stages of growth reduce production. Additionally, excess moisture can increase disease levels and reduce yields. This potential reduction in yield is an added risk to growing camelina. Therefore, the opportunity cost of growing camelina in high rainfall zones is greater than lower rainfall zones making camelina a less desirable crop. See Figure 3 for a map of the Northwest U.S. with April to June precipitation and refinery locations.

Camelina's tolerance to herbicides is a concern and will affect the acres suitable for camelina production. Winter wheat producers rely on numerous types of herbicides, each having a different effect on camelina. Unfortunately there are very few studies addressing this issue (Stougaard 2009; Stougaard 2010; Johnson et al. 2008; Campbell and Walton 2007). However, the studies show that camelina is tolerant to certain

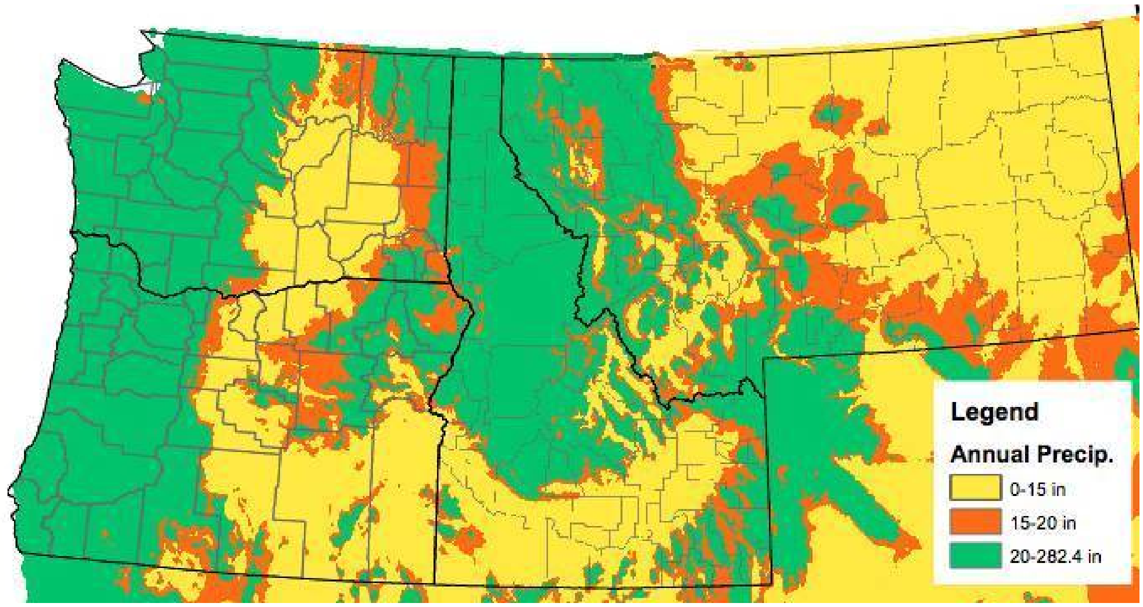

Figure 2: Precipitation Map of Northwest U.S.

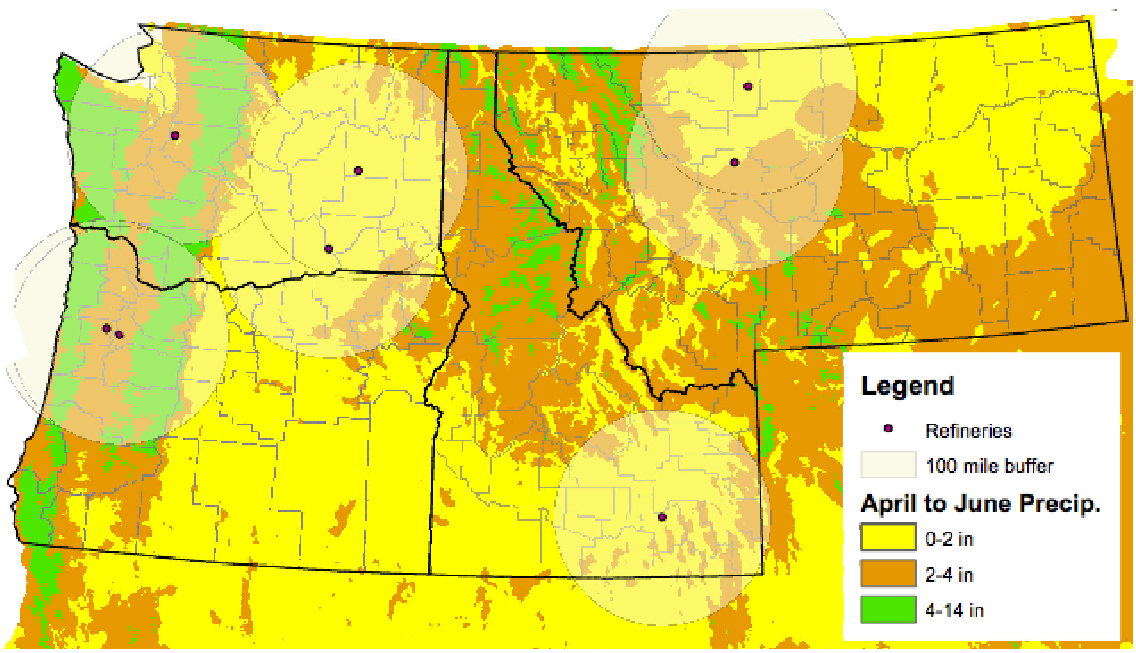

Figure 3: Map of Northwest U.S. with April to June Precipitation and Refinery Locations

postemergent and postemergent herbicides. Crop injury ranged from 0% to 100%, depending on the herbicide used and the rate applied. There are herbicides used in winter wheat production that show potential for use in camelina, but the rate adoption will be hindered.

3.2.2. Allocation of Crop Yields

Yields were estimated using data obtained from the NASS and various yield trials performed in each state (Fretz 2009; Jackson and Miller 2006; Karow et al. 2010; Montana State University 2006a, 2006b, 2008, 2009a, 2009b, 2010a, 2010b; Schillinger et al. 2012; Wichman 2008). As with the acres data, county level data was available every year for winter wheat and barley, but not for the other crops. A five-year average yield was calculated for winter wheat and barley using the NASS data. For the other rotation crops, average yield estimates were estimated by using the Census data. Since camelina is not included in NASS nor the Census, average yield estimates were estimated by using various camelina yield trials preformed in each state. OSU, UI, MSU, and WSU have all conducted camelina yield trials. After compiling all of the available yield data for each crop, the average crop yields were calculated and allocated across state and rainfall zones. Appendix C contains the yield data used in the partial equilibrium model.

3.2.3. Allocation of Crop Production Costs

An enterprise budget is a listing of all estimated income and expenses associated with a specific enterprise to provide an estimate of its profitability. A budget can be developed for each existing or potential enterprise in a farm or ranch plan. Several budgets could be developed for a single crop to represent alternative combinations of inputs and outputs. Each budget should be developed on the basis of a small common unit such as one acre of camelina. This permits comparison of the profit for alternative and competing enterprises (Kaan and Sharp).

With the permission of Kathleen Painter, the Idaho wheat rotation enterprise budget was used for the preliminary budgets (Painter 2011). The budget was then edited and updated to create the necessary budgets for the model (In Appendix D, I explain the process of developing these enterprise budgets). The camelina budgets were separated by state and rainfall zone. The camelina budgets were used to construct budgets comparing different wheat rotations. The rotation crops evaluated were the regional crops that are most likely to be used as a rotation crop for wheat. Barley, mustard, canola, pea, and lentil were all included in the comparison budgets. Appendix E contains the summarized crop expenses from various enterprise budgets.

These budgets can be viewed as "typical" or "representative," rather than a mathematical average of a large number of producers. Where such factors as farm size, machinery complement and hourly use, cultural practices and yield differ from those assumed in this study; substantially different enterprise costs and returns may result. Also, these budgets include only production costs and do not consider storage, handling, transportation, and interest costs associated with marketing the crop (Baldree and Hinman 2003).

The following assumptions were made in developing the enterprise budgets:

1. The representative farms are 2,500 acres.
2. Since yield variability is quite common in dryland farming, yields were varied for each enterprise to demonstrate the substantial impact yields have on per unit costs. Camelina yields were estimated using various camelina yield trials preformed in each state.
3. A 10-year prices received average was calculated for the budgeted crops using data from the NASS site. Prices are $7.13 per bushel for winter wheat, $4.65 per bushel for spring barley, $9.26 per bushel for soft white spring wheat, $9.34 per bushel for hard red spring wheat, $0.13 per lb for field peas, $0.27 per lb for lentils, $0.38 per lb for garbanzos, $0.24 per lb for flax, $.26 per lb for mustard, and $.25 per lb for canola. Prices received for camelina was posted by Great Plains Camelina Company at $0.16 per lb for 2010.
4. Machinery values and costs vary widely from farm to farm. When replacing machinery producers replace with both new and used equipment. Thus, the machinery complement used in constructing these budgets is a representation of what a machinery complement might look like on a typical farm in the relevant rainfall area.
5. The interest rate is 4.5%.
6. The farm is owned, managed, and operated by the same person.

3.2.4. Profitability of Land in Alternate Uses

One of the underlying assumptions of the analysis is that farmers will not convert their land to camelina production unless they can earn at least as great a profit from the wheat-camelina rotation as from using the land for alternative uses such as a wheat-fallow rotation. For each county, profit per acre for each crop rotation was calculated and used to determine the supply of camelina. The per acre profit of the wheat-barley and wheat-fallow rotations for each county were estimated using the production costs from the enterprise budgets, the 5-year yield average calculated from the NASS data, and the 5-year prices received average calculated from the NASS data (a complete list of prices are included in Appendix F). The per acre profits of the other wheat rotations were estimated using the production costs from the enterprise budgets, the yield average calculated from the 2007 Census, and the 5-year prices received average calculated from the NASS data. The per acre profit of the wheat-camelina rotation for each county was estimated by adding the per acre profit of wheat to the per acre profit of camelina at different prices for camelina. The camelina prices used ranged from $0 to $.40. To avoid double counting, the land costs were not included in the profitability estimates. Instead, the per acre cropland rental rate for each county was used from the NASS data. The rental rate can be viewed as being equivalent to the opportunity cost of growing winter wheat, rotation crops, and camelina.

