AN ABSTRACT OF THE THESIS OF

Ryan W. Siegel for the degree of Master of Science in Agricultural and Resource Economics presented on April 22, 2008.
Title: Modeling Oregon's Biodiesel Subsidies and their Potential Effects on the Willamette Valley Agricultural Landscape.

Abstract approved:

William K. Jaeger

The beginning of the twenty-first century has seen an upsurge in petroleum prices and an increased concern over greenhouse gas emissions. Consequently, the interest in biodiesel production has heightened. Policy at the Federal level, such as the blender's tax credit which provides $1 for every gallon of biodiesel blended with regular diesel, lends substantial support to biofuel production. In 2007 the State of Oregon enacted laws which provide substantial incentives to promote oilseed production in the state for conversion into biodiesel fuel through 2012. In response to these actions, biofuels' potential benefits and costs are being increasingly debated.

The purpose of this study is to understand the possible effects of subsidies on the composition of the Willamette Valley's agricultural system in the aggregate and by general land/soil categories. A nonlinear mathematical programming model of the Willamette Valley's agricultural system is constructed to account for 17 major soil types, 19 major crops, irrigated/non-irrigated production options, 11 crop rotations, and 3 major regions. Oilseeds are assumed to serve as rotations for other crops. Estimates of yield differentials over soil types, transportation costs by region, costs by soil types, yield-based costs, and prices (endogenous & exogenous), are major determinants in the model. Programmatic constraints include contract limits for certain crops and feasible crop rotations. Land use constraints by region, soil type, and irrigation availability are derived using a Geographic

Information System (GIS) developed by the author drawing upon multiple sources. The model is programmed to run using GAMS (General Algebraic Modeling System).

The study finds that current oilseed subsidies are sufficient to induce oilseed production (approximately 240 million pounds total) on about 75 thousand acres, or about 7% of total the Willamette Valley's land devoted to the production of its major and relatively-easily interchangeable crops. Iterations of the model demonstrate that fallow and wheat acres are the first to decline due to increased oilseed production and that there is minimal change in terms of crops shifting from being grown on one general soil class to another. If flax and camelina can be grown for two years in a row before needing a year's rotation, production levels would double given current subsidies and land use changes would be more dramatic. The model developed as a result of this research effort has the potential to be modified and used for future studies.

Modeling Oregon's Biodiesel Subsidies and their Potential Effects on the Willamette Valley Agricultural Landscape

by
Ryan W. Siegel

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented April 22, 2008
Commencement June 2008

Master of Science thesis of Ryan W. Siegel presented on April 22, 2008.

APPROVED:

Major Professor, representing Agricultural and Resource Economics

---

Head of the Department of Agricultural and Resource Economics

---

Dean of the Graduate School

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

Ryan W. Siegel, Author

ACKNOWLEDGEMENTS

The author is sincerely appreciative for the assistance of many people. The members of my committee Dr. Perry, Dr. Jaeger, and Dr. Karow have shown a great deal of patience and grace as I've repeatedly asked them for their opinions and shared my challenges. Each one helped me in a particular way. Dr. Perry greatly assisted me by providing a basic model for the research and assisted me with other issues around mathematical programming. Dr. Karow was an excellent addition to the committee as he helped me navigate my way to the right agronomists and contacts to get the right pieces of information. He and Dr. Perry both helped substantially in understanding the general form of the Willamette Valley agriculture. Dr. Jaeger was of great assistance in the policy analysis of the thesis and challenged me to apply and think more deeply about the economic issues at hand.

I am also profoundly indebted to the agronomists who helped me. The list includes Mr. Mark Mellbye, Mr. Tom Silberstein, Mr. Daryl Ehrensing, Mr. Gene Pirelli, Dr. Michael Flowers, Mr. Gale Gingrich, Dr. William Young, Dr. Edward Peachey, and Mr. Michael Gamroth. They all were supportive of me by responding to my questions over email and over the phone. I remember spending hours speaking with several of them in order to understand the agronomic side of the issues involved. Dr. Eleveld, an extension economist in my own department also provided invaluable help by sharing his latest enterprise budget files and showing me how to use the software to produce new budgets.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

Modeling Oregon's Biodiesel Subsidies and their Potential Effects on the Willamette Valley Agricultural Landscape

1. Introduction

In a time fraught with concern over environmental sustainability, global warming, and the dependence on foreign oil, the United States is poised for interest in the production of biofuels - fuels derived from renewable biological matter as opposed to fossil fuels. One of the two biofuels in today's spotlight is ethanol, a type of alcohol which can be created by fermenting high-starch or sugar containing plant materials (typically grains or sugarcane) or, through a more complex process using woody biomass, perennial grasses and even urban waste. Biodiesel, another biofuel in today's spotlight, can be created using animal fats, oils recycled from restaurants or oils extracted from oilseed crops or even algae. Both biofuels have a long history of development and while manufacturing processes are still being refined, each presents an opportunity for society that must be carefully examined and cautiously implemented. There is concern that quickly enacted governmental policies may have unintended consequences and could impact the socio-economic landscape. This thesis seeks to examine what kind of change may occur in Oregon's Willamette Valley agriculture given federal and state incentives to grow oilseeds for the production of biodiesel while recognizing that current incentives as well as market prices may change (consider for example, the nearly-doubling price of wheat evidenced from 2005 to 2007 in the Valley).

Biofuels have been around for many years but today's public interest is heightened for many reasons. One reason has to do with global warming and the need to reduce GHG. Since biofuels are derived from renewable organic matter (e.g. corn plants, oilseed crops, trees) and absorb GHG from the atmosphere when they are grown, they are presumed to emit less GHG (after deductions) than fossil fuels when burned. When burning fossil fuels we are releasing into the atmosphere GHG, such as carbon dioxide, which were absorbed millions of years ago and have been trapped under the earth. When we burn fossil fuels we are effectively pumping carbon dioxide into the atmospheric system whereas with biofuels we are theoretically cycling carbon dioxide into the plant and back into the atmosphere. Secondly, during a time of war in the middle-east and rising fossil fuel prices, people's negative attention is focused on the United States' reliance on foreign oil. Clearly, biofuels produced in the United States should reduce our dependence on foreign sources of oil by replacing what would have been consumed with local, renewable sources of energy. Finally, it is thought that by encouraging the development of biofuels, more jobs will emerge and rural development will be fostered.

The idea that we can turn the waste of society or renewable agricultural products into an energy source that will displace the burning of foreign fossil fuels, reduce our dependence on foreign oil, lower our greenhouse gas emissions, and contribute to a more sustainable pattern of life may be perceived, when first considered, as an integrated and complete solution to many aspects of society's problems. However, when one looks more closely at the matter, it becomes more complex. In principle, biofuels derived from agricultural commodities such as sugar cane or canola seed should be "net-zero emitters" of GHG (particularly carbon dioxide). However, this assumes that no GHG from fossil fuels are released during the production and processing of the crops. This is a poor assumption since fossil fuels are used for crop production equipment as well as in fertilizer and pesticide manufacture (Hill, et. al. 2007). In fact, another set of studies (Ainslie et al., 2006; Crutzen, Mosier, Smith, & Winiwarter, 2008) disagree on whether canola production, for example, releases more GHG into the atmosphere than it consumes (due to the generation of nitrous oxide from fertilizer). In terms of energy independence, the issue, not unlike greenhouse gas reduction, has much to do with how much "foreign oil" is used to produce the biofuel feedstock. Furthermore, it must be realized that a biofuel promotion policy is only one possible policy response to reducing foreign oil dependence. In a recent study conducted by OSU researchers it was found that although subsidies for large-scale corn-based ethanol, wood-based ethanol, and canola-based biodiesel in Oregon could contribute to energy independence, they are 6 to 28 times more costly than policies such as raising the gas tax or raising corporate average fuel economy (CAFE) standards. Finally, the issue of fostering rural development is complex. Although at first glance a plant located in a rural area should increase jobs and foster the local economy through a demand on biofuel feedstocks, a larger view is warranted. For example, with all of the governmental subsidies in place, a growing number of large firms are emerging with very little local sources of feedstock such as a new biodiesel processor in Washington. This processor is hard-pressed to find enough raw materials for its 100 million gallon per year plant and may import palm oil from Indonesia and Malaysia (Gonzales, 2007) where feedstocks are expected to be much cheaper. While there are many intriguing and unsettling aspects to the promotion of biofuels, public interest remains.

Interest is sufficiently high to promote biodiesel and oilseed feedstocks through significant subsidies at the state and federal level. These could result in changes in agricultural cropping systems in the Willamette Valley of Oregon, a major agricultural zone in the state. Current socio-political arrangements are promoting the use of biodiesel and present possibilities for farmers and processors alike to consider. Governmental incentives, such as the federal $1/gallon tax credit for blended biodiesel or Oregon's $0.05/lb of oilseeds grown for biodiesel production, provide monetary incentive to make what would otherwise prove to be an economically neutral endeavor (Jaeger & Siegel, 2008) given today's fuel prices. Renewable fuel standards (RFSs) like those set by the City of Portland or the State of Oregon directly increase the demand for biodiesel, thereby increasing the demand for its raw materials (oilseed, algae, etc.). Furthermore, farmers' interest in a rotation crop, especially due to the possibility of disease suppression and/or subsequent yield increases, also provides an added reason for which oilseeds may be established in Oregon. At the same time, oilseeds in the Valley will have to compete with existing land uses and high land-rents in some areas. Given Oregon's biofuel-related subsidies and the Willamette Valley's fertile ground, biodiesel's versatility in terms of an oilseed feedstock may provide several options for farmers to consider in response to the increasing subsidies and demand for biodiesel/feedstocks.

1.1. Problem Statement

From an economic perspective, the promotion of biofuels raises questions regarding policy cost-effectiveness as well as policy implications on regional producers. Two evaluations (Hahn & Cecot, 2007; Jaeger, Cross, & Egelkraut, 2007) on the cost-effectiveness of biofuel promotion have been undertaken and raised doubts regarding the efficacy of policies which support them for purposes of reducing GHG or increasing energy independence. There is a strong need for more evaluations in this regard but the substantial action already undertaken by federal and state government compels the author to evaluate the policy's impact on the agricultural landscape. A $0.05/lb of oilseed tax credit, a subsidy potentially covering 15-30% of crop growing costs (Jaeger & Siegel, 2008), and a $0.10/gallon credit for oil delivered to and from an Oregon processor are some of the major Oregon-level subsidies recently signed into law.

Current governmental subsidies and other incentives are forces that could change the socio-economic landscape of the Willamette Valley. They should be carefully analyzed in terms of the questions that matter most. If forces are analyzed prior to their affecting large changes one can gain insight into the appropriateness as well as the effectiveness of certain policies. The Willamette Valley is a major agricultural area in the state and has a variety of land rent costs and crops such as specialty seeds, grains, grasses, row crops, fruit and vegetables. The introduction of oilseed and biodiesel subsidies in the state encourage the production of oilseed crops and raises questions on how the agricultural landscape might change. Several questions come to mind. How and to what extent will oilseeds actually be grown in the Valley? What crops might oilseeds replace? Will they be grown on marginal lands? Will they be clustered in certain areas? These questions help us get a sense of how the landscape is likely to be affected by the subsidy and may provide hints for further economic as well as agronomic questions to be addressed by other researchers. Future economic and agronomic researchers may, for example, have better reason to ask a series of questions: If oilseeds grown in the Valley are fully converted into biodiesel to what degree will the goals of energy independence and a reduction in greenhouse gases be met? Will the clustering of oilseeds present disease problems? Will *Brassica* oilseed (e.g. canola) production exert pressure on specialty seed growing regions even if genetically-modified organisms (GMOs) are excluded? Will added oilseed crop pesticide and fertilizer use present new problems (e.g. water pollution and GHG emissions) in the Valley or does it appear to be a moot point?