3.3. Limitations to Model

The partial equilibrium modeling approach used has several limitations. First, the decision framework used in the model is simple. It does not allow one to differentiate between farm production options and practices. Additionally, it does not account for the reallocation of resources to produce the combination of crops that leads to maximum profit. Furthermore, the model is static with fixed cost and yield estimates. The enterprise budgets used in the model have fixed input variables and do not account for increases in price. The method also does not endogenously allocate land between the competing crops, requiring the analyst to make the calculation after the fact (Walsh 2000).

The partial equilibrium approach, unlike a general equilibrium approach, assumes that all other parameters remain fixed except for that parameter which the analyst is varying. For example, as camelina production increases and displaces land from competing crop production, the price of the competing crops will increase. This partial equilibrium model assumes that the price of all competing crops remain fixed and thus underestimates the price that must be paid for camelina to make it as profitable as the competing crops. Another limitation is that there is no upper bound constraint. The model estimates that all acres could be shifted to camelina production. This was corrected by applying an adoption rate to the data (Walsh 2000).

4. Results and Discussion

This partial equilibrium model focused on the potential supply of camelina in the Northwest U.S. The analysis is meant to estimate the potential supply of camelina, evaluate the changes in the agricultural landscape, and determine what policy, market, and/or agronomic changes are necessary to meet the biofuel goals stated in the "Farm to Fly" initiative. The potential supply of camelina is first estimated under current market conditions. This estimation is then compared to a reference-dataset to determine its validity. Next, adoption rates are applied to the supply curve to get a more pragmatic estimate. Then the policy, market, and agronomic changes necessary to meet the "Farm to Fly" biofuel goals are discussed. Lastly, the land use change implications are explained.

4.1. Potential Supply of Camelina

The supply curve for camelina in Idaho, Montana, Oregon, and Washington is presented in Figure 4 (see Appendix G for the individual supply curves for each state). Given the current price of camelina, $0.15, the estimated supply of camelina in all 4 states is 1,756,076,887 lbs, with 1,493,684 planted acres. Depending on oil content, oil recovery from processing and yields, approximately 1.3 to 1.6 billion lbs of camelina or 900,000 to 1.8 million acres would be needed to achieve the 50 million gallon biofuel goal annually.

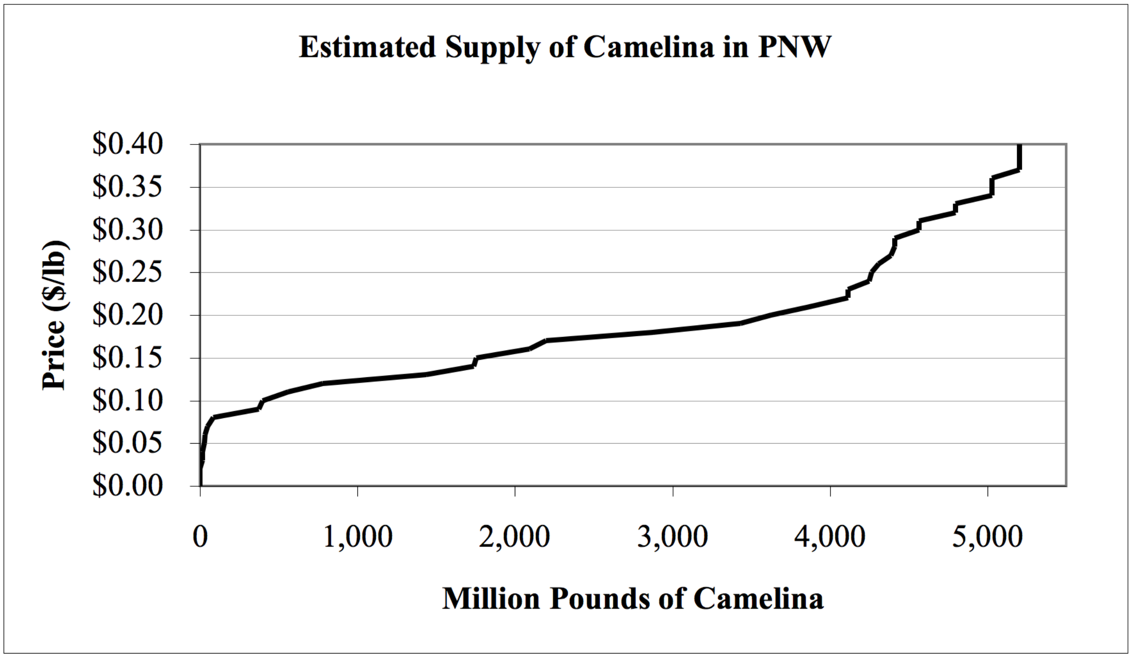

Figure 4: Estimated Supply Curve for Camelina in Idaho, Montana, Oregon, and Washington

This means that the “Farm to Fly” biofuel goal could be reached if the adoption rate of camelina was close to 100%. This seems unlikely considering that camelina is a new crop and farmers tend to be risk averse. 61 counties were excluded from the analysis because of the unsuitability of data, climate, and geographic location. Note, however, that only the counties most likely to convert acreage to camelina production were included in the analysis.

The map in Figure 5 shows the predicted camelina planted acreage by county. This model predicts where camelina will be grown and the quantity produced at $0.15 per lb. The majority of camelina acreage is concentrated in southeastern Idaho, northern Montana, northeastern Oregon, and eastern Washington. At $0.15 per lb, 121,253 acres in

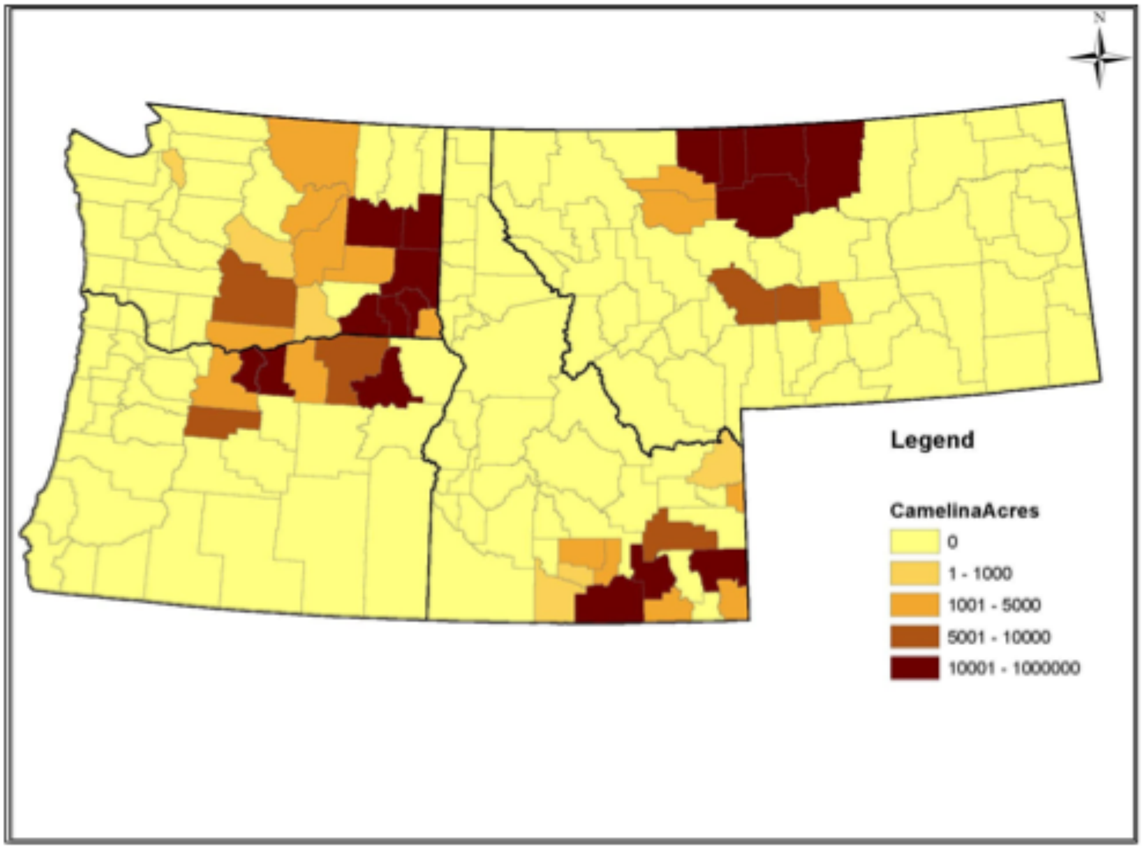

Figure 5: Camelina Acreage Composition by County Assuming 100% Adoption Rate and a Price of $0.15 per lb

Idaho, 588,633 acres in Montana, 54,950 acres in Oregon, and 728,848 acres in Washington are converted to camelina.

4.1.1. Model Validation

The partial equilibrium model contains supply estimates for every county in all 4 states. Ideally, these county estimates should be compared to a reference-dataset (Siegel 2008). County level acreage data for camelina is available from the NASS website, but only for Montana (U.S. Department of Agriculture 2011b). Table 2 is a side-by-side

Table 2: Comparison of Camelina Planted Acreage by County, Montana, USA

2009 NASS	Camelina Planted Acres[a]	Partial Equilibrium Model	Acres Converted to Camelina[b]
Big Horn	5,100	Big Horn	0
Broadwater	500	Broadwater	0
Chouteau	800	Chouteau	2,897
Dawson	900	Dawson	0
Garfield	600	Garfield	0
Glacier	700	Glacier	0
Golden Valley	0	Golden Valley	2,841
Liberty	900	Liberty	2,951
McCone	2,300	McCone	0
Phillips	500	Phillips	0
Pondera	1,800	Pondera	0
Sheridan	1,500	Sheridan	0
Stillwater	500	Stillwater	0
Teton	1,400	Teton	4,751
Toole	0	Toole	1,189
Wheatland	0	Wheatland	8,379
Other	3,300	Other	0
Total	20,800	Total	23,008

[a] Camelina acreage is drawn from the NASS website (U.S. Department of Agriculture 2011b).
[b] These are the results from the partial equilibrium model with a camelina price of $0.09 per lb and an adoption rate of 100%.

comparison of the 2009 NASS data and the partial equilibrium model estimates. In 2009 there were 20,800 planted acres of camelina in Montana. The partial equilibrium model shows that if the price of camelina is $0.09 per lb and the adoption rate is 100% the number of acres converted to camelina is 23,008.