1.2. Thesis Objectives

In order to evaluate the influence of economic forces on the agriculture of the Willamette Valley one needs a robust model with which to analyze a series of questions. The following list presents the main objectives of the thesis which the corresponding model should be able to achieve:

1. Estimate the production response in the Willamette Valley if farmers take full or moderate advantage of subsidies on oilseeds.
2. If incentives aren't high enough to induce oilseed production in the Valley, evaluate what level subsidy would be required.
3. Evaluate how crop practices in the Valley may change if oilseeds have entered the agricultural landscape (i.e. crop composition in the Valley by soil type and section of the Valley)
4. If relevant, evaluate whether or not restriction zones on seed growing areas change oilseed growing patterns

1.3. Thesis Organization

Following the introduction, the thesis will provide a context for the research, present the methodology, discuss the results, and summarize the findings with a conclusion. The context for the thesis provides a literature review covering the reasons for the recent interest in biofuels (particularly biodiesel); federal and state incentives for biodiesel production in the Willamette Valley; and the Valley's biodiesel potential. The methodology section will explain the procedure used for modeling, some theoretical and empirical considerations having to do with nonlinear programming/sectoral modeling, as well as the relevant assumptions (economic and programming). The results section will present model findings and the discussion section will analyze them in a larger context. Finally, the conclusion will summarize what has been learned using the model and will discuss what topics should be pursued by future researchers.

2. Context

In order to analyze the effect of oilseed-subsidies on agriculture in the Willamette Valley, it is necessary to review the historical context (both worldwide and regional); relevant Federal and state biofuel legislation; Oregon's agriculture and oilseed crop potential; as well as theoretical and empirical considerations having to do with programming a sectoral model of the Valley. The following sections review each topic in order to gain a good grasp of the context.

2.1. Reasons for Interest in Biodiesel

Of the many reasons employed to promote biodiesel, rising energy prices, energy security, and global warming are three areas which come up repeatedly in the literature and will be reviewed in this section[1]. Rising energy prices and energy security are closely related but they will be reviewed each in turn. Global warming is a major issue and may be the greatest motivator behind formally supporting biodiesel, particularly in Europe (Frondel & Peters, 2007). The following section provides a brief examination of each issue and summarizes some of the economic analyses conducted to shed light on biodiesel's cost-effectiveness in addressing each goal.

2.1.1. Rising Energy Prices

Diesel produced from oil crops is an old idea but wasn't seriously considered as a fuel source until recently when fossil fuel prices have increased substantially. Rudolph Diesel used peanut oil for his demonstration engines at the beginning of the twentieth century and even viewed locally grown oil-crops as a fuel source. However, petroleum distillate, being cheap and accessible at the time, became the main fuel source for engines. It wasn't until the late twentieth century that petroleum distillate prices increased and biofuel production took off (Radich, 2004). A cursory examination of fuel prices over the last

[1] An added benefit to fostering agricultural biodiesel which is often cited is that of supporting local agriculture and increasing employment in rural areas.

thirteen years shows that diesel and gasoline prices have increased substantially. Figure 1 shows real diesel and gasoline price data since 1995 from the Energy Information Administration (2007d). Other statistics from the same source indicate that fuel prices have somewhat steadily risen by about 30 cents per year.

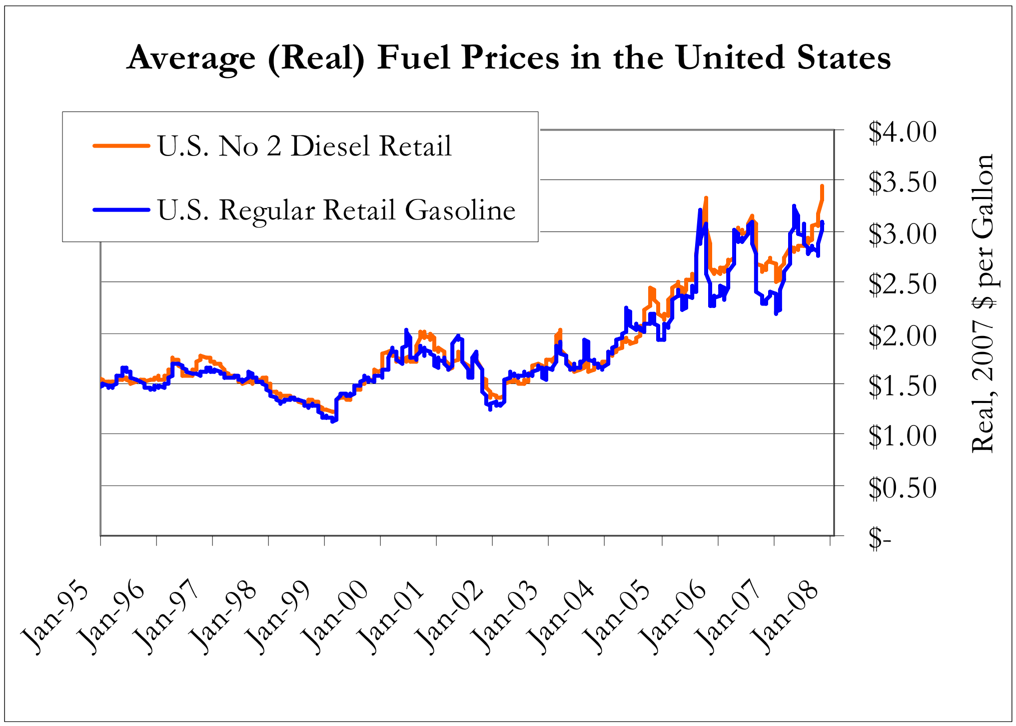


Figure 1 – Average Real Fuel Prices in the United States

Despite the perceptions that some may have regarding ever-increasing fuel prices—especially given the increases witnessed in the last ten years—the Department of Energy says otherwise. The Department's Annual Energy Outlook for 2008 projects that real petroleum prices will lower from now until 2016 due to investment in exploration which will result in the discovery of additional sources of oil (Energy Information Administration, 2007a). Afterwards, they expect that prices will rise again once higher-costing supplies are tapped into. The International Energy Agency's World Energy Outlook echoes the U.S. Department of Energy's report but cautions that a "supply-side crunch" (International Energy Agency, 2007b) may result in abrupt escalation in prices before 2015.

Whatever the precise reason for the high gasoline and diesel prices, biodiesel prices appear to be more competitive. The U.S. Department of Energy (2007a) estimates that the average price for biodiesel was approximately $3 in the West Coast and about $2.80 for the whole country. Major factors in biodiesel becoming more price competitive are the Federal subsidies as well as the previously discussed increase in the price of diesel fuel.

Many countries around the world have had to institute mandates and direct incentives to guarantee the financial viability of biodiesel production. Europe's three major producers have production targets established. France targets 5.75% biofuels by 2008, Germany requires 4.4% biodiesel in 2007, and Italy mandated a 1% blend of biodiesel since 2006 (International Energy Agency, 2007a). The same countries have established tax exemptions to ensure biodiesel can compete with diesel. Tax exemptions such as France's 0.33 Euro per liter of biodiesel (about $1.8 US dollars per gallon), Germany's 0.47 Euro per liter of biodiesel (about $2.6 dollars per gallon), and Italy's 0.29 Euro per liter of biodiesel (about $1.6 dollars per gallon) (Frondel & Peters, 2007), are major examples which shed light on the high societal cost of biodiesel production.[2]

2.1.2. Energy Security

Energy security, another issue intimately tied with energy consumption patterns into the future, is considered by many to motivate the production of locally-based biodiesel. The International Energy Agency makes it clear that in the coming years consumption of fossil fuel will markedly increase (most notably by India and China) and supply will

[2] Brazil, on the other hand, stands out as an example of a producer of an economically competitive biofuel, in this case ethanol. Brazil can produce economically viable ethanol from sugarcane without government subsidies when oil prices are above $35 per barrel, whereas maize-based ethanol in the U.S. is only competitive when oil prices are above $45 to $50 per barrel. (De la Torre Ugarte, 2006)

become increasingly limited to the Middle East and Russia (International Energy Agency, 2007b). The same document points out that due to the fact that production channels will be geographically limited there is a greater risk of interruptions in the flow of energy supply.

Biodiesel-supporting legislation must be examined carefully in terms of the goal of energy security. In a recent study, although biodiesel produced from canola contributes to energy independence in the form of less fossil fuel consumption, there are other mechanisms that can achieve the same goal at a substantially lower cost (Jaeger & Siegel, 2008).

A cursory analysis of the agricultural land in Oregon and the state's substantial energy demand yields some interesting insights. For example, if canola were grown once every four years (a minimum crop rotation requirement) on the approximately 1.6 million acres producing grains & grass seed in Oregon (crops which are believed to rotate with canola without major problems) and didn't consider Brassica-exclusion zones (for the specialty seed areas) then approximately 0.4 million acres of canola would be grown every year. Given an optimistic 3000 lbs/acre and a 25 lb/gallon of biodiesel conversion rate, approximately 47 million gallons of biodiesel could be produced, or about 5.6 trillion BTUs. Considering the approximately 800 million gallons of diesel consumed in the state[3], the previous hypothetical level of production would produce enough to satisfy nearly 6% on a volumetric basis[4].

2.1.3. Global Warming and Greenhouse Gases

Since the turn of the twenty-first century, the world's increased interest in the issue of anthropogenic (i.e. human-induced) climate change has spurred greater interest in the promotion of biofuels as a low GHG-emitting car fuel. The latest document (Fourth

---

[3] Deduced from Oregon Environmental Council, 2007

[4] This figure does not account for the input energy used to produce biodiesel. Accounting for such energy will likely lower the figure significantly (Jaeger, Cross, Egelkraut, 2007).

Assessment Report) from the United Nations' Intergovernmental Panel on Climate Change discusses the changes occurring around the world due to global warming such as rising sea levels, rising surface temperatures, reduction in ice cover, and other changes in physical as well as biological systems. The document clearly states that there is "very high confidence" (Intergovernmental Panel on Climate Change, 2007) that human activity has lead to global warming and calls on policy makers to act now on a situation which can only be exacerbated without immediate and meaningful attention.

Although there are many types of GHG, carbon dioxide (CO_2) is the most substantial anthropogenic source rated at about 83 percent of total GHG emissions in 2006 in the United States. Over 90 percent of these CO_2 emissions are due to fossil fuel combustion, about 33 percent of which is traced to the transportation sector (Environmental Protection Agency, 2006). These statistics highlight why there would be so much interest in mitigating the use of fossil fuels with a less-emitting GHG fuel.

Biodiesel may or may not, to varying degrees, satisfy the need to reduce greenhouse gas emissions. Biodiesel produced from oilseed crops is thought to be carbon neutral since the carbon dioxide which is released when the fuel is burned should be approximately equal to the carbon dioxide absorbed through plant growth. However, fossil-fuel use in mechanization, fertilizer use, and pesticide use can contribute to releases in greenhouse gases. Nitrogen use as a fertilizer in particular can convert into Nitrous Oxide (N_2O), a potent GHG, through microbial processes in the soil. One recent study (Crutzen, et al., 2008) found, through a partial life-cycle analysis, that the nitrogen fertilizer interaction to produce N_2O actually negated the GHG-reduction benefits from producing biodiesel from rapeseed. Conversely, a full life-cycle analysis done by Canada's Canola Council (Ainslie, et al., 2006) concludes that greenhouse gas benefits remain positive drawing on the IPCC's and other studies' significantly smaller estimate for N_2O release. The Council's study does point out that N_2O emissions vary depending on where a crop is grown. Finally, one other study (Hill, Nelson, Tilman, Polasky, & Tiffany, 2006) published through the Proceedings of the National Academy of Sciences (PNAS) found that although biodiesel produced from soybean oil emits less GHG—accounting for the aforementioned factors—than regular diesel on a net energy basis, it contains only about 40% less grams of GHG emissions per megajoule. Overall, it might be safely stated that the way in which oilseed crops are cultivated will influence, to a large extent, how much and whether or not net greenhouse gases are reduced.

The economic cost of reducing GHG emissions through the use of biodiesel produced from oilseeds may vary. Based on the PNAS numbers mentioned above, biodiesel production/use from canola oil is estimated to reduce greenhouse gases at a cost of about $31 per ton compared to other methods which range from 0 to $50/ton (Jaeger, et al., 2007). Another study (Frondel & Peters, 2007) finds that the GHG abatement cost through biodiesel production is approximately $290 per ton compared to a medium-term European CO_2 emissions trading system price of about $30 per ton. Clearly, costs will vary tremendously based on N_2O releases due to crop decomposition/growth and fertilizer use. However, the latest studies cast doubt on the use of biodiesel from oilseeds as a policy to reduce GHG. As a recent Wall Street Journal article (Etter, 2007) points out, the topic of biofuels has, as of late, shifted from a "panacea to pariah in the eyes of some," due to the series of studies recently published demonstrating how complex the issue is and the potential deleterious environmental effects.

2.2. Incentives for Biodiesel Production in the Willamette Valley

Although public scrutiny of biofuels has become more pronounced, legislation has been enacted at the state and federal levels in the United States to promote biodiesel production. As the last section demonstrated, some of the recent literature suggests that although biofuels contribute to energy independence/security as well as reductions in greenhouse gases, they are not a cost-effective way to do so when compared to other cheaper methods. Governmental interest in the form of formal legislation incentivizes biodiesel production and may (already) have impacts which may or may not be warranted.

This section attempts to summarize some of the major legislation which exists at the federal and state level which can have a substantial effect on biodiesel production in the Willamette Valley, and therefore its agriculture/environment.

2.2.1. United States Federal Biofuel Legislation

Current US legislation has fostered the production of biofuels such that production has increased dramatically. US ethanol production has increased from 1.8 billion gallons in 2001 to 3.9 billions gallons (or 2.9% of the gasoline pool) in 2006 whereas biodiesel production has increased from 9 to 91 millions gallons (or 0.02 to 0.2% of the diesel fuel pool) during the same period (Energy Information Administration, 2007c). A series of incentives created at the federal level have undoubtedly brought much to bear on the realization of such production levels. What follows is a non-exhaustive list of incentives intended to promote biodiesel production and consumption at a federal level[5]:

- <u>Biodiesel and Ethanol (VEETC) Tax Credit / Volumetric 'Blender' Tax Credit:</u> The American Jobs Creation Act of 2004 (Public Law 108-357) was extended by the Energy Policy Act of 2005 (Section 1344) to enable a credit of 51 cents/gallon of ethanol (190 proof or greater), $1/gallon of agri-biodiesel, and 50 cents/gallon of waste-grease biodiesel. The credit, based on the percentage of ethanol or biodiesel in the mixture, is provided to blenders certified by the IRS. For example, one receives a credit for agri-biodiesel of $1/gallon of B100 or 10 cents/gallon of B10, which contains 10 percent agri-biodiesel. The credit expires December 31, 2008.

- <u>Small Agri-Biodiesel Producer Tax Credit:</u> The Energy Policy Act of 2005 (Section 1345) allows producers of up to 60 million gallons per year to receive a

---

[5] The following series of bullet points are reproduced from the report by Jaeger & Siegel in 2008 with permission from the authors.

$0.10 tax credit per gallon of agri-biodiesel produced, with 15 million gallons maximum eligible.

- Alternative Fuel Refueling Infrastructure Tax Credit: The Energy Policy Act of 2005 (Section 1342) provides a tax credit equal up to "30% of the cost of installing alternative fueling equipment, not to exceed $30,000. Qualifying alternative fuels are natural gas, liquefied petroleum gas, hydrogen, E85, or diesel fuel blends containing a minimum of 20% biodiesel. Fueling station owners who install qualified equipment at multiple sites are allowed to use the credit towards each location. Consumers who purchase residential fueling equipment may receive a tax credit of $1,000. The credit is effective for equipment put into service after December 31, 2005, and before December 31, 2009" (US Department of Energy, 2007b).

- Rural Renewable Energy Systems and Energy Efficiency Improvements Grants and Guaranteed Loans: In 2005, the USDA Office of Rural Development made money available for grants and guaranteed loans towards renewable energy systems and energy efficiency improvements in rural areas. Applicants must provide 75% of eligible project costs. "Qualified projects must occur in a rural area and implement technology that is pre-commercial or commercially available and replicable. Research and development does not qualify" (US Department of Energy, 2007c). Grant assistance may not exceed $750,000. Applications for funds in 2008 are due at various times depending on whether one is applying for a grant, guaranteed loan, or combination package.

2.2.2. Oregon Biofuel Legislation

Oregon is known for being an environmentally-proactive state and recently-enacted incentives for biodiesel production at three levels of production (crop growth, crushing and processing) testify, in the minds of many, to this inclination. Oregon's strategy for greenhouse gas reductions published in 2004 by Oregon's Department of Energy can be seen as a guiding document for the state's most recent legislation. The document focuses on the urgency of action to lessen GHG emissions, sets reduction goals, reminds the public that systematic attention can actually enrich the economy (rather than hamper it), and outlines several major strategies. Strategies include fostering efficiency, replacing GHG-emitting source with cleaner alternatives, increasing biological sequestration, as well as promoting education, research and development (Governor's Advisory Group on Global Warming, 2004). Very much in line with the document, a series of legislative acts were put into place (some before or after the document). Oregon was, in fact, the first state in the U.S. to provide incentives for the production of biodiesel feedstocks locally (Oregon Environmental Council, 2007). The following list examines some of the most relevant items to our discussion on biofuels[6].

- Business Energy Tax Credit (House Bill 2211, included in House Bill 3201): The Business Energy Tax Credit now covers 50% of renewable energy systems and has a limit of $20 million (previously 35% and $10 million). The bill applies to projects constructed or installed after January 1, 2007 (tax credits not applicable on or after January 1, 2016). This applies to capital costs involved in crop growth, seed crushing and oil processing for biofuel production. Capital expenses are reimbursed over a five-year period.

- Tax Credit for Producers of Biofuel Raw Materials (House Bill 2210): This bill encourages the use of biological material for different energy uses (including biofuels and electricity) through a variety of tax credits "for producers of plant or animal material used as biofuel or used to produce biofuel, and to collectors of forest products, wood wastes waste grease, wastewater biosolids and other

[6] The following series of bullet points closely resemble those used in the report by Jaeger & Siegel in 2008 with permission from the authors.

organic material used as biofuel or to produce biofuel" (Oregon Department of Energy, 2007) (applicable January 1, 2007 to January 1, 2013). Subsidies include:

  - Oilseed crops $0.05 per pound,
  - Grain crops $0.90 per bushel,
  - Virgin oil/alcohol delivered to and based from Oregon $0.10 per gallon,
  - Used cooking oil or waste grease $0.10 per gallon,
  - Wastewater biosolids $10.00 per wet ton,
  - Woody biomass $10.00 per green ton,
  - Yard debris and municipally generated food waste $5.00 per wet ton,
  - Animal manure or rendering offal $5.00 per wet ton.

- <u>Rural Renewable Energy Development Zones (House Bill 2210):</u> The bill also defines a rural renewable energy development zone wherein certain property tax exemptions are available and extends it to include places where biofuels as well as electricity is produced. The amount may not exceed $250 million.

- <u>Renewable Fuel Standards (House Bill 2210):</u> The bill requires biofuel testing requirements (e.g. meeting ASTM D 6751 standards) the final specifications and frequencies of which will be determined by the director of agriculture). It also establishes that when biodiesel fuel production from sources in Oregon, Washington, and Montana reaches at least 5 million gallons per year, all retail, nonretail, and wholesale dealers in the state will be required within 3 months to sell diesel with at least two percent biodiesel (or another renewable diesel) by volume. When production reaches 15 million gallons per year, dealers will be required to sell diesel with at least five percent biodiesel. Similarly, when ethanol production reaches 40 million gallons/year, all dealers will have to sell gasoline with at least 10 percent ethanol by volume.

- Portland Biofuels Incentives: The city of Portland mandated a citywide renewable fuels standard (RFS) which requires a minimum of B5 fuel to be sold by fuel marketers to fuel vendors in the city beginning July 1, 2007. August 15 onwards all diesel fuel sold by fuel vendors will be B5. Similarly, July 1, 2010 onwards a minimum of B10 biodiesel (10% biodiesel blended with 90% regular diesel) must be sold by fuel marketers and vendors in the city. November 1, 2007 onwards gasoline sold in the city must be E10 (gasoline with 10% ethanol). Finally, when the amount of biodiesel from Oregon-based canola, flax, sunflower, safflower, and cooking oil (palm oil is specifically excluded) reaches a level of two and a half million gallons then 50% of the biodiesel used to meet the city's RFS will have to come from these sources.

2.3. Willamette Valley Biodiesel Potential

The production of biodiesel in the Valley depends upon two major factors which will be examined in this section. The first deals with the demand potential and infrastructure built to deliver biodiesel. The second deals with the oilseed supply potential considering the agricultural diversity in the Valley and high-valued alternatives.

2.3.1. Current Biodiesel Demand & Production

In order to examine the biodiesel potential in Oregon it is best to first examine current demand for diesel, the closest substitute. Oregon consumed, on average, since 2001, approximately 770 million gallons of diesel per year. As discussed on page 10 a maximum production level of 47 million gallons of biodiesel per year for Oregon could potentially satisfy a level of approximately 5.4% of total diesel consumption in the state[7]. Applying the same parameters (oil content and oilseed yield) to the Willamette Valley, approximately 6.3 or 17 million gallons of biodiesel would be produced depending on

[7] Not on a net, BTU-basis

whether or not specialty-seed growing areas are excluded, respectively. These values equal approximately 0.8 and 2.2%, respectively, of the state's diesel consumption.

Oregonians have already begun producing and selling biodiesel in various places across the state. In northeastern Oregon, a farmer has been growing canola for several years. He currently has his own crushing operation, sells his oil for processing and remains economically viable with an important contract with the city of Portland, Oregon (Hill & Learn, 2007). Recently, a crushing plant, capable of processing 4.2 million gallons of oil per year[8], was established in the middle of the Willamette Valley—Rickreall—thereby opening up opportunities for growers to transport seed at a low cost (Rose, 2007). The National Biodiesel Board (NBB) currently has 26 biodiesel distributors and 39 retailers listed for Oregon (compared to 60/60 in California or 68/37 in Iowa, respectively). SeQuential Biofuels is one of the major retailers in Oregon which was established in 2002 (SeQuential, 2007) and is located throughout the state. Another major player in Oregon is Imerjent, an LLC established at the end of 2006 which creates automated oil-to-biodiesel processing facilities (Kish, 2007). The major structures appear to be in place now for seed to be crushed, processed into biodiesel, and sold to the public in the Willamette Valley. What is needed is an increase in the local production of oilseeds.

2.3.2. Willamette Valley Agriculture

Assuming current crushing and biodiesel processing companies are financially sustainable, in order for biodiesel to be produced in the Valley, oilseed production need be viable given the Valley's diverse agricultural options. What follows is an analysis on Oregon's agriculture in order to better understand the options that farmers face including oilseeds.