The partial equilibrium model overestimates camelina production by only 2,200 acres. At the county level, the model predicted camelina adoption in 3 of the 6 counties correctly. According to the 2009 NASS data, the total production of camelina in Montana was approximately 12 million lbs with an average yield of 615 lbs per acre. The model estimated that approximately 28 million lbs of camelina would be produced with an average yield of 1,184 lbs per acre, almost double the 2009 NASS data. However, in

2010 the average yield in Montana was 1,010 lbs per acre (U.S. Department of Agriculture 2011a).

The partial equilibrium model seems to predict camelina acreage and total production accurately for Montana. However, in 2010 the price of camelina was between $0.09 and $0.12 per lb but only 9,900 acres were planted in Montana. The model predicts approximately 40,000 acres in Oregon and 200,000 acres in Washington would be converted to camelina at $0.09 per lb. It is obvious that the model must be modified in order to more accurately estimate the supply of camelina.

4.1.2. Potential Supply of Camelina Using Varied Adoption Rates

The supply curve presented in Figure 4 and the acres converted to camelina presented in Table 2 were estimated by assuming that if the wheat-camelina rotation is more profitable than the current crop rotation, then all of the acres will be converted to camelina. However, it is more likely that only a percentage of the available acres will be converted to camelina because farmers are risk averse and growing a new crop like camelina is perceived as a risk. To more accurately approximate the potential supply of camelina, adoption rates will be applied to the data to get a more pragmatic estimate.

Camelina is best suited for low rainfall cropland. For this reason, a higher adoption rate will be applied to counties in the low and intermediate rainfall zones. Data on the current production of camelina is available from the NASS website. The NASS data only has camelina production data for Montana. No data is available for the other states or Canadian provinces. The NASS data shows acreage declining from 2007 to 2008 from 22,500 to 12,200 acres. Similarly, from 2009 to 2010 acreage declined from 20,800 to 9,900. It also shows yields considerably lower than those achieved in trials. From 2007 to 2009 the average yield was approximately 600 lbs/acre but increased to 1,010 lbs/acre in 2010 (U.S. Department of Agriculture 2011a).

Tomas Endicott, VP of Business Development at Willamette Biomass Processors in Rickreal, Oregon attributes some of the acreage reduction to the fact that Great Plains Camelina Company cancelled contracts with farmers. An article in the Western Producer states that Great Plains cancelled contracts it signed with growers due to financial difficulties and extreme weather conditions preventing delivery (Pratt 2012). According to Endicott, Willamette Biomass Processors has contracted 1,000 acres of camelina in Oregon and none in Idaho and Washington (T. Endicott, personal communication, February 2012). This means that in 2010 there was approximately 11,000 acres of camelina being grown in Idaho, Montana, Oregon, and Washington.

At first glance, it seems that the partial equilibrium model overestimates the supply of camelina. In 2010 the price of camelina was between $0.09 and $0.12 per lb. At $0.09 per lb, the number of acres converted to camelina is 270,772. When a 5% adoption rate is applied to the low, 5% to the intermediate, and a 1% to the high rainfall zones the number of acres converted to camelina decreases to 11,988. This estimation is very close to the 11,000 acres that was produced in 2010. Figure 6 shows the number of acres converted to camelina using these adoption rates.

Approximately 1.3 to 1.6 billion lbs of camelina would be needed to achieve the "Farm to Fly" biofuel goal. Given the current price and expected yields of camelina, the

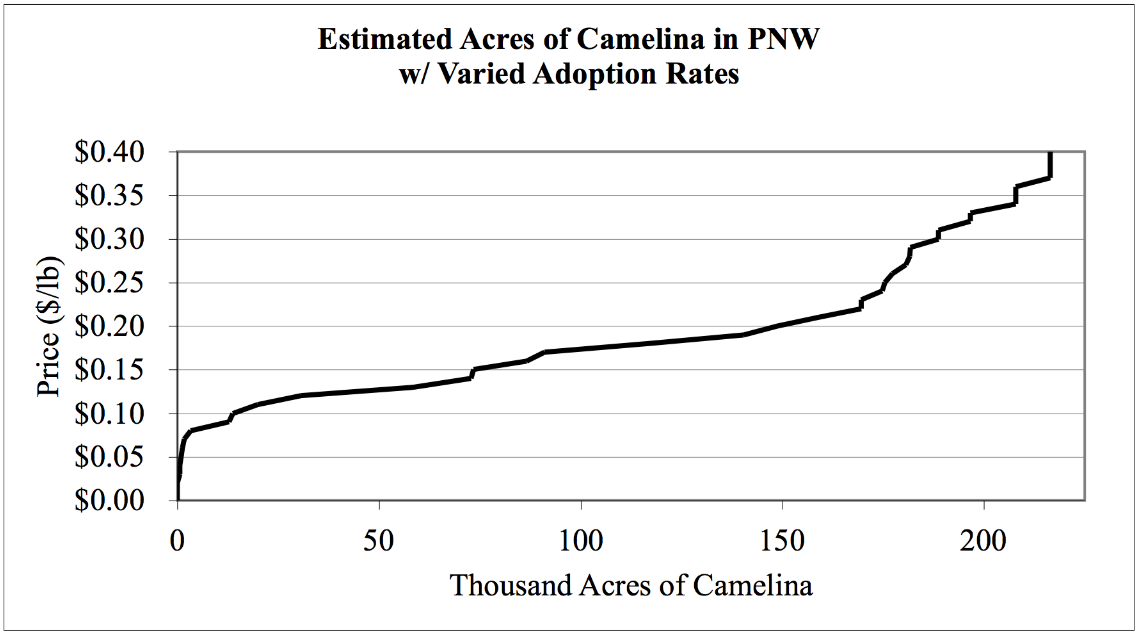

Figure 6: Estimated Acres Converted to Camelina in Idaho, Montana, Oregon, and Washington Using Varied Adoption Rates (5% for Low and Intermediate Rainfall Zones, 1% for High Rainfall Zones).

biofuel goal could not be met unless 100% of farmers adopted camelina when the wheat-camelina rotation is more profitable than the competing crop rotation. In order to meet the “Farm to Fly” biofuel goal, the profitability of camelina must increase either through government incentives or agronomic improvements.

4.1.3. Policy and Agronomic Changes

The government uses a variety of policy incentives including subsidies, tax credits, grants, loans, and crop insurance programs to stimulate biofuel production. The two most common policy incentives used to promote biofuel crop production are subsidies and crop insurance programs. Biofuel subsidies, when paid directly to the grower, are equivalent to an increase in the price of the product. A camelina subsidy would increase the price of camelina thus making it more profitable to grow. A camelina subsidy may seem like an easy way to meet the “Farm to Fly” biofuel goal. However, even at a price of $.80 per lb only 269 million lbs of camelina would be produced, assuming a 5% adoption rate. The adoption rate would have to increase to 25% in order for production to reach 1.3 billion lbs at a price of $0.80 per lb. Also, an increase in price would not reduce the yield risk associated with growing camelina. There would still be a chance of crop failure, which would leave the farmer with a huge loss in revenue. A camelina subsidy could be used to increase production, but is a costly and potentially ineffective approach.

Another important issue regarding subsidies is the indirect costs that arise because subsidies are paid by taxpayers. Public finance economics recognizes that taxes introduce distortions and thus inefficiencies in the economy. This means that any government program funded with taxes has an additional cost associated with it. The cost is referred to as the “deadweight loss” or “excess burden” of the tax. To finance biofuel subsidies, governments must either raise funds through additional taxation or reduce funding for other programs. In either case, there is a cost of financing the program (Jaeger and Siegel 2008).

Crop insurance is another approach used by governments to increase biofuel crop production. It is purchased by farmers to protect themselves against either the loss of their crops due to natural disasters or the loss of revenue due to a decrease in price. It is a type of economic incentive that would decrease the risk of growing camelina. Crop insurance programs protect against specific crop losses and work by transferring the risk away from the farmer to both federal and private insurance companies. A crop insurance program could increase the adoption rate of camelina but is very costly. One of the major concerns of crop insurance is that it removes almost any financial risk for planting land where crop failure is almost certain. Farmers could take advantage of the program by farming on low-quality land knowing that it won't produce and still make a profit (Nixon 2012). A crop insurance program for camelina would likely increase adoption but could cost the government a lot of money if the yields remain low.

A less costly way of increasing camelina adoption is through agronomic improvement and increased yields. If yields increased and the threat of crop failure decreased, camelina production would increase and adoption would likely expand. A 50% increase in yield would result in approximately 272 million lbs being produced at $0.20 per lb, assuming an adoption rate of 5%. This is more than the amount that would be produced at $0.80 per lb given current yields. If yields increased and became more consistent, camelina would be a more profitable crop thus more farmers would be likely to grow it. Farmers won't devote acreage to camelina if they are not confident in the crop. The "Farm to Fly" biofuel goal could be achieved if yields doubled, the adoption rate was 25%, and the price was $0.18 per lb. Approximately 1.4 billion lbs of camelina would be produced at this price. Once again this is more than the amount produced given current yields at $0.80 per lb with an adoption rate of 25%. This would require yields of 1,500 to 2,500 lbs per acre for low and intermediate rainfall zones. If these yields could be achieved consistently, the adoption rate of camelina would increase significantly, and the

"Farm to Fly" biofuel goal could be reached. However, how will the increased production affect the agricultural landscape?

4.2. Land Use Change

The debate over land use change caused by increased biofuel production in the U.S. is an important issue with two major concerns. First, increased biofuel crop production diverts land from natural ecosystems thus negating the direct reduction in GHG emissions caused by lower gasoline use. Second, when agricultural cropland is diverted to biofuel production rather than food production the price of food increases and there is a potential for food shortages. If camelina is grown on fallow land and does not divert significant acres from agricultural land devoted to food production, the negative externalities associated with changes in land use are avoided.