Oregon and its Willamette Valley have a diverse array of agricultural commodities produced through all regions. Over 220 agricultural commodities are produced in the

[8] This is approximately 100-140 million pounds of seed per year or 26,000 to 86,000 acres per year depending on oil content, extraction efficiencies, and yields.

state. Commodities include nursery crops, berries, vegetable crops, grass seed, wheat, fruit, Christmas trees hazelnuts, and peppermint (Oregon Department of Agriculture, 2006). The Willamette Valley stretches from Portland down to Eugene and includes a large portion of the Willamette River (see Figure 2). In the Willamette Valley major crops[9] include: perennial ryegrass, tall fescue, non-alfalfa hay (mostly grass), wheat (multiple varieties combined), hazelnuts, snap beans, sweet corn, orchardgrass, hay silage, red clover, corn silage, oats, and alfalfa hay. There are over 70 crops besides the ones just mentioned which are also grown in the Valley (the top 20 crops produced in the Valley in 2007 are shown in Table 1).

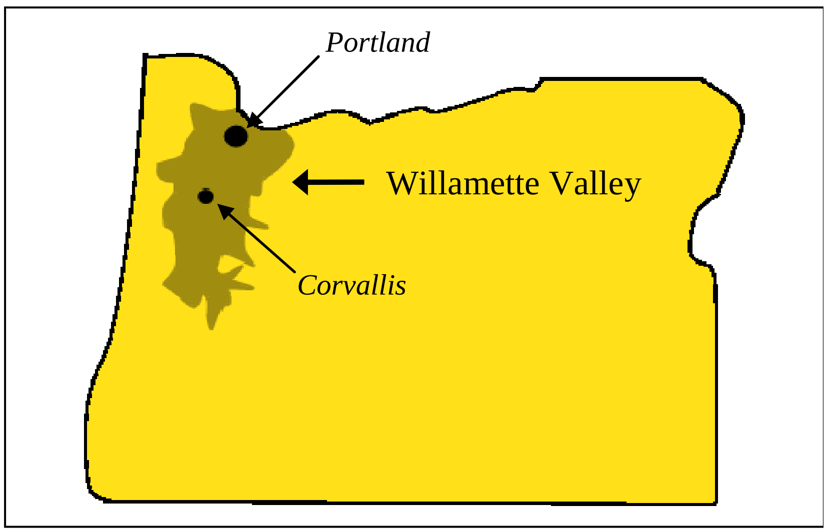


Figure 2 - Placement of the Willamette Valley in Oregon

[9] Above 10,000 acres in production average over 2004-2006 period.

Table 1 – 2007 Acreage for the Twenty Most-Produced Crops in the Willamette Valley

Crop	Acreage	% of Total Ag. Acreage
Perennial ryegrass	166,050	19.8%
Tall fescue	153,600	18.4%
Annual ryegrass	130,800	15.6%
Other hay	128,800	15.4%
Hazelnuts	28,275	3.4%
Wheat	27,300	3.3%
Orchardgrass	15,700	1.9%
Red clover	15,150	1.8%
Hay silage	13,150	1.6%
Silage, corn	12,800	1.5%
Oats	11,350	1.4%
Alfalfa hay	10,100	1.2%
Other misc. veg. and truck crops	9,590	1.1%
Wine grapes	9,387	1.1%
White clover	8,400	1.0%
Peppermint for oil	7,850	0.9%
Chewings fescue	7,330	0.9%
Marion and other blackberries	5,843	0.7%
Bentgrass, creeping	5,030	0.6%
Other misc. grass seed and leg	4,515	0.5%
Total of Top-Twenty Crops	771,020	92.1%
Total Acreage in Production	**836,889**	**100.0%**

Only a few constraints limit where crops can be grown in the Willamette Valley. Of the 8.5 million acres in the Valley[10] approximately one million acres is active crop land and another half a million is farm pastureland (National Agricultural Statistical Service, 2002). Since climate is fairly homogenous throughout the Valley, it does not present a major constraint for crop production for the purposes of this analysis. Instead, soil type is the major determinant for crop production as well as yields and costs. On the agricultural

[10] Measured on a county-basis including Benton, Clackamas, Lane, Linn, Marion, Multnomah, Polk, Washington, and Yamhill counties.

land in the Valley there are approximately 176 soil series names[11] which may be grouped into a dozen or so classifications. Crop production variable and capital costs can vary across soil types. Yield-based costs also vary across soil types. Finally, transportation costs play a role in increasing costs for producers across geographical regions (northern, central, and southern).

Processed vegetable crops are limited by contracts with local processors. Snap peas and sweet corn are the two main crops grown and processed in the Valley. Major processors include the National Frozen Food Corporation as well as NORPAC. Processors are located in the middle of the Valley so that transportation costs increase from the center. NORPAC, for example, has processing plants in Stayton, Salem, and Brooks (NORPAC, 2005). National Frozen Foods has a processing plant only in Albany (as well as a couple of locations in Washington) (National Frozen Foods Inc. Field Representative, personal communication, December 17, 2007).

An examination of the structure of farms and farm ownership in Oregon yields insight into who may decide to grow oilseeds for biodiesel production. Over 98 percent of the 40,000 farms in Oregon are family owned. 70% of farm and ranches are small-scale (less than $10,000 in annual sales) and account for less than 2% of total agricultural sales for the state. Eighty percent of total sales are derived from large, full-time commercial family operations which constitute less than 6% of all farms in the state. Total agricultural activities constitute approximately 10% of Oregon's gross state product (Oregon Department of Agriculture, 2007).

Oregon, and more specifically the Willamette Valley, has little experience with the growth of oilseeds such as canola, oilseed flax, camelina, yellow mustard, safflower and sunflower. Field trials have been conducted on all of the aforementioned crops in the

[11] This number of soil series names is based on the intersection of geographical data from: Institute for a Sustainable Environment, 1999; Institute for a Sustainable Environment, 2005

Valley, but more extensively in north-eastern Oregon, near Pendleton. Commercially-grown canola for the purpose of crushing and producing biodiesel has, likewise, occurred near Pendleton since 2005. There is extensive historic experience with fiber flax in the Willamette Valley but limited recent experience and minimal experience with oilseed flax[12].

In order to limit the analysis of this thesis to only a few oilseeds the author kept in mind several factors. A recent analysis conducted by Jaeger & Siegel (2008) demonstrates that, out of all of the aforementioned oilseeds, winter-grown oil flax and canola are the only ones that are economically viable if the producer credit (5 cents per lb) is fully taken advantage of. Furthermore, after speaking with an oilseed agronomist at Oregon State University (D. Ehrensing, personal communication, December 14, 2007) it became clear that since sunflower and safflower require irrigation to be optimally grown and irrigated lands in the Willamette Valley will be used for higher value purposes, it did not make sense to include sunflower and safflower seed in the crop mix due to low economic potential (Jaeger & Siegel, 2008). Camelina, on the other hand, presents an interesting case of a lower yielding, low-input oil seed which is not a member of the Brassica genus and therefore avoids issues in regard to the cross-pollination with much of the Brassica specialty seed crops in the Valley. For the aforementioned reasons, camelina, winter-grown canola, and oil flax were selected for analysis in the study.

Of immediate interest is how oilseed crops—particularly canola, camelina, and oil flax—fit into current agricultural practices. Disease factors, weed suppression, and inter-pollination of genetically-modified plants are some of the major issues surrounding the growth of oilseeds. To begin, it is clear that none of the three oilseeds being considered here can be grown repeatedly from one year to the next due to the just mentioned issues. Instead, it is often emphasized that they should be grown as a rotation crop every four or

---

[12] This paragraph as well as those below detailing the particulars regarding Canola, Flaxseed, and Canola are drawn from the report by Jaeger & Siegel in 2008 with permission from the authors.

five years. Perhaps the greatest source of concern over the growth of oilseeds in the Willamette Valley arises over the issue of canola cross-pollinating with the high-value Brassica specialty seed crops during the season the canola crop is being grown (Herring, 2006). Significant seed shatter occurs to a lesser extent when canola is harvested and in subsequent seasons. Once canola is grown in a field, canola seed and volunteer plants may be present for many years (Lies, 2007). Recent trials indicate that volunteer in fields may be controlled by commonly used herbicides but that volunteer canola on field edges could be problematic (R. Karow, personal communication, February 19, 2008.) A horticulturalist at Oregon State confirms that seed shatter could be a problem and goes on to say that oilseeds are more viably rotated with grasses and possibly with wheat, albeit with increased herbicidal costs (E. Peachey, personal communication, December 14, 2007). An agronomist (D. Ehrensing, personal communication, December 14, 2007) believes oil flax specifically could rotate with *Brassica* vegetables and that all the oilseeds under discussion (canola, camelina, and oil flax) could rotate with non-*Brassica* vegetables.

Despite the agronomic challenges inherent to producing canola in the Willamette Valley, it was initially included in the optimization model. In addition, because most of those 'cross-pollinating crops' are specialty seed crops, whose growers are very concerned about GMO oilseed cross-pollination, and they reside in the central region of the Valley, the thesis will examine how much pressure may exist on that area to grow canola, given other available crop options.

To complete the analysis on growing oilseeds in the Willamette Valley for biodiesel, the following three sections will discuss each of the three oilseeds in terms of crop practices and also its seed, oil and meal characteristics:

2.3.2.1. Canola

Crop practices: Canola (*Brassica napus* L.) is a type of rapeseed developed in Canada to have a low euricic acid and glucosinolate content. Both winter and spring varieties have been developed. Most canola in the United States is produced in North Dakota. A

Brassica crop, it can cross-pollinate with other *Brassica* plants such as rutabaga, Chinese cabbage, and turnip (Myers 2006) unless buffer distances are adequate. In addition, it is problematic to grow canola among infestations of mustard-family weeds.

Canola grows on most soil types but requires good drainage. The emerging crop is very susceptible to soil crusting; seedbed preparation is important. Canola is susceptible to blackleg and Sclerotinia stem rot. If not rotated with resistant crops, seed treatment may be necessary and is currently required by ODA administrative rules. Current Oregon rules restrict canola growth to "General Production Areas" which do not include the Willamette Valley. The same rules permit growth of canola in "Protected Districts" only once a special permit is obtained from the Oregon Department of Agriculture and several standards are taken care of (e.g. seed certification and minimum distance from cross-pollinating crops). In General Production Areas, canola may be grown on the same plot of land no more than two years in every five. In Protected Districts, however, canola can be grown no more than one year in every four. Planting should be in mid-September for fall crops and as early as possible in spring for spring crops (Oregon Department of Agriculture, 2008). Later fall plantings are susceptible to stand loss and later spring plantings to significant yield reductions, depending on spring and summer rain patterns. Responses to fertilizer and soil fertility are similar to those for small grains; however, canola is a heavy user of sulfur. In a 2,000 pounds/acre crop, for example, about 12 and 15 pounds/acre of sulfur are in the straw and seed, respectively. Canola competes well with weeds, and herbicides are registered for use in the crop.

Seed, meal, and oil: Most canola grown in Oregon is of the B. napus type. Seed size ranges from 80,000 to 135,000 seeds/pound, depending on variety. (Seed size can significantly affect seeding rate in pounds per acre.) Seed shattering at harvest is a potential problem, so crops commonly are swathed or "pushed" (mechanically bent over without cutting the stem) when seed moisture is about 35 percent. Canola is handled and stored like flax; tight containers are necessary to avoid loss in transit. Canola meal has about 38 percent protein. Canola oil is high in oleic acid, which makes it competitive with other cooking oils (Berglund & McKay, 2007), a market in which it is well established. The oil also is a high-grade lubricant and fuel additive; conversion to biodiesel, therefore, is just one of its several potential end uses.