In order to evaluate how the production of camelina affects the agricultural landscape, it is necessary to understand how total crop acreages change given the price of camelina. The results show that fallow land is the most affected by increased camelina production. As shown in Figure 7, camelina production first pressures fallow acres into production and then other crop acreage to switch. Crop acreage switches occur in barley, pea, canola, mustard, and lentil, in order of occurrence. At $0.15 per lb 1,081,319 fallow; 371,442 barley; 35,853 pea; 2,701 canola; 1,474 mustard; and 895 lentil acres are converted to camelina assuming an adoption rate of 100%. This analysis assumes that camelina will not replace wheat acres, but if the profitability of camelina were to be greater than that of wheat, it is likely that some wheat acres will be converted to

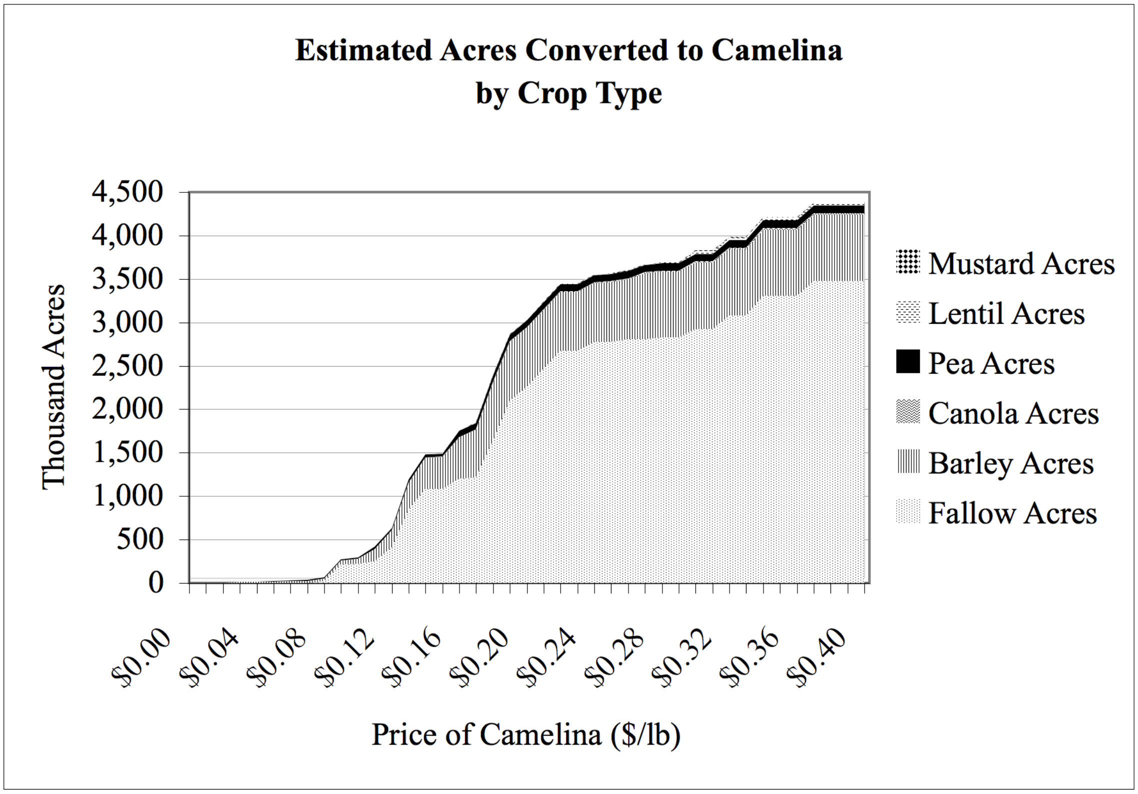

Figure 7: Estimated Acres Converted to Camelina by Crop Type.

camelina. However, the majority of acres will still come from fallow land thus making the impact of indirect land use change minimal. Table 3 shows the crop acreage composition for each crop as a % of total supply. At $0.15 per lb, 72% of the total supply comes from fallow cropland and 25% from barley. The remaining 3% comes from pea, canola, lentil, and mustard acres. One of the reasons camelina is considered to be an ideal energy crop is because it does not displace land from food crops. These results are consistent with that claim. When the price of camelina increases to $.20 per lb the crop acreage composition changes very little. Even at a price of $.40 per lb, 79% of the acres converted to camelina come from fallow acres. One of the most common criticisms of

Table 3: Crop Acreage Composition- % of Total Supply of Acres

Camelina Price	Fallow %	Barley %	Canola %	Pea %	Lentil %	Mustard %
$0.10	75.49	19.20	0.00	5.31	0.00	0.00
$0.11	59.05	34.33	0.00	6.41	0.21	0.00
$0.12	64.72	30.72	0.10	4.32	0.14	0.00
$0.13	71.05	25.65	0.23	3.00	0.07	0.00
$0.14	73.04	24.29	0.18	2.42	0.06	0.00
$0.15	72.39	24.87	0.18	2.40	0.06	0.10
$0.16	68.18	27.33	0.19	4.16	0.05	0.08
$0.17	65.67	30.06	0.18	3.96	0.05	0.08
$0.18	68.60	27.96	0.20	3.05	0.04	0.16
$0.19	73.36	23.63	0.16	2.64	0.03	0.17
$0.20	74.65	22.47	0.16	2.52	0.03	0.18
- - -	- - -	- - -	- - -	- - -	- - -	- - -
$.40	79.28	17.45	0.37	2.01	0.77	0.12

corn ethanol and soybean biodiesel is that it diverts farmland from food production. If camelina is grown as a rotation crop with wheat the food versus fuel debate is eliminated.

5. Conclusion

This research shows that given current market conditions, the supply of camelina in Idaho, Montana, Oregon, and Washington will not be enough to meet the 50 million gallon biofuel goal state in the "Farm to Fly" initiative unless the adoption rate of camelina is between 75% and 90%[2]. Camelina can replace fallow land and be grown in rotation with other crops for exclusive use in the creation of biofuels for the aviation industry, but farmers must have an economic incentive before devoting significant acreage to it. Currently, the profitability of camelina is a major concern because the price and the observed yields of camelina are too low. Before farmers will adopt camelina, many improvements and changes must be made to make it a less risky and more profitable crop.

First, the price of camelina must increase in order for camelina to be profitable enough for farmers to adopt. This can be achieved through a change in the competitive market or through government intervention. Economic theory postulates that if the demand for a good increases and the supply remains unchanged, then it will lead to a higher price. This means that the price of camelina could increase due to the growing demand caused by the "Farm to Fly" initiative. However, as the price increases the supply will increase diminishing the price effect. The price of camelina would also increase if the government provided economic incentives through subsidies. As discussed in section 4.1.3, subsidies have indirect costs and result in a "deadweight loss". Also, an

[2] Depending on yield and oil content

increase in price to $0.80 per lb would not increase production enough to meet the “Farm to Fly” biofuel goal and would not reduce the yield risk associated with growing camelina.

Second, an increase in yield and a reduction in yield variability would increase camelina’s profitability and make it a less risky crop to grow. Yield improvements can be achieved through agronomic research. Research should focus on obtaining varieties of camelina that are high yielding, have low yield variability and contain disease resistance. If yields ranging from 1,500 to 2,500 lbs per acre could be achieved consistently, camelina production and the rate of adoption would increase. Without a significant improvement in yield, the “Farm to Fly” biofuel goal cannot be reached.

An alternative approach to reducing the yield risk associated with growing camelina is through crop insurance. If the government provided crop insurance for farmers growing camelina, the adoption rate would likely increase. However, without agronomic improvements the effect of the crop insurance programs on camelina adoption would not be enough to meet the 50 million gallon biofuel goal. If camelina yields do not improve, an adoption rate of nearly 100% would be required to achieve this goal. As stated in section 4.1.3, the biofuel goal could be achieved if yields doubled, the adoption rate was 25% and the price of camelina was $0.18 per lb. These changes will not occur without agronomic improvements and government intervention.

The results of this research can be used to draw important implications for state and federal policy makers. Without the help of policy makers, camelina and other biofuels are not cost-competitive with fossil fuels and thus aren’t produced on a large enough scale to meet the growing demand. The enterprise budgets used in the partial equilibrium model could be used as a tool to determine the profitability of camelina and the other rotation crops examined in this study. This research shows the improvements and changes that must be made in order to meet the “Farm to Fly” biofuel goal. Camelina is a promising new energy crop, but without agronomic improvements and government intervention the supply of camelina will fall short of the growing demand.

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APPENDICES

Appendix A. Camelina Comparison to Other Crops

Table A.1 Biomass Advisors Camelina Comparison to Other Crops in Eastern Montana

	Camelina	Winter Wheat	Spring Wheat	Canola	Barley
Price ($/lb)	0.13	0.09	0.10	0.15	0.08
Yield (lb/ac)	1,350	2,400	1,680	1,250	2,256
Total Revenue	168.75	223.20	168.00	181.25	180.48
Variable Cost ($/ac)	80.27	127.74	129.21	131.71	139.35
Gross Margin ($/ac)	88.59	95.46	38.79	49.54	41.13
Break-Even Price	0.06	0.05	0.08	0.11	0.06

Table A.2 Camelina Comparison to Other Crops in Idaho

	Camelina	Barley	Canola	Peas	Lentil	Mustard
Price ($/lb)	0.15	0.11	0.19	0.13	0.30	0.32
Yield (lb/ac)	1,205	3,616	1,326	1,908	1,103	657
Variable Cost ($/ac)	195.57	229.18	228.42	259.06	211.60	248.74
Gross Margin ($/ac)	-14.82	168.58	23.52	-11.02	119.30	-38.50
Break-Even Price	0.16	0.06	0.17	0.14	0.19	0.38

Table A.3 Camelina Comparison to Other Crops in Montana

	Camelina	Barley	Canola	Peas	Lentil	Mustard
Price ($/lb)	0.15	0.10	0.18	0.12	0.26	0.32
Yield (lb/ac)	1,336	2,088	1,262	1,626	1,059	819
Variable Cost ($/ac)	204.80	252.97	242.95	244.36	195.51	253.57
Gross Margin ($/ac)	-4.40	-44.17	-15.79	-49.24	79.83	8.51
Break-Even Price	0.15	0.12	0.19	0.15	0.18	0.31

Table A.4 Camelina Comparison to Other Crops in Oregon

	Camelina	Barley	Canola	Peas	Lentil	Mustard
Price ($/lb)	0.15	0.09	0.19	0.16	0.28	0.32
Yield (lb/ac)	1,375	2,871	1,586	2,198	1,128	865
Variable Cost ($/ac)	220.25	283.41	241.58	247.49	202.32	254.49
Gross Margin ($/ac)	-14.00	-25.02	59.76	104.19	113.52	22.31
Break-Even Price	0.16	0.10	0.15	0.11	0.18	0.29

Table A.5 Camelina Comparison to Other Crops in Washington

	Camelina	Barley	Canola	Peas	Lentil	Mustard
Price ($/lb)	0.15	0.08	0.19	0.13	0.31	0.32
Yield (lb/ac)	1,451	2,732	1,707	2,004	1,250	856
Variable Cost ($/ac)	216.82	279.66	246.13	260.83	208.31	246.10
Gross Margin ($/ac)	0.83	-61.10	78.20	-0.31	179.19	27.82
Break-Even Price	0.15	0.10	0.14	0.13	0.17	0.29

Appendix B. Acres Suitable for Camelina Production for Partial Equilibrium Model

Table B.1 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Idaho Low Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Ada	3,764	552	1,063	-	-	-	-	-
Bingham	73,434	5,163	13,980	-	-	-	-	-
Canyon	19,810	2,389	2,627	-	1,082	-	-	-
Cassia	54,893	15,825	28,785	-	-	-	-	-
Elmore	6,571	1,408	2,281	-	-	-	-	-
Gem	3,001	542	561	-	-	-	-	-
Gooding	1,876	-	2,141	-	-	-	-	-
Jerome	7,500	715	14,336	-	187	-	-	-
Lincoln	2,387	1,030	3,023	-	-	-	-	-
Minidoka	12,774	1,727	30,078	-	361	-	-	-
Owyhee	4,654	1,698	1,917	-	-	-	-	-
Payette	4,894	962	-	-	-	-	-	-
Power	48,716	31,712	1,280	-	-	-	-	-
Twin Falls	19,470	695	23,235	41	1,830	-	-	-

Table B.2 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Idaho Intermediate Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Bannock	18,838	16,185	5,656	-	-	-	-	-
Bear Lake	298	2,182	3,996	-	-	-	-	-
Caribou	21,881	14,889	53,578	-	-	-	-	-
Franklin	16,354	7,331	5,573	-	-	-	-	-
Oneida	22,282	22,604	3,002	-	-	-	-	-
Teton	2,514	3,108	32,774	-	-	-	-	-

Table B.3 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Idaho High Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Benewah	29,635	1,756	4,414	-	1760	4,752	-	-
Boundary	10,813	882	3,352	2,636	-	-	-	-
Clearwater	7,315	499	1,094	-	-	-	-	-
Fremont	2,284	702	54,392	-	-	-	-	-
Idaho	63,581	18,543	18,374	5,826	911	536	-	-
Kootenai	7,774	3,004	1,022	-	-	-	-	-
Latah	66,954	3,810	11,659	-	8095	18,475	-	-
Lewis	82,290	8,511	17,739	5,814	3514	4,286	-	-
Nez Perce	84,985	5,709	15,037	1,819	4767	7,724	-	-
Washington	5,565	1,840	1,249	-	-	-	-	-

Table B.4 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Montana Low Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Blaine	63,626	183,491	16,681	-	615	-	-	-
Broadwater	12,093	20,331	3,723	-	-	-	-	-
Chouteau	429,504	396,179	39,397	-	2,897	-	-	-
Custer	11,350	28,441	3,454	-	-	-	-	-
Daniels	2,562	57,676	2,145	2,430	49,000	6,764	3,613	4,762
Dawson	26,899	73,765	14,361	-	3,902	1,570	-	-
Garfield	56,049	109,614	5,482	-	1,783	-	-	-
Glacier	28,981	132,242	102,991	-	3,270	-	-	-
Golden Valley	13,075	15,633	2,841	-	-	-	-	-
Hill	268,806	384,820	23,787	-	2,338	895	-	-
Lewis and Clark	11,682	6,110	10,329	-	-	-	-	-
Liberty	164,622	179,146	21,685	-	2,951	-	-	-
McCone	34,820	107,503	14,729	-	5,102	-	-	-
Madison	1,569	2,938	2,431	-	-	-	-	-
Meagher	6,206	8,095	5,855	-	-	-	-	-
Musselshell	22,302	9,894	1,295	-	-	-	-	-
Petroleum	8,274	18,797	375	-	-	-	-	-
Phillips	27,000	119,003	13,628	-	4,644	-	-	-
Pondera	132,013	166,649	74,747	1,600	3,735	-	-	-
Prairie	11,884	27,398	2,655	-	-	-	-	-
Roosevelt	15,356	123,077	5,722	-	23,806	4,178	-	-
Rosebud	24,605	41,343	1,999	-	-	-	-	-
Sheridan	6,015	47,723	9,390	-	50,007	58,365	2,480	4,084
Teton	123,436	129,224	64,116	-	4,751	-	-	-
Toole	89,089	206,972	52,425	2,033	1,189	-	-	-
Treasure	2,180	-	4,130	-	-	-	-	-
Valley	12,553	148,373	7,570	-	43,412	6,518	4,628	4,084
Yellowstone	57,473	62,230	17,683	-	4,240	-	-	-

Table B.5 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Montana Intermediate Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Big Horn	87,729	82,269	18,048	-	-	-	-	-
Carbon	2,777	5,959	6,840	-	-	-	-	-
Carter	23,030	24,038	1,673	-	-	-	-	-
Cascade	113,473	98,083	27,869	-	-	-	-	-
Fallon	15,530	21,140	3,022	-	511	-	-	-
Fergus	126,166	95,731	32,604	-	766	-	-	-
Judith Basin	49,869	28,206	14,902	-	2,540	-	-	-
Lake	2,491	3,562	2,266	-	-	-	-	-
Powder River	10,749	13,097	1,759	-	-	-	-	-
Richland	10,137	74,239	25,171	-	4,050	1,997	2,050	-
Wheatland	24,363	16,987	8,379	-	-	-	-	-
Wibaux	9,546	20,289	1,537	-	4,240	1,668	-	-

Table B.6 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Montana High Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Flathead	7,462	6,954	10,350	-	1,422	-	-	-
Gallatin	19,409	27,749	25,140	-	1,507	-	-	-
Stillwater	21,288	34,422	5,379	-	366	-	-	-

Table B.7 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Oregon Low Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Baker	6,019	1,174	646	-	-	-	-	-
Crook	650	762	0	-	-	-	-	-
Gilliam	85,545	86,419	10,958	-	-	-	-	-
Jefferson	3,904	5,640	284	-	-	-	-	-
Malheur	20,852	7,082	958	-	93	-	-	-
Morrow	141,979	99,940	3,822	-	488	-	-	-
Sherman	109,183	116,260	10,861	-	-	-	-	-
Wasco	52,562	32,829	1,211	-	-	-	-	-

Table B.8 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Oregon Intermediate Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Umatilla	268,819	157,183	6,040	2,308	2,641	-	692	-
Union	19,587	11,275	3,783	668	-	-	-	-
Wallowa	3,778	1,927	3,827	-	-	-	-	-

Table B.9 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Oregon High Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Benton	3,024	2,406	-	-	-	-	-	-
Clackamas	428	1,373	-	-	-	-	-	-
Klamath	1,132	1,603	9,383	-	-	-	-	-
Lane	1,407	1,619	-	-	-	-	-	-
Linn	2,779	3,623	121	-	-	-	51	-
Marion	2,702	5,797	168	-	-	-	152	-
Polk	1,525	2,599	-	-	71	-	-	-
Washington	7,866	794	428	-	-	-	-	-
Yamhill	1,701	1,095	-	-	-	-	-	-

Table B.10 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Washington Low Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Adams	234,604	222,098	1,957	3,228	532	-	-	-
Benton	80,546	99,338	180	-	-	-	-	-
Douglas	145,455	157,657	2,781	1,302	761			
Franklin	61,579	55,357	-	-	1,034	-	-	-
Grant	117,172	95,104	2,170	1,423	1,207	-	-	-
Lincoln	236,314	233,465	39,870	1,144	588	-	1,062	-
Okanogan	9,714	12,916	3,218	-	-	-	-	-
Walla Walla	165,205	107,788	4,496	-	5,245	-	-	-
Yakima	15,261	7,161	-	-	-	-	-	-

Table B.11 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Washington Intermediate Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Asotin	20,381	16,300	2,096	-	-	-	-	-
Garfield	48,757	38,874	11,010	-	-	-	-	-
Spokane	98,638	24,195	26,482	709	5,961	-	782	-
Whitman	334,197	159,779	108,689	1,900	37,187	32,969	2,400	-

Table B.12 Acres Suitable for Camelina Production for Partial Equilibrium Model across Counties in Washington High Rainfall Zone

	Winter Wheat	Summer Fallow	Barley	Canola	Peas	Lentil	Mustard	Flax
Columbia	58,543	35,373	11,591	-	11,416	-	378	-
Island	228	334	777	-	-	-	-	-
Kittitas	195	579	-	37	-	-	-	-
Klickitat	16,401	17,808	1,786	-	-	-	-	-
Skagit	4,385	487	1,100	-	-	-	-	-
Snohomish	311	508	56	-	-	-	-	-
Whatcom	430	25	-	-	-	-	-	-

Appendix C. Assumed Yields for Partial Equilibrium Model

Table C.1 Assumed Yields for Partial Equilibrium Model across Counties in Idaho Low Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Ada	6,831	5,085	742	-	-	-	-	-
Bingham	6,309	5,026	742	-	-	-	-	-
Canyon	6,707	5,208	742	-	2,496	-	-	-
Cassia	5,246	5,503	742	-	-	-	-	-
Elmore	5,513	4,795	742	-	-	-	-	-
Gem	6,514	2,951	742	-	-	-	-	-
Gooding	6,541	4,710	742	-	-	-	-	-
Jerome	6,850	5,817	742	-	2,393	-	-	-
Lincoln	6,466	5,517	742	-	-	-	-	-
Minidoka	6,316	5,586	742	-	2,263	-	-	-
Owyhee	6,672	4,479	742	-	-	-	-	-
Payette	5,815	-	742	-	-	-	-	-
Power	3,497	4,734	742	-	-	-	-	-
Twin Falls	6,835	5,557	742	1,228	2,382	-	-	-

Table C.2 Assumed Yields for Partial Equilibrium Model across Counties in Idaho Intermediate Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Bannock	2,766	2,375	1,205	-	-	-	-	-
Bear Lake	1,359	1,922	1,205	-	-	-	-	-
Caribou	2,861	1,811	1,205	-	-	-	-	-
Franklin	2,403	2,964	1,205	-	-	-	-	-
Oneida	1,740	1,496	1,205	-	-	-	-	-
Teton	3,298	2,205	1,205	-	-	-	-	-