2.3.2.2. Flax

Crop practices: There are both fiber and oilseed varieties of flax. Fiber varieties were grown in Oregon in the 1800s and 1900s, until the advent of synthetic fibers and of other, more profitable crops such as grass seed. Oilseed flax (*Linum usitatissimum* L.) can grow in a variety of climates but in cool climates it has higher oil content. The crop does best on well-drained soils. Winter flax is less sensitive than canola to planting date and can be planted later in the fall. The crop fares poorly against weeds and registered herbicides in the U.S. currently are limited.

Seed, meal, fiber and oil: Winter flax with sufficient moisture can yield 2,000 to 3,000 pounds/acre of seed; spring flax without irrigation typically yields 1,800 to 2,400 pounds/acre. Oilseed flax has both high- and low-linolenic varieties, called linseed and linola or solin, respectively. Solin varieties have been developed in Canada and are not yet released for use in the United States (Ehrensing, 2007b). Flax oils are high in omega-3 fatty acids and have significant value in the food oil market. Cold-pressed flax meal also has high omega-3 fatty-acid content and may have increased value in feed markets. Flax seeds are used in a number of high-value food applications such as flax flour rich in omega-3s, flax meal sold as a food additive, and flax oil supplements. Local food markets for these products might exist in Oregon. Linoleum flooring materials derived from flax are common in the "green" building materials market, and there may be possibilities for small-scale, local production on linoleum. Work has been done in Europe on using fiber from oilseed flax in industrial applications, such as automotive and recreational vehicle parts. These uses, if feasible, could increase fuel savings because flax fiber weighs less than fiberglass.

2.3.2.3. Camelina

Crop practices: Camelina (*Camelina sativa* L.) has been grown for millennia in parts of Europe, but US experience is limited. In Montana, researchers and growers have grown it for 5 years; in Idaho, Washington, and Oregon, it's been grown since 2005. Camelina does not yet have Generally Regarded as Safe (GRAS) status from federal agencies for use as human or animal feed but evaluations are underway. As of January 2008, the FDA, Montana industries, and the Montana Department of Agriculture are working to establish GRAS and Association of American Feed Control Officials (AFFCO) status for camelina. Camelina is generally grown as a summer annual crop but can be a winter crop in milder climates such as in the Willamette Valley. Camelina has a short season (under 100 days) and can survive drought and lower rainfall better than most other oilseed crops. Broadcast seeding is possible. Two varieties have recently been released by Montana State University. Camelina is resistant to blackleg (a disease common in *Brassica* plants such as canola), has few insect problems, and competes well with weeds if grown at high densities (except for perennial weeds, which may be difficult to control). No herbicides are registered to date, but research needed for registration is underway.

Seed, meal, and oil: Camelina seeds are small (220 to 450,000 seeds/pound), and oil content is 29 to 41%. Montana reports yields of 1,800 to 2,000 pounds/acre in dry land areas with 16 to 18 inches of precipitation, and Idaho reports 1,700 to 2,200 pounds/acre in areas with 20 to 24 inches. Limited work has been done to breed higher yielding varieties. Camelina oil is considered high quality—high in omega-3 fatty acids and low in saturated fatty acids—and has been used as cooking oil in Europe and in cosmetics, soaps, and soft detergents. Anecdotal reports say camelina oil sells to cosmetic markets for about $5/gallon. Its meal has 45 to 47 percent protein (near or above soybean) and 10 to 11% fiber. However it also contains glucosinolates which can be detrimental to animal health (Ehrensing, 2007a; McVay & Lamb, 2007). With many varieties and growing conditions, there remains substantial uncertainty about the oil and glucosinolate content.

3. Methodology

In order to answer the questions posed in the introduction while keeping in mind the context presented in the second section, a coherent methodology is needed. The following three sub-sections will describe why developing a nonlinear programming model will assist in answering the questions posed in the introduction, what the model-developing procedure looks like, and what the major components of the model turned out to be.

3.1. Why Model?

How does one determine the effects of a subsidy on an agricultural system before it has occurred? The Willamette Valley presents a unique case in the United States as described in section 2. It is extremely varied in its production options due to its fertile soils. One would be hard-pressed to find another area similar to the Valley already having faced several years of similar governmental subsidies. If that were possible, a case-study approach might be warranted. The Valley is facing opportunities with the subsidy of oilseeds and biodiesel that it never faced before. Otherwise, a historical evaluation approach might be fruitful.

Several economic tools have been developed to study the effects of a policy. Econometric tools can be used to study the relationship between variables and determine statistically significant effects. However, econometrics requires good historical data in order to compute relevant supply curves, for example, and such data is not available for Oregon. Input-output models have been developed to examine the effects between different sectors of an economy. Mathematical programming is yet another tool used to examine the effects of a policy on sectors of an economy. The latter, as it turns out, has proved to be very useful in agricultural contexts (McCarl & Spreen 1980) and is particularly well suited to the study at hand.

Mathematical programming is a broad category including several specific applications yet has two defined purposes: insight and simulation. Put simply, mathematical programming techniques seek to select quantities for choice-variables given a set of constraints and an objective function. Mathematical programming techniques include dynamic vs. static (i.e. taking into account time-pathways in decisions), nonlinear vs. linear (i.e. including nonlinear elements in the objective function or constraints—i.e. including a variable raised to a power other than one), as well as integer (i.e. using only whole numbers) vs. continuous. Regardless of how they are specified, models are developed to yield insight into a system as well as to simulate the changes that might occur within it.

3.2. Modeling Procedure

Mathematical programming models are developed through an iterative process. Generally speaking, the process includes: 1) studying and understanding the system of interest; 2) developing an initial model that reflects the relevant constraints and variables; 3) testing the model against real-world data (referred to as validation); and 4) refining the model accordingly. The process of testing and revision continues until the modeler is satisfied that the model is a reasonable approximation of real world behavior.

3.3. Model Structure

After proceeding through the aforementioned steps, a model was created through which answers and insights could be gained pertaining to the objectives laid out in the first chapter of this thesis. Study of the system included much of the research which contributed to the literature review in the second chapter of this thesis as well as complementary work already performed by the researcher for other papers (Jaeger, et al., 2007; Jaeger & Siegel, 2008). Thanks to the contribution of a model structure[13] by Dr.

[13] Originally designed to analyze agriculture throughout the northwest—i.e. Washington, Oregon, and Idaho.

Perry[14], many of the basic elements of an agricultural sectoral mathematical programming model were defined. Through conversations with agronomists at Oregon State University as well as county extension agents the author gained a better understanding of the agronomic system in the Valley and was able to identify some of the structural components that would be necessary to include in an analysis of local oilseed production. Once the basic structure was laid out, and the relevant pieces of information were updated, the model was tested against the current agronomic situation and was refined accordingly. The model was eventually ready to be used for analysis and several scenarios were simulated to try to answer the questions posed initially in this thesis. What follows is a description of the main programming and economic assumptions; a discussion of the final major components of the model; and the precise simulations run to investigate the oilseed policy effects.

3.3.1. Mathematical Programming Assumptions:

Several assumptions are implicit to the use of mathematical programming and are extremely important to keep in mind when analyzing programming results. The following list describes mathematical programming's major assumptions. If all assumptions are fully met then the model should produce correct results.

- Completeness/Appropriateness of Problem. The model is comprehensive and includes all of the relevant aspects to the problem in the objective function, the decision variables, and the constraints.

- Proportionality. A per unit contribution of activity to the objective function or use of each resource by each activity is the same across all feasible levels (e.g. every additional pound of oilseed sold increases income by the same amount). (This assumption can be softened through the use of multiple constraints).

[14] Thesis committee member and interim head of the Department of Agricultural and Resource Economics.

- Additivity. Resources used under each constraint as well as the terms of the objective function can be combined or summed.

- Divisibility. Decision variables can take on all non-negative values.

- Certainty. All values used in the model are correct.

It is likely that not all assumptions are in fact fully satisfied. However, this cannot be completely verified since there is no "ultimate dataset" to which all of the model's assumptions can be compared to. What the author has done is to strive to meet these aims as best as possible.

3.3.2. Economic Assumptions

Economics assists the analyst to simplify a certain problem enough so that it is possible to create a model, discover useful insights, and simulate results accurately. In order to create a programming model its objective function and choice variables must be carefully selected. But what set of choices and objective function should be included in the model? Agricultural production in the Valley involves a large host of choices only a portion of which could be included in the model. At a high level of complexity one might observe that a set of thousands of farmers/agents in the Valley are facing crop production decisions relating to a multifaceted set of conditions. It would be virtually impossible, however, to model every single decision faced by every single farmer in the Valley. In order to evaluate the changes in the agricultural landscape it becomes necessary to make certain generalizations about agent behavior and therefore behavior of the system overall.

Basic microeconomic theory explains the kinds of assumptions that can be made about market behavior and, therefore, will help build a generalized model of the Valley's agricultural market. Two major economic assumptions will be employed in this model, each to be discussed in the following paragraphs. The first will assist with the development of an objective function for the model and has to do with economics' "perfectly competitive" condition. The second has to do with whether prices are considered endogenous or exogenous to the system and help determine that this model should be nonlinear. Another issue will also be discussed regarding the concept of opportunity cost and why land rent is not included in the model.

Basic microeconomic theory builds a case for how the market as a whole behaves and, therefore, how the mathematical programming model's objective function should be defined. Building upon the assumption that businesses maximize profits, the condition of "perfect competition" indicates that the globally optimal point is reached[15]. This "perfect competition" condition assumes that a large number of firms produce homogenous goods; firms maximize profits; firms take prices as given (i.e. its own production does not affect prices); price information is known by all buyers & sellers; and finally, there are no costs associated with transactions (Nicholson, 2005), or, to put it in a more general, resource-economics perspective, there are no market externalities[16]. The aforementioned assumptions may be said to be relatively fulfilled in the Willamette Valley. The crops examined in the model are each relatively homogenous. The profit-maximizing assumption is met since most growers look to the economic bottom-line when looking at what to grow. Many growers in the Valley are price takers except for the substantially sized grass seed market which will be addressed subsequently. Price information is well established/known. Market externalities may or may not be fully accounted for in the agricultural market. On the one hand, agriculture has a long and well-established history which suggests that any externalities would have been accounted for (e.g. bee pollination benefits which are now accounted for in some crop budgets). On the other hand, issues of sustainability may shed light, for example, on practices that may be damaging the environment at the expense of future generations—a dynamically inefficient situation. Although *conditions* are likely not to be perfectly competitive, the *behavior* may be best

[15] Otherwise known as "Pareto Optimality" or the point at which no other resource allocation could be employed to make another agent better off without making another worse off

[16] Market externalities are costs or benefits from resource use that are unaccounted for in the prices/costs.

described assuming it. It also appears that most of the assumptions of perfect competition are met. Thus, perfect competition is assumed in modeling the Valley's agricultural production and, as a result, the objective function of the model should be set to maximize profit for those price-taking crops.

It would be incorrect, as was shown above, to assume that the growth of crops in the Willamette Valley doesn't have an effect on the price received by farmers. Therefore, some allowance must be made for endogenous[17] prices, or prices which Willamette Valley growers, in the aggregate, have some effect on. Whereas modeling firm behavior in a market with exogenously-determined prices would imply maximizing only producer surplus, firms in a competitive market with endogenously-determined prices should be set to maximize producer and consumer surplus because the demand curve is accounted for in the firms' decisions (see Figure 3). Appendix F explains mathematically and verbally the reasoning and resultant objective function for the model. This approach is confirmed by McCarl and Spreen (1980) who show how, based on basic assumptions about agent behavior at an individual and aggregate level, a mathematical programming model can simulate policy effects on a sector of the economy by setting the maximization of consumer and producer surplus as its objective while making relevant prices endogenous.

[17] Endogenous and exogenous are ways of describing elements that are explained within or outside of the current framework/model, respectively. In the Valley's model, for example, exogenous prices are those that are set by forces outside of its parameters. Growers who, in the aggregate, behave as price takers do so because prices are exogenous.