Table C.3 Assumed Yields for Partial Equilibrium Model across Counties in Idaho High Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Benewah	3,979	2,973	1,668	-	1,729	1,129	-	-
Boundary	4,735	3,314	1,668	2,007	-	-	-	-
Clearwater	3,420	1,582	1,668	-	-	-	-	-
Fremont	4,609	2,988	1,668	-	-	-	-	-
Idaho	3,942	2,289	1,668	1,407	1,230	1,079	-	-
Kootenai	3,957	2,764	1,668	-	-	-	-	-
Latah	4,476	2,850	1,668	-	1,666	1,165	-	-
Lewis	3,127	2,492	1,668	799	1,385	919	-	-
Nez Perce	4,002	2,590	1,668	1,191	1,627	1,222	-	-
Washington	5,035	3,292	1,668	-	-	-	-	-

Table C.4 Assumed Yields for Partial Equilibrium Model across Counties in Montana Low Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Blaine	2,075	1,593	1,160	-	1,505	-	-	-
Broadwater	1,680	3,092	1,160	-	-	-	-	-
Chouteau	2,806	1,573	1,160	-	1,079	-	-	-
Custer	1,698	2,344	1,160	-	-	-	-	-
Daniels	1,277	1,428	1,160	873	1,851	753	363	383
Dawson	2,034	1,935	1,160	-	1,207	1,281	-	-
Garfield	1,737	1,792	1,160	-	1,272	-	-	-
Glacier	1,280	1,165	1,160	-	852	-	-	-
Golden Valley	2,110	1,065	1,160	-	-	-	-	-
Hill	2,107	1,524	1,160	-	1,640	443	-	-
Lewis and Clark	1,700	3,541	1,160	-	-	-	-	-
Liberty	1,780	1,323	1,160	-	983	-	-	-
McCone	1,734	1,602	1,160	-	1,895	-	-	-
Madison	2,781	3,715	1,160	-	-	-	-	-
Meagher	1,366	1,753	1,160	-	-	-	-	-
Musselshell	1,595	1,533	1,160	-	-	-	-	-
Petroleum	1,596	1,139	1,160	-	-	-	-	-
Phillips	2,001	1,584	1,160	-	1,388	-	-	-
Pondera	2,264	2,004	1,160	1,982	1,323	-	-	-
Prairie	1,679	1,219	1,160	-	-	-	-	-
Roosevelt	2,490	1,884	1,160	-	2,053	1,137	-	-
Rosebud	1,757	3,421	1,160	-	-	-	-	-
Sheridan	2,662	1,489	1,160	-	2,153	1,265	513	562
Teton	2,373	3,139	1,160	-	853	-	-	-
Toole	1,678	1,338	1,160	930	1,021	-	-	-
Treasure	1,534	4,248	1,160	-	-	-	-	-
Valley	1,819	1,166	1,160	-	1,595	871	348	1,313
Yellowstone	1,722	3,629	1,160	-	2,268	-	-	-

Table C.5 Assumed Yields for Partial Equilibrium Model across Counties in Montana Intermediate Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Big Horn	2,213	3,060	1,317	-	-	-	-	-
Carbon	1,907	4,419	1,317	-	-	-	-	-
Carter	2,217	1,744	1,317	-	-	-	-	-
Cascade	2,512	2,073	1,317	-	-	-	-	-
Fallon	1,880	968	1,317	-	1,600	-	-	-
Fergus	2,595	1,484	1,317	-	1,858	-	-	-
Judith Basin	2,315	1,383	1,317	-	1,239	-	-	-
Lake	3,395	3,073	1,317	-	-	-	-	-
Powder River	2,037	1,459	1,317	-	-	-	-	-
Richland	1,748	2,805	1,317	-	2,316	1,180	640	-
Wheatland	1,670	1,591	1,317	-	-	-	-	-
Wibaux	2,555	1,353	1,317	-	2,268	1,540	-	-

Table C.6 Assumed Yields for Partial Equilibrium Model across Counties in Montana High Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Flathead	3,889	2,906	1,530	-	2,159	-	-	-
Gallatin	2,963	2,515	1,530	-	2,536	-	-	-
Stillwater	1,735	1,698	1,530	-	1,746	-	-	-

Table C.7 Assumed Yields for Partial Equilibrium Model across Counties in Oregon Low Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Baker	5,285	3,812	1,224	-	-	-	-	-
Crook	6,156	-	1,224	-	-	-	-	-
Gilliam	2,493	1,146	1,224	-	-	-	-	-
Jefferson	7,206	4,931	1,224	-	-	-	-	-
Malheur	6,393	3,698	1,224	-	1,862	-	-	-
Morrow	2,253	1,951	1,224	-	2,222	-	-	-
Sherman	2,839	2,051	1,224	-	-	-	-	-
Wasco	2,508	1,868	1,224	-	-	-	-	-

Table C.8 Assumed Yields for Partial Equilibrium Model across Counties in Oregon Intermediate Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Umatilla	3,292	1,750	1,462	2,142	1,883	-	761	-
Union	4,852	2,767	1,462	1,030	-	-	-	-
Wallowa	2,493	3,251	1,462	-	-	-	-	-

Table C.9 Assumed Yields for Partial Equilibrium Model across Counties in Oregon High Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Benton	6,430	-	1,438	-	-	-	-	-
Clackamas	4,684	-	1,438	-	-	-	-	-
Klamath	5,032	4,773	1,438	-	-	-	-	-
Lane	6,310	-	1,438	-	-	-	-	-
Linn	5,184	2,564	1,438	-	-	-	987	-
Marion	4,539	2,830	1,438	-	-	-	847	-
Polk	6,019	-	1,438	-	2,824	-	-	-
Washington	5,667	2,806	1,438	-	-	-	-	-
Yamhill	4,918	-	1,438	-	-	-	-	-

Table C.10 Assumed Yields for Partial Equilibrium Model across Counties in Washington Low Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Adams	2,999	2,771	1,027	1,523	1,941	-	-	-
Benton	3,058	2,324	1,027	-	-	-	-	-
Douglas	2,677	1,804	1,027	1,196	1,932	-	-	-
Franklin	3,647	-	1,027	-	2,364	-	-	-
Grant	4,061	2,039	1,027	2,060	2,349	-	-	-
Lincoln	3,533	2,330	1,027	2,048	2,118	-	692	-
Okanogan	2,695	1,180	1,027	-	-	-	-	-
Walla Walla	4,068	3,374	1,027	-	1,954	-	-	-
Yakima	4,664	-	1,027	-	-	-	-	-

Table C.11 Assumed Yields for Partial Equilibrium Model across Counties in Washington Intermediate Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Asotin	2,661	1,797	1,432	-	-	-	-	-
Garfield	3,349	2,586	1,432	-	-	-	-	-
Spokane	3,768	2,844	1,432	1,168	1,593	-	695	-
Whitman	4,365	3,387	1,432	1,843	1,884	1,250	798	-

Table C. 12 Assumed Yields for Partial Equilibrium Model across Counties in Washington High Rainfall Zone

	Winter Wheat	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Columbia	4,393	3,447	1,894	-	1,898	-	1,239	-
Island	4,823	4,817	1,894	-	-	-	-	-
Kittitas	5,095	-	1,894	2,114	-	-	-	-
Klickitat	2,278	1,709	1,894	-	-	-	-	-
Skagit	5,143	3,899	1,894	-	-	-	-	-
Snohomish	3,712	3,402	1,894	-	-	-	-	-
Whatcom	3,386	-	1,894	-	-	-	-	-

Appendix D. Enterprise Budgeting Procedure

The first step in constructing an enterprise budget is to estimate total production (output or yield) and expected output price. The estimated yields and prices should be what you expect under normal conditions (Baldree and Hinman 2003). The yield estimates were estimated by talking with agronomists and agricultural economists. Then, the average yield for each crop was calculated by using data obtained from the Census and NASS. The census data was arranged by state and rainfall zone. The final yield estimates took into account the input from agronomists/economists and the Census data. Since camelina is not included in the Census, average yield estimates were estimated by using various camelina yield trials preformed in each state. UI, MSU, OSU and WSU have all conducted camelina yield trials. The expected prices, except camelina, were obtained from the NASS website. The 2010 camelina price posted by Great Plains Camelina Company was used.

The second step is to estimate variable costs. These are associated with operating machinery, labor and purchasing services and materials. Variable costs vary directly with the crop grown and the number of acres produced. Variable costs include fuel, oil, repairs, fertilizer, chemicals, custom work, overhead and interest on operating capital. Labor, including that provided by the owner-operator, is also included as a variable cost. The price of inputs and the quantity of inputs used greatly affects the variable costs calculation (Baldree and Hinman 2003).

Fertilizer prices were taken from the USDA's Economic Research Service (ERS) average U.S. farm prices spreadsheet (U.S. Department of Agriculture, Economic

Research Service 2011). The spreadsheet contains average U.S. farm price of selected fertilizers[3]. These prices were then converted into price per lb for N, P, S, and potassium (K)[4] (Baldree and Hinman 2003). The quantity of fertilizer and chemicals applied is based on the findings of studies estimating fertility/chemical requirements for each crop and input from various agronomists. Chemical input prices are based on January, 2011 quotes from chemical and seed dealers.

The third step is to assess machinery and land fixed costs. Fixed costs will occur and will stay about the same no matter how much you produce, or, in most cases whether or not you produce at all. Machinery fixed cost includes depreciation, interest on the investment, property taxes, insurance and housing. For the overall farm operation these costs do not vary with the crops produced, given the ownership of a specific machinery complement, and are incurred whether or not crops are grown. Machinery fixed costs were determined by multiplying the machine hours per acre times the hourly fixed cost. The hourly fixed costs were determined by dividing the total fixed cost by the annual hours of machinery use for the representative farm (Baldree and Hinman 2003).

Machinery interest costs were calculated on the average annual investment in the machine. The formula used to calculate the average machine investment was:

(Purchase cost + Salvage value)/2

A 4.5% interest charge made against this average investment represents an opportunity cost (returns forgone by investing in a given machine implement rather than

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[3] \$526/tonne for 46-0-0, \$633/tonne for 0-46-0, \$601/tonne for 0-0-60, and \$423/tonne for 21-0-0-24

[4] \$0.58/lb actual N, \$.69/lb actual P, \$0.50/lb actual K, and \$0.38/lb actual S

in an alternative investment) or interest paid on money borrowed to finance machine purchases, or both. Machinery interest cost for one acre of the crop enterprise being analyzed was determined by multiplying the respective machine hours per acre times the per hour interest costs (Baldree and Hinman 2003).

Land fixed costs include taxes and net rent which is based on a one-third land owner and two-thirds tenant crop share with the land owner paying the land taxes and one-third the cost of fertilizer, chemicals and crop insurance. The tenant pays all other production costs. While the owner-operator will not actually experience a land rental cost, the cost represents the minimum returns the owner-operator must realize to justify growing the crop him or herself. This net rent return represents the income the owner-operator forgoes by producing the crop rather than renting to a tenant who produces the crop. As a result of owning land, the farmer receives both current returns from the farming operation and any long-term appreciation in land value. However, the farmer would continue to realize land value appreciation even if the land is rented out. Consequently, the appropriate land charge for growing the crop is only the forgone net rent. As used in this study, for land that is owned and not rented, land cost was termed an opportunity cost to indicate that it was not an out-of-pocket expense, but rather a return that was forgone as a result of choosing to use the land to grow this crop. To determine the profitability of crop production relative to other activities, the owner-operator may want to consider these forgone returns, or opportunity costs, along with the usual production expenses (Baldree and Hinman 2003). In this study, net land rental cost was calculated as:

1/3 Crop Value − 1/3 Fertilizer Cost − 1/3 Chemical Cost − 1/3 Crop Insurance Cost − Land Taxes

Appendix E. Summarized Crop Expenses from Various Enterprise Budgets for Partial Equilibrium Model[5]

Table E.1 Summarized Crop Expenses for Idaho Low Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	14.00	0.00	13.20	16.00	30.00	66.00	22.50	12.50	9.20
Fertilizer	48.95	0.00	40.25	39.50	32.05	20.35	14.40	32.05	32.05
Pesticide	9.67	23.28	24.79	6.87	16.79	33.29	26.58	12.13	21.49
Machinery	58.15	47.73	79.28	68.62	68.62	64.56	63.39	68.62	68.62
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	23.27	5.48	16.81	14.63	16.32	18.80	14.64	14.52	14.97
Fixed Costs	32.53	22.52	38.80	36.38	36.38	34.81	34.81	36.38	36.38
Total Costs	195.82	103.51	220.88	186.25	211.16	246.31	184.82	184.70	191.21

Table E.2 Summarized Crop Expenses for Idaho Intermediate Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	14.00	0.00	13.20	16.00	30.00	66.00	22.50	12.50	9.20
Fertilizer	60.10	0.00	48.95	48.20	43.80	32.25	26.30	43.80	43.80
Pesticide	9.67	23.28	24.79	6.87	16.79	33.29	31.58	12.13	21.49
Machinery	58.15	47.73	79.28	68.62	68.62	64.56	64.56	68.62	68.62
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	24.23	5.48	17.44	15.26	17.17	19.65	15.95	15.38	15.82
Fixed Costs	32.53	22.52	38.80	36.38	36.38	34.81	34.81	36.38	36.38
Total Costs	207.93	103.51	230.21	195.58	223.76	259.06	204.20	197.31	203.81

[5] Summarized crop expenses exclude land costs

Table E.3 Summarized Crop Expenses for Idaho High Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	18.00	0.00	13.20	16.00	30.00	66.00	22.50	12.50	9.20
Fertilizer	74.70	0.00	54.75	56.90	64.25	44.15	38.20	64.25	64.25
Pesticide	9.67	23.28	24.79	6.87	16.79	33.29	26.58	12.13	21.49
Machinery	58.15	47.73	79.28	68.62	68.62	64.56	64.56	68.62	68.62
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	25.83	5.48	17.86	15.90	18.65	20.52	16.45	16.86	17.30
Fixed Costs	32.53	22.52	38.80	36.38	36.38	34.81	34.81	36.38	36.38
Total Costs	228.13	103.51	236.43	204.92	245.69	271.83	211.60	219.24	225.74

Table E.4 Summarized Crop Expenses for Montana Low Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	14.00	0.00	18.70	24.00	24.00	66.00	22.50	12.50	11.50
Fertilizer	63.00	0.00	43.00	27.00	58.45	20.35	20.35	58.45	45.90
Pesticide	9.67	23.28	9.65	24.85	9.07	31.17	31.17	31.17	31.17
Machinery	52.98	43.53	72.21	62.54	62.54	63.95	57.79	62.54	62.54
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	24.03	5.17	15.80	15.17	16.80	18.60	15.00	17.38	16.40
Fixed Costs	30.90	21.39	36.85	34.56	34.56	33.06	33.06	34.56	34.56
Total Costs	203.83	97.87	203.96	192.37	216.42	241.63	188.37	225.10	210.57

Table E.5 Summarized Crop Expenses for Montana Intermediate Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	14.00	0.00	18.70	24.00	24.00	66.00	22.50	12.50	11.50
Fertilizer	81.10	0.00	63.60	38.60	85.00	26.30	26.30	85.00	66.50
Pesticide	9.67	23.28	44.59	24.85	9.07	31.17	31.17	31.17	31.17
Machinery	52.98	43.53	72.21	62.54	62.54	63.95	57.79	62.54	62.54
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	25.59	5.17	19.83	16.01	18.72	18.66	15.51	19.30	17.90
Fixed Costs	30.90	21.39	36.85	34.56	34.56	33.06	33.06	34.56	34.56
Total Costs	223.49	97.87	263.53	204.81	244.89	247.64	194.83	253.57	232.67

Table E.6 Summarized Crop Expenses for Montana High Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	14.00	0.00	18.70	24.00	24.00	66.00	22.50	12.50	11.50
Fertilizer	98.25	0.00	89.60	50.20	106.15	32.25	32.25	111.55	89.60
Pesticide	9.67	23.28	44.59	24.85	9.07	31.17	31.17	31.17	31.17
Machinery	52.98	43.53	72.21	62.54	62.54	63.95	57.79	62.54	62.54
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	27.06	5.17	21.71	16.85	20.25	19.09	15.94	21.23	19.57
Fixed Costs	30.90	21.39	36.85	34.56	34.56	33.06	33.06	34.56	34.56
Total Costs	242.11	97.87	291.41	217.25	267.57	254.02	201.21	282.05	257.44

Table E.7 Summarized Crop Expenses for Oregon Low Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	20.00	0.00	26.40	16.00	24.00	66.00	25.00	12.50	9.20
Fertilizer	64.00	0.00	46.10	39.50	57.10	20.35	20.35	72.00	58.49
Pesticide	17.07	23.28	30.27	18.63	9.07	17.21	25.35	12.13	21.49
Machinery	64.33	53.98	87.05	75.65	75.65	71.59	70.44	75.65	75.65
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	26.25	5.93	19.15	16.00	17.65	18.14	15.68	17.93	17.39
Fixed Costs	36.56	26.68	43.70	40.91	40.91	39.33	39.33	40.91	40.91
Total Costs	237.46	114.37	260.42	210.94	235.38	241.12	204.65	239.62	231.63

Table E.8 Summarized Crop Expenses for Oregon Intermediate Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	20.00	0.00	26.40	16.00	24.00	66.00	25.00	12.50	9.20
Fertilizer	73.25	0.00	56.85	48.20	62.90	26.30	26.30	81.25	82.35
Pesticide	17.07	23.28	30.27	18.63	9.07	17.21	25.35	12.13	21.49
Machinery	64.33	53.98	87.05	75.65	75.65	71.59	70.44	75.65	75.65
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	27.04	5.93	19.93	16.62	18.07	18.57	16.19	18.61	19.12
Fixed Costs	36.56	26.68	43.70	40.91	40.91	39.33	39.33	40.91	40.91
Total Costs	247.50	114.37	271.95	220.26	241.60	247.50	211.11	249.55	257.22

Table E.9 Summarized Crop Expenses for Oregon High Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	20.00	0.00	26.40	16.00	24.00	66.00	25.00	12.50	9.20
Fertilizer	79.60	0.00	63.20	56.90	74.05	32.25	32.25	90.50	93.10
Pesticide	17.07	23.28	30.27	18.63	9.07	17.21	25.35	12.13	21.49
Fungicide	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Machinery	64.33	53.98	87.05	75.65	75.65	71.59	70.44	75.65	75.65
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	27.59	5.93	20.39	17.26	18.87	19.00	16.62	19.27	19.90
Fixed Costs	36.56	26.68	43.70	40.91	40.91	39.33	39.33	40.91	40.91
Total Costs	267.40	114.37	278.76	229.60	253.55	253.88	217.49	259.46	268.75

Table E.10 Summarized Crop Expenses for Washington Low Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	18.00	0.00	18.70	16.00	24.00	66.00	22.50	12.50	9.20
Fertilizer	76.70	0.00	43.15	39.50	74.05	20.35	20.35	72.00	71.60
Pesticide	9.67	23.28	44.59	18.63	9.07	33.29	26.58	12.13	21.49
Machinery	63.55	52.13	86.68	74.98	74.98	70.54	69.25	74.98	74.98
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	26.47	5.80	19.39	15.94	18.83	19.23	15.49	17.88	18.29
Fixed Costs	34.16	23.64	40.73	38.19	38.19	36.54	36.54	38.19	38.19
Total Costs	237.80	109.35	260.99	207.49	250.12	254.45	199.21	236.18	242.25

Table E.11 Summarized Crop Expenses for Washington Intermediate Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	18.00	0.00	18.70	16.00	24.00	66.00	22.50	12.50	9.20
Fertilizer	76.70	0.00	51.85	48.20	62.90	26.30	26.30	81.25	82.35
Pesticide	9.67	23.28	44.59	18.63	9.07	33.29	31.58	12.13	21.49
Machinery	63.55	52.13	86.68	74.98	74.98	70.54	70.54	74.98	74.98
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	26.47	5.80	20.02	16.58	18.02	19.67	16.39	18.55	19.07
Fixed Costs	34.16	23.64	40.73	38.19	38.19	36.54	36.54	38.19	38.19
Total Costs	237.80	109.35	270.32	216.83	238.16	260.84	212.35	246.10	253.78