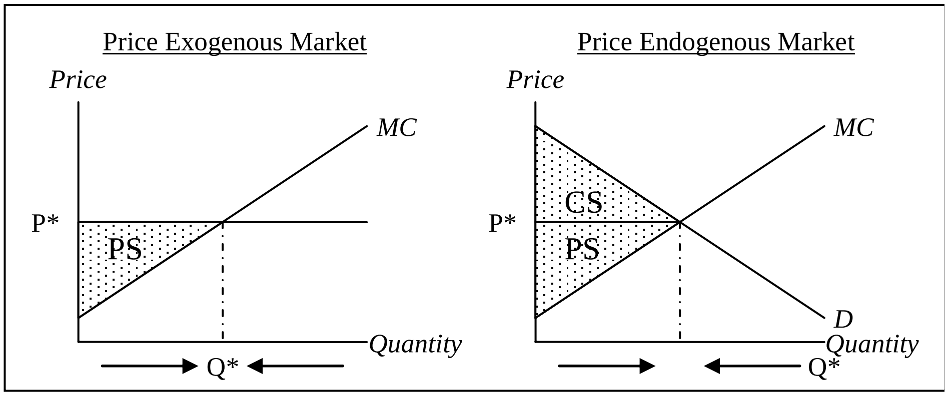


Figure 3 – Firms' Response to Price-Exogenous vs. Price-Endogenous Markets

Note: The graphs above show the perspective the model has of the market depending on whether crop prices are endogenous or exogenous. When prices are exogenously determined the market produces as much as possible to capture the profits available (PS). When prices are endogenously-determined, due to competitive forces, the market maximizes consumer and producer surplus. This is further explained in6.Appendix F . (Abbreviations: CS = Consumer Surplus, PS = Producer Surplus, MC = Marginal Costs, D = Demand, P* = Equilibrium Price.)

Although land rent is a cost that growers face in producing crops it should not be included as a cost for the purposes of this mathematical programming model. There are a few interwoven reasons for this. First of all, it is easy to become confused and think that the mathematical programming model is optimizing *growers'* choices. This is not exactly true. The programming model is actually evaluating the final choice of crops across a landscape (which involves growers but also land owners). Secondly, land rent represents the opportunity cost, or the highest-valued option for the land[18]. And since most opportunities for the land are accounted for in the model, the opportunity cost becomes

[18] If, for example, a land-owner lacked the means to do anything on her land her best alternative-use would be to rent it at a price determined by the market (i.e. land rent). Even if a land owner used her own land to make money, economically-speaking (contrary to an accounting perspective), land rent is a cost that she still faces. For example, if a land owner grew crops and made 20 dollars net profit per acre but has a land rent of 200 dollars per acre, then she is losing money because if she hadn't grown crops she could have simply rented the land to someone else and made more money.

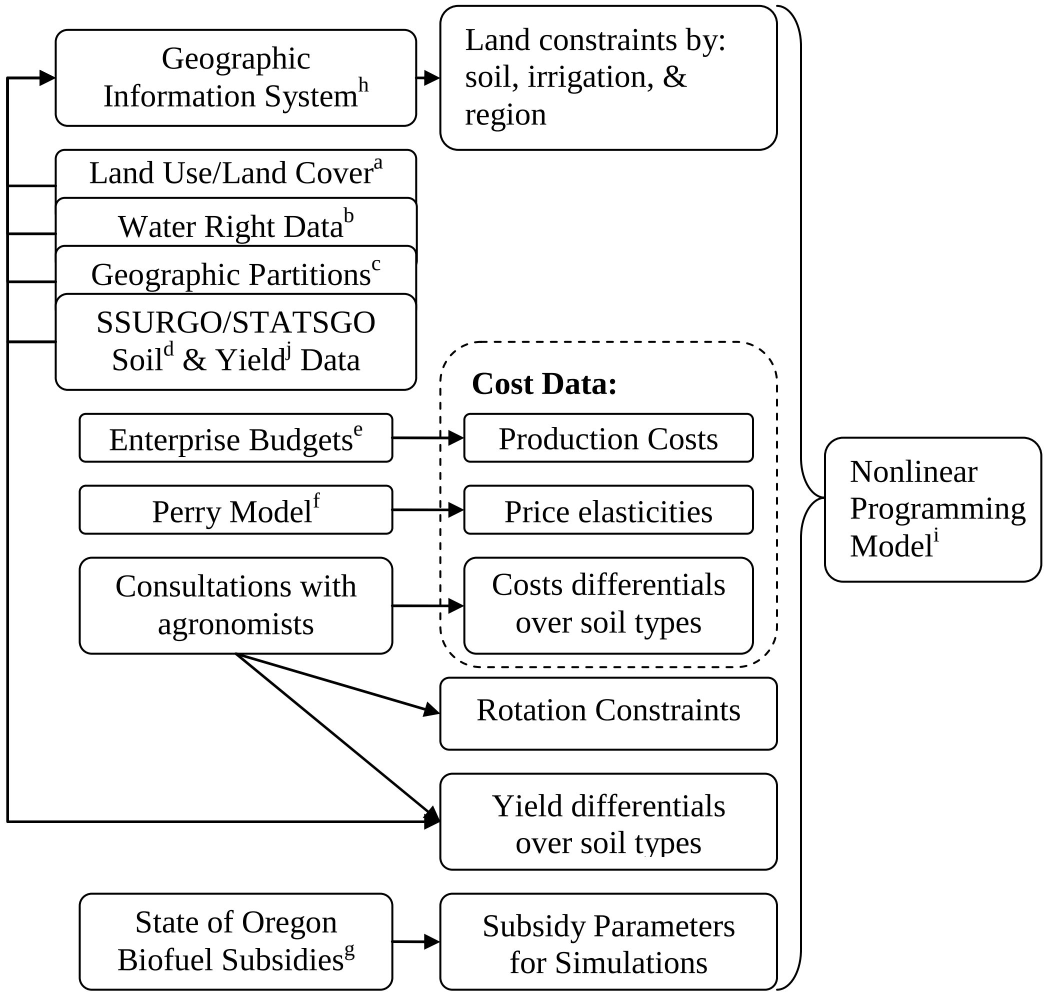
endogenous to the structure of the model itself. Thirdly, it would be inconsistent with the objective function (described above and in Appendix B) to include land rent in the costs since it would decrease the consumer and producer surplus of the Valley. Land rent is paid, by definition, to local land owners. Therefore, land rent is actually simply a transfer payment between agents (growers to land owners) and doesn't reduce overall consumer/producer surplus in the model (keep in mind it incorporates land owners *and* growers). Finally, although it has already been explained economically, the following mathematical reasoning reaffirms the thinking thus far. If land rent were included in the costs of production, the model would yield the same result (in terms of composition not consumer/producer surplus) since the relative costs (between crops) remains the same (i.e. land rent doesn't differ if you plant wheat, if you plant spring oats, or even if you let it fallow since this is "costing" the same amount to someone).

3.3.3. Components

The economic analysis described above and Perry's provisional model of the Northwestern States' agriculture help define the major components of the proposed model[19]. The economic analysis provides the rationale for defining the objective function to maximize producer and consumer surplus. Perry's model provides the overarching framework that is necessary to create an agricultural sectoral mathematical programming model. Several components used in Perry's model are included in the model: a series of crops representing major production options to producers in the Valley; soil and irrigated lands constraints; the effects of soil/irrigation on crop yields and costs; rotation constraints; contract limits on appropriate crops; endogenous and exogenous price data/elasticities; and, very importantly, cost data on producing crops. Figure 4 below summarizes the major components of the model and sites data sources.

---

[19] A graphical counterpart to this section is found in Appendix B which displays the data sources and major parts of the Willamette Valley mathematical programming model.



[a] Institute for a Sustainable Environment, 2005
[b] Oregon Water Resources Department, 2006
[c] Willamette basin cut up into three equally sized pieces by author
[d] Institute for a Sustainable Environment, 1999
[e] Grass/wheat budgets from Dr. Bart Eleveld, oilseed provisional crop budgets from Jaeger & Siegel, 2007, and 12 other crop provisional budgets produced by author with agronomists/growers
[f] Elasticities from Greg Perry, updated by shifting demand curves
[g] Jaeger & Siegel, 2007
[h] Developed using ESRI ArcGIS 9.0
[i] Developed using GAMS 2.0.33 and NLP MINOS solver
[j] Natural Resources Conservation Service, 2008

Figure 4 –Major Features of the Willamette Valley Mathematical Programming Model

The Willamette Valley contains a plethora of crops, more than can be properly represented in this type of model. Consequently, crops were included based on two major considerations. First is the importance of each crop. On average, between 2004 and 2006 over 800,000 acres were used to produce over eighty different crops. However, only about twelve of them averaged more than 10,000 acres per year. Secondly, it is important to consider developing a model that serves the purpose intended: to see how agriculture in the Valley will adapt to the economic stimulus provided by current oilseed incentives. In consultation with experts at Oregon State University it became clear that the model should be limited to those crops that can relatively easily be shifted out of production or combined with oilseed crops as a rotation crop. This means that crops like peppermint for oil were excluded because they require substantial and long-term capital cost investments. After keeping these aspects in mind and consulting with committee members, the list was narrowed to eighteen different crops (including three oilseed crops) several of which have irrigated and non-irrigated versions.

Land constraints constitute another basic parameter that must be clearly defined for the model. Although the Willamette Valley's nine counties constitute approximately 8.5 million acres, only a portion of it is farmland—approximately 1.8 million (National Agricultural Statistical Service, 2002). Furthermore, of this farmland, only a portion of it is dedicated to the crops that have been described above. A Geographic Information System (GIS) dataset developed by the Institute for a Sustainable Environment (2005) describes the land use for the Willamette Valley's ecoregion in the year 2000. Another dataset compiled by the same institute (1999) drawing upon SSURGO[20] datasets provides geographic soil series data. Another dataset from the Water Resources Department (2006) provides geographically-linked water rights data. What resulted from this GIS was a

[20] Soil Survey data from the Natural Resources Conservation Service

tabulation of the total number of acres for agricultural use by soil type and irrigation-right[21,22].

Special attention was given to soil in this model because it is a major determinant for where crops are grown in the Valley. Whereas other larger areas need to account for different climate, a model for the Valley need not account for climate since it is relatively homogenous. Soils affect not only where crops can be practically grown, but they also have a role to play in yields and costs. In order to manage the over two-hundred soils types in the Valley, however, a categorization system is required. Perry's model included a method of classifying the over two-hundred soil names in the Valley based on drainage as well as slope. These he developed in concert with soil scientists at OSU in the early 1990's and serve the purposes of this model well (see Appendix A for a summary of the classification system that was used). The detailed SSURGO database documents how yields vary across soils in the Valley for crops that were, at the time of documentation[23], in production. Consultations with agronomists helped broaden and update this yield information to include potential yields in soils undocumented by SSURGO. This is important in order to ensure that the model optimizes where crops *can* go instead of where they *have* been. Costs vary across soil types due to yield-based costs as well as other factors. Enterprise budgets help calculate yield-based per-unit costs. Consultations with agronomists help understand how costs might vary across soil types due to other factors like decreased fertilizer application rates or increased capital costs. Of substantial weight in this regard is tile drainage which has become more commonplace and can substantially affect yield. The crop yields and costs, therefore, take this into account (see Appendix A for a summary of the final yields used in the model).

---

[21] Appendix G has a visual representation of what the layer intersection process looks like for the soils and land-use datasets.
[22] A special precaution was also undertaken by excluding fallow lands within a certain radius from urban land uses since these are probably unrealistic options for cropland.
[23] Some parts of the SSURGO database are more updated than others. It was for this reason together with the incompleteness of the database that consultations with agronomists took precedence.

Environmental factors, market limitations, and unofficial contractual arrangements also have a role to play in how the agricultural production mix will occur. Environmentally speaking, rotation constraints are a natural consideration for growers. Crop rotations can increase soil fertility, decrease disease problems and help alleviate several other problems associated with excessive monoculture. Crops like wheat, for example, require a rotation to avoid Take-all, a fungus infecting the roots and stem of plants (Christensen & Hart, 1993). For a few crops there is a limit to how much can be grown due to limited buyers. Red and Crimson clover are one example of this. Snap beans and sweet corn for processing are limited by the number of processors in the area. These same two crops are also tied to each other through unofficial contractual arrangements in order to get growers to produce corn (what has historically been a money-loosing crop). In consultation with Dr. Karow and Mr. Mellbye[24], rotations and production limits were devised to represent the physical and contractual constraints currently faced by, especially, wheat and grass growers[25]. Table 2 summarizes the rotation constraints and briefly notes the reason behind each.

[24] OSU Extension Agronomist

[25] Grass seed rotations were difficult to ascertain since many can be grown for very lengthy periods of time (over twenty years). The author and Mr. Mellbye had to content themselves with an estimate for the average rotation across the Valley floor.

Table 2 – Crop Restrictions in Model

Crop	Crop Restriction	Rotation	Reason for Constraint
Winter Wheat	2 years max	All other crops	Disease Issues
Perennial Ryegrass	6 years min	All other crops	Contracts
Annual Ryegrass	None		
Tall Fescue	10 years min, 15% grown on poorly drained soils	All other crops	Contracts, Historical Production
Chewings Fescue	10 years min	All other crops	Contracts
Orchardgrass	14 years min	All other crops	Contracts
Canola	Once every 4 years	n/a	State Law
Snap Beans & Sweet Corn for Processing	1:1 Ratio	n/a	Unofficial Contracts
Corn Silage	13,000 Acre max	n/a	Market limit
Snap Beans/Sweet Corn for Processing	20,000 Acre max ea.	n/a	Market limit
Alfalfa	90,000 Tons max	All other crops (no legumes)	Market limit

As was described in the previous section, price endogeneity had to be accounted for in the model and this was achieved using Perry's elasticities/flexibilities. It is apparent from an examination of the markets that the production of grass seed, clover seed, and grass hay impact local market prices. Due to the limited timeline, the author decided, in consultation with committee members, to use Perry's elasticity/flexibility figures even though they are somewhat dated. For the purposes of this study it was assumed that elasticities remained constant over this period. Although the elasticities/flexibilities used are dated the actual calculations of demand curve slope and intercept values were done using current price and production levels (see Figure 5).

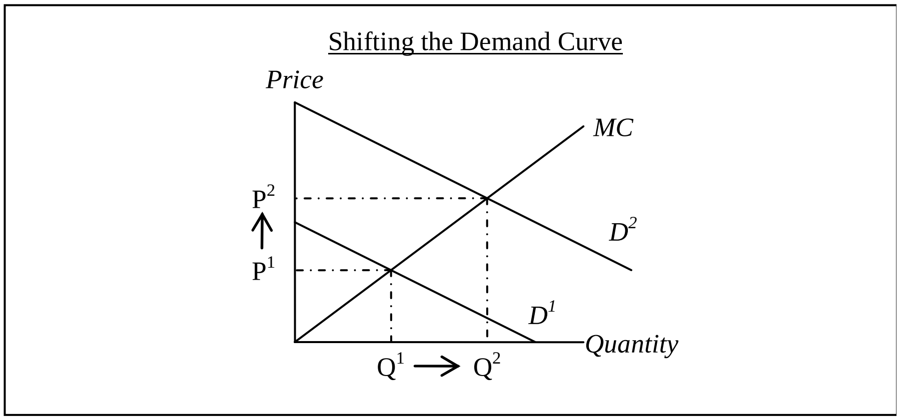


Figure 5 – Shifting a Demand Curve to New Price/Quantity Pairs

Note: The graph above shows how the demand curve was shifted for the purposes of the model. D1 represents the demand curve using Dr. Perry's elasticities and its price/quantity (P1/Q1) relationship. D1 is shifted out to D2 using the same elasticity but a new, more recent price/quantity (P2/Q2) relationship. (Abbreviations: MC = Marginal Cost, D = Demand.)

Cost data, together with price data, are some of the most important components of the model because they are major drivers in the model determining which crops are preferable to others. Gathering such data is not without challenge. In order for cost data to be comparable across crops it has to be generated using as similar assumptions as possible. Several of the crops selected (approximately ten) did not have enterprise budgets created in the last four years. For this reason, the author had to work with agronomists around the state to create new enterprise budgets based on assumptions similar for the recently (2007) created grass, wheat, and oilseed budgets. Using software (the Mississippi State Budget Generator) and input/budget files available in the Agricultural and Resource Economics department, the author was able to create budgets that were comparable to the grass and wheat budgets created just a few months previous. The set of new budgets did not pass through the review process a typical budget would go through (creation with agronomists/experienced growers, review by agronomists, review by experienced growers, revision, etc.) and are, therefore, provisional. However, for the purposes of this thesis, they present the best data available in order to have relatively accurate and comparable estimates (a summary of the enterprise budget's costs are presented in Appendix C). The author makes the simplifying assumption that fallow acres incur zero cost. Transportation costs, another major consideration for growers of oilseeds, wheat, and vegetable growers should be included. For this reason the model is divided into three evenly-divided regions (north, central, south). In consultation with local trucking companies estimated transport costs were established and are included in the model's costs (see Appendix D for a summary of the assumed costs).

3.3.4. Model Validation

To ensure that the model functions relatively accurately, it should be tested against real data (a reference-dataset) and/or reviewed by some agronomists. The purpose of the model is to examine how agricultural practices change at the aggregate levels (e.g. each crop's total acreage for the Valley) as well as by soil types (poorly drained versus high quality, etc.). However, in order to rely on those results another dataset, which is just as detailed, is required to verify them. The OAIN database assists in verifying aggregate results but there is no other comprehensive database to verify results by soil type. Instead, agronomists are relied upon to verify this aspect.

OAIN statistics contain aggregate levels of production, but they do not contain acreages by soil series. OAIN statistics collected by Oregon State University are useful in that they contain historical production (units produced), harvest (acreage), and price data for crops at a county level for the last 20+ years. While estimates for aggregate Valley production and county-based production can be ascertained using this dataset, it does not capture agricultural practices by soil type.

The last NRI database detailed enough to compute acreages for a variety of crops was created in 1997[26] but is organized by soil surface texture and soil capability class—not by

[26] Subsequent NRI datasets were not created for inter-state level analysis

soil series name (the method used in the model). Although there is a chance that the NRI database could be spatially linked to the SSURGO dataset to produce crop acreage by soil series name, significant issues remain. First, the dataset is ten years old and modeling 1997 production would entail developing new yield, cost, and price data for that time period—a time-consuming endeavor which would result in the comparison, essentially, of different model because the major parameters (yield and cost) have all changed. Second, intersecting the NRI and SSURGO datasets will likely have large margins of error on some soil types, particularly those with smaller acreages. This is because the 1997 NRI dataset was designed for relatively accurate use down to the level of an entire 6-digit HUC[27], not *sections* of a 6-digit HUC.

Because there was no extremely thorough reference-dataset to use in validating the model, the author had to make use of the OAIN statistics combined with professional opinion in order to test how well the model worked. After multiple revisions, the model produced results which are depicted in Table 3. In order to ensure predictability, the model was run to simulate 2003 and 2007 acreages. This was done using price data obtained from the OAIN for the 2001-2002 and 2005-2006 periods. It was assumed that growers' decisions were based on a weighted average of their current and previous year's prices. The 2001-2002 prices were converted into 2007 dollars to ensure comparability with the 2007 cost-data. Model results are within 26,000 acres for all crop types except for grass hay.

---

[27] A geographic designation equivalent to the Willamette Valley's water basin

Table 3 – 2007 Simulation Results by Broad Soil Grouping

(Acres)	High Quality	Poorly Drained	Foothill	Coastal	Total
Alfalfa	18,750				18,750
Alfalfa Establishment	3,750				3,750
Annual Ryegrass	14,730	88,960			103,690
Corn Silage	13,000				13,000
Fallow	7,125	72,473	103,193	2,271	185,063
Chewings Fescue			6,631		6,631
Grass Hay	59,010	9,628	14,898	289	83,825
Orchard grass	12,981				12,981
Pasture	31,760	19,257	54,552	1,354	106,923
Perennial Ryegrass	140,999	28,225			169,224
Red Clover	16,585				16,585
Snap Beans, Processed	20,000				20,000
Sweet Corn, Processed	20,000				20,000
Tall Fescue	116,714	20,597			137,311
Winter Wheat					0
Total	475,404	239,140	179,274	3,914	897,732

Since the model has no reference-database containing crop allocation by soil series expert opinion was relied on for verification of results for the larger soil groupings used in the analysis. The model's 17 soil series groupings were grouped into major categories: "High Quality," "Poorly Drained," "Foothill," "Mountain," and "Coastal" (Table 4 lists which soil series groupings were part of each major category). Results tabulated by these major groupings were then reviewed by agronomists to ensure crop acreage allocation results were reasonable (Table 3 depicts these results). Aggregate acreages were also checked against data in the OAIN database (see Table 5). In general, the evaluations indicated that the model behaves relatively well and is ready for use in simulations with the oilseed crops.

Table 4 – Major Soil Groupings

Major Soil Category	Soil Series Groupings Included
High Quality	Excellent WD terrace soils of WV (Willamette-Malabon-Salem) Excellent MWD terrace soils of WV (Woodburn-Coburg) Excellent SWPD terrace soils of WV (Amity-Aloha-Clackamas) Excellent WD bottomland soils of WV (Newberg-Chehalis-Cloquato) Poor EWD bottomland soils of WV (Briedwell-Camas)
Poorly Drained	Average PD bottomland soils of WV (Bashaw-Wapato-Waldo) Average PD Columbia River soils of WV (Sauvie-Rafton) Average PD terrace soils of WV (Dayton-Concord-Awbrig)
Foothill	Good WD foothills soils of WV (Jory-Cornelius-Laurelwood) Somewhat shallow WD foothills soils of WV (Nekia-Bellpine-Salkum) Good SWPD foothills soils of WV (Hazelair-Cascade-Dupee) Shallow foothills soils of WV (Philomath-Climax-Witzel)
Coastal	Good PD bottomland soils of Coastal Valleys (Nestucca-Wauna) Good WD bottomland soils of Coastal Valleys (Nehalem-Eilertsen) Good WD terrace soils of Coastal Valleys (Coquille-Langlois) Good WD terrace soils of Oregon Coast (Knappa) Mountainous soils of Coast Range (Etelka-Orford)

Table 5 – 2003/2007 Model Validation by Aggregate Crop Acreage

	2003 Data	2003 Simulation	2007 Simulation	2007 Data
Alfalfa	12,050	19,655	18,750	10,000
Alfalfa Establishment		3,931	3,750	
Annual Ryegrass	121,130	86,785	103,690	127,300
Crimson Clover	6,400	0	0	3,580
Corn Silage	13,490	13,000	13,000	13,000
Fallow	70,000[28]	80,842	185,063	n/a
Chewings Fescue	4,660	2,919	6,631	8,630
Grass Hay	147,000	89,344	83,825	128,000
Orchard grass	18,880	15,936	12,981	15,490
Pasture	170,000[28]	106,897	106,923	170,000[28]
Perennial Ryegrass	159,450	150,386	169,224	155,050
Red Clover	11,600	8,053	16,585	14,250
Snap Beans, Processed	0[29]	20,000	20,000	0[29]
Spring Oats	14,050	0	0	10,600
Sweet Corn, Processed	2,630[29]	20,000	20,000	1,700[29]
Tall Fescue	135,800	129,849	137,311	157,180
Winter Wheat	78,250	150,137	0	27,900
Total Production	**725,390**	**794,180**	**712,543**	**672,680**
Total Farm Acreage		897,732	897,732	

3.4. Simulations

In order to explore and properly satisfy the objectives presented in the beginning of this thesis, a variety of simulations need to be run in comparison to an appropriate baseline. The recent decade has seen a fluctuation in price for a variety of crops (see Figure 6 which draws from the OAIN, 2007). Prices in the last three years, in fact, presents an

---

28 Fallow and pasture acreages are drawn from the NASS Agricultural Census of 2002. Pasture acreages are assumed to have remained the same since pasture land is often established in areas due to other factors than those described in the model (e.g. marginal lands, high-sloping land, etc.).