Table E.12 Summarized Crop Expenses for Washington High Rainfall Zone from Various Enterprise Budgets

Crop	Winter Wheat	Summer Fallow	Barley	Camelina	Canola	Peas	Lentil	Mustard	Flax
Unit	lb	lb	lb	lb	lb	lb	lb	lb	lb
Seed	18.00	0.00	18.70	16.00	24.00	66.00	22.50	12.50	9.20
Fertilizer	76.70	0.00	60.55	56.90	74.05	33.25	32.25	90.50	93.10
Pesticide	9.67	23.28	44.59	18.63	9.07	33.29	26.58	12.13	21.49
Machinery	63.55	52.13	86.68	74.98	74.98	70.54	70.54	74.98	74.98
Custom & Consultants	9.25	4.50	7.75	4.25	11.00	8.50	8.50	8.50	8.50
Other	26.47	5.80	20.65	17.20	18.83	20.09	16.45	19.23	19.85
Fixed Costs	34.16	23.64	40.73	38.19	38.19	36.54	36.54	38.19	38.19
Total Costs	237.80	109.35	279.65	226.15	250.12	268.21	213.36	256.03	265.31

Appendix F. Assumed Prices for Partial Equilibrium Model

Table F.1 Assumed Prices for Partial Equilibrium Model Idaho

	Unit	Price
Wheat	$/lb	$0.10
Barley	$/lb	$0.11
Camelina	$/lb	$0.15
Canola	$/lb	$0.19
Peas	$/lb	$0.13
Lentil	$/lb	$0.30
Mustard	$/lb	$0.32
Flax	$/lb	$0.21

Table F.2 Assumed Prices for Partial Equilibrium Model Montana

	Unit	Price
Wheat	$/lb	$0.10
Barley	$/lb	$0.10
Camelina	$/lb	$0.15
Canola	$/lb	$0.18
Peas	$/lb	$0.12
Lentil	$/lb	$0.26
Mustard	$/lb	$0.32
Flax	$/lb	$0.23

Table F.3 Assumed Prices for Partial Equilibrium Model Oregon

	Unit	Price
Wheat	$/lb	$0.11
Barley	$/lb	$0.09
Camelina	$/lb	$0.15
Canola	$/lb	$0.19
Peas	$/lb	$0.16
Lentil	$/lb	$0.28
Mustard	$/lb	$0.32
Flax	$/lb	$0.21

Table F.4 Assumed Prices for Partial Equilibrium Model Washington

	Unit	Price
Wheat	$/lb	$0.10
Barley	$/lb	$0.08
Camelina	$/lb	$0.15
Canola	$/lb	$0.19
Peas	$/lb	$0.13
Lentil	$/lb	$0.31
Mustard	$/lb	$0.32
Flax	$/lb	$0.21

Appendix G. Estimated Supply Curves for Camelina

Figure G.1 Estimated Supply Curve for Camelina in Idaho

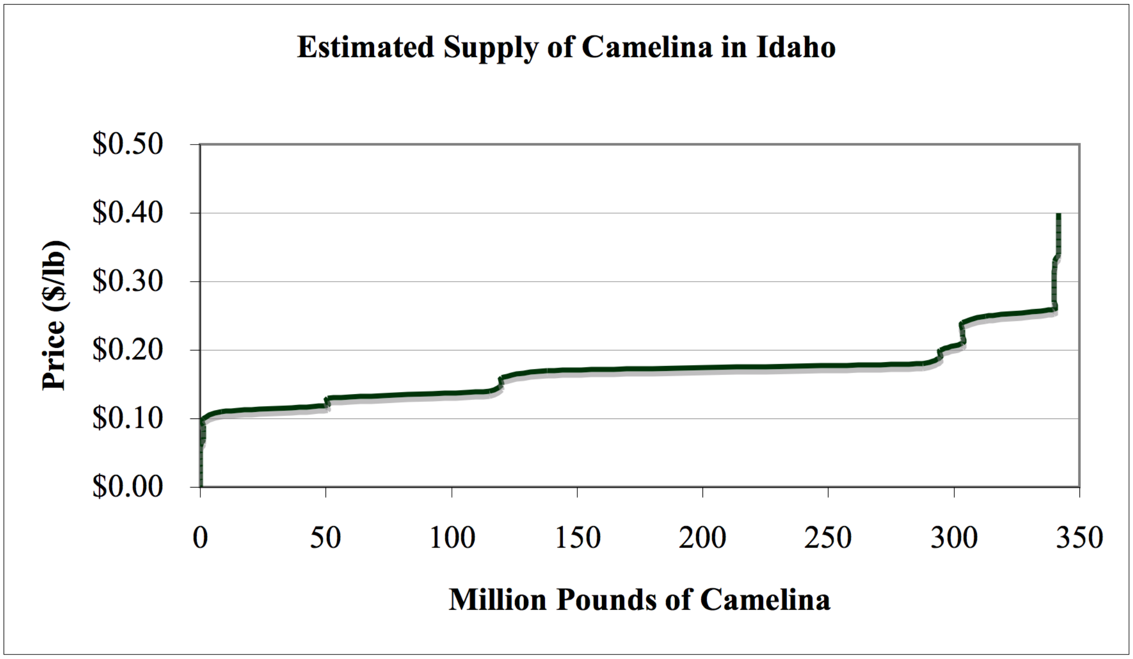

Figure G.2 Estimated Supply Curve for Camelina in Montana

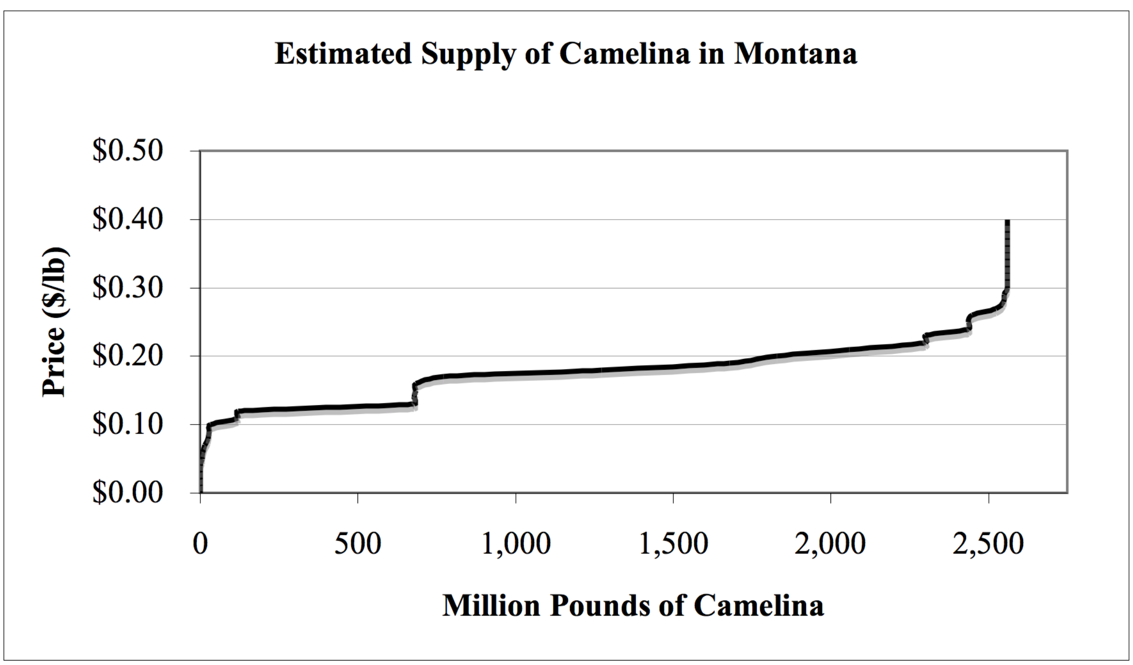

Figure G.3 Estimated Supply Curve for Camelina in Oregon

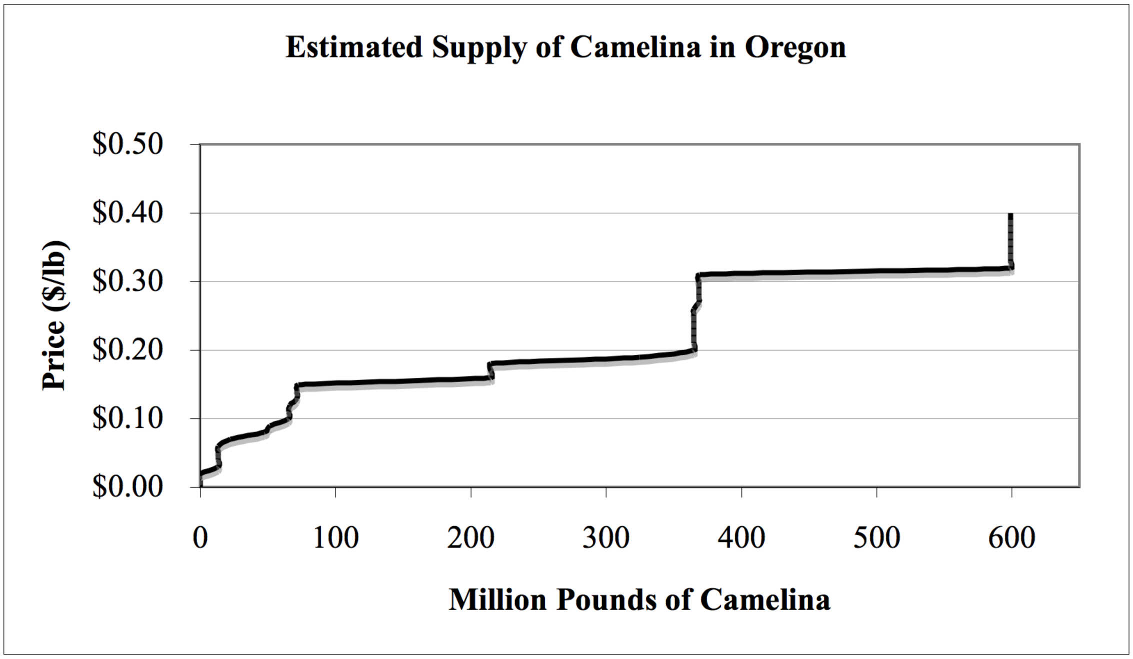

Figure G.4 Estimated Supply Curve for Camelina in Washington