29 Snap Bean and Sweet Corn crops for processing are under-reported in the OAIN due to the small acreage and, thusly, confidentiality issues. These numbers are therefore difficult to verify.

interesting landscape within which oilseeds may compete. In order to keep the model relevant and realistic, the baseline prices will be based on a three-year average between 2005 and 2007. Each objective of the thesis can be evaluated using one or more simulations and/or an analysis of estimated shadow prices. Simulations will show how crop allocations will differ based on crop prices. Shadow prices are derived from the model and can show, for example, the increase in price required for a crop to increase production by one-thousand pounds. These can then be utilized to construct simulated oilseed supply curves which will assist in the study.

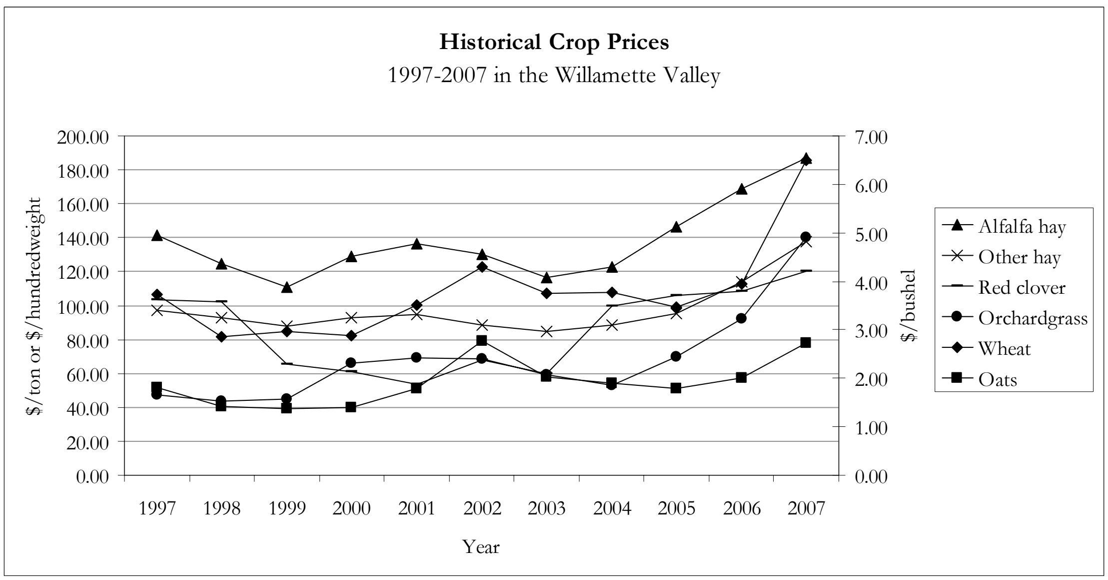


Figure 6 – Crops Displaying Major Price Changes from 1997 to 2007

Since the analysis seeks to simulate the effects of biofuel-related subsidies, the issue of subsidy incidence must be given some thought. The major relevant State of Oregon subsidies include the 5 cent/lb of seed tax credit, the 10 cent/gallon tax credit on vegetable oil produced for biodiesel, as well as the 50% BETC (Business Energy Tax Credit) for growers and crushers/refiners. Federally, there is the blender's $1/gallon of biodiesel tax credit. All of these subsidies have a role to play in influencing, at least in part, not only the price for biodiesel but also the price of oil and of oilseeds themselves. The effects of the subsidy from one market price to another depend not only on elasticities but also on the degree to which markets satisfy the requirements of perfect competition.

The simulations will be limited to subsidies promoted by the State of Oregon and the subsidy incidence discussed above will be accounted for in a separate simulation. (The baselinesimulation does not include any of the subsidies including the incidence). The major assumption made here is that the current price of biodiesel already incorporates the major federal tax incentives such as the blender's biodiesel one-dollar tax credit. This is a reasonable assumption given that the incentive has existed since 2005 and, without it, business would not be feasible[30]. This assists in limiting the analysis of biofuel-related subsidies to Oregon, which only recently (2007) initiated the subsidies discussed above. The 5 cent/lb of oilseed credit and the grower's BETC directly affect the Oregon oilseed markets by increasing the price received by growers. The BETC as applied to crushers and processors also may affect the price received by growers. Continuing on this line of thought would lead one to believe that, assuming perfect competition and certain market elasticities, the full BETC subsidy would pass through all the way to growers' asking price. This may be incorrect. It assumes that biodiesel production as well as oilseed production is a market open only to Oregon when it is not. There is no provision in the law, as far as the author can tell, that producers who receive the BETC must purchase raw materials only from Oregon. This means that the BETC that benefits processors in Oregon may be partially transferred to raw-material (including oilseed) suppliers in markets outside of the state. On the other hand, it seems likely that production costs are similar in places near Oregon and that transportation costs of oilseeds any farther than the immediate region might exclude them from being demanded for local biodiesel production. The BETC for crushers and processors would amount to approximately 60 cents/gallon of biodiesel (assuming a production scale of 5 million gallons per year) or

[30] This is indicated not only by previous research conducted by the author but also by the dramatic increase in biodiesel production that has been seen in the last four years: in 2002, 250 thousand barrels; 2003: 430; 2004: 666; 2005: 2,162. Source: Energy Information Administration, 2007b.

approximately 2 cents per pound of oilseed. Without analyzing market elasticities, cross-market price effects, etc. this seemingly small figure of 2 cents per pound is used as an upper-bound in the 'additional incidence' of Oregon's subsidies for growers in the analysis.

Prices are the major driver for the model and so they must be chosen carefully for the multiple simulations. In order to reflect recent increases in prices for various crops (e.g. wheat, hays, etc.) average price data for 2005 through 2007 will be used whenever possible. Local price data were used for all crops except oilseeds, for which there is currently no major market (except for some in Eastern Oregon). In order to ensure comparability, the flaxseed and canola prices will come from the USDA's National Agricultural Statistical Service (NASS) dataset (National Agricultural Statistical Service, 2002). Nationally, flaxseed increased from about 10.6 cents per pound in 2004 to about 23.2 cents per pound in 2007. Likewise, canola has seen a recent increase from about from about 9.6 to 18.5 cents per pound during the same years. Averages from 2005 to 2007 take into account the recent spike in prices nationally but serve to keep the estimate more realistic for what one might expect in a state with a relatively small, if any, market. For the sake of the model, canola will be priced at $0.133 and flaxseed at $0.147 per pound. Because there are extremely little data and indications are that camelina may be valued higher than it was two years ago (Brown, 2008), a slightly higher price than that used in a previous report (9.5 cents per pound, Jaeger & Siegel, 2008) should be used. A review of the contracts that the crusher in Rickreal has posted on its website (Willamette Biomass Processors, 2008) shows that it will pay a maximum of $0.11 per pound of camelina seed (lower prices are given based on diminished oil content). Accounting for possible sub-optimal oil yields, this study assumes camelina is valued at 10 cents per pound.

4. Results

Results from model simulations are presented in the following sections using a shorthand notation for the simulations. The four objectives presented in the first chapter of the thesis are broken down into a series of four questions/analyses. First, it is ascertained, by way of developing supply curves, whether or not state incentives are sufficient to begin oilseed crop production. Second, finding that this is the case, simulations are run to see how the landscape changes due to the subsidies. Changes in production practices (e.g. fallow, wheat acreage) are analyzed as subsidies increase. Third, in order to understand the value of the land in the central region of the Valley (where most specialty seed growers are—and thus, the Brassica-restriction zones) a simulation is run where canola may not grow in the central region. Finally, one more simulation is run to understand how relaxing the rotational constraint for oilseeds affects oilseed acreage allocation. In order to reduce wordiness the letter 'N' will indicate that there is no subsidy; 'A' indicates that there is only the 5-cent subsidy; 'B' indicates that there is the 5-cent subsidy and full advantage of the BETC; 'C' indicates that the previous two subsidies are accounted for as well as a 2 cent upper-bound subsidy incidence (from crushing and processing markets).

4.1. Will Incentives Motivate Oilseed Production?

The first step was to examine the supply curves for each oilseed crop to see if at current prices plus subsidies they may enter into production in the Valley. Figure 7 and Figure 8 show at different magnification levels how the camelina, flaxseed, and canola supply curves vary given constant prices for other crops in the Valley (05-07 averages). Figure 9 through Figure 11 show that incentives appear to be sufficient to induce production of the three examined oilseed crops in the Valley.

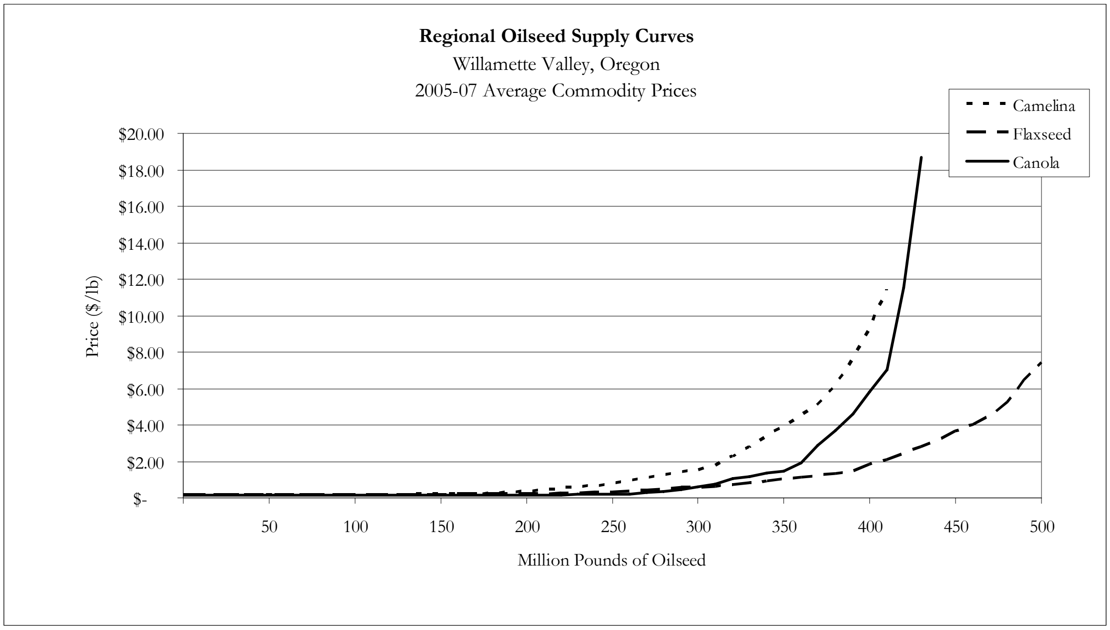


Figure 7 – Regional Oilseed Supply Curves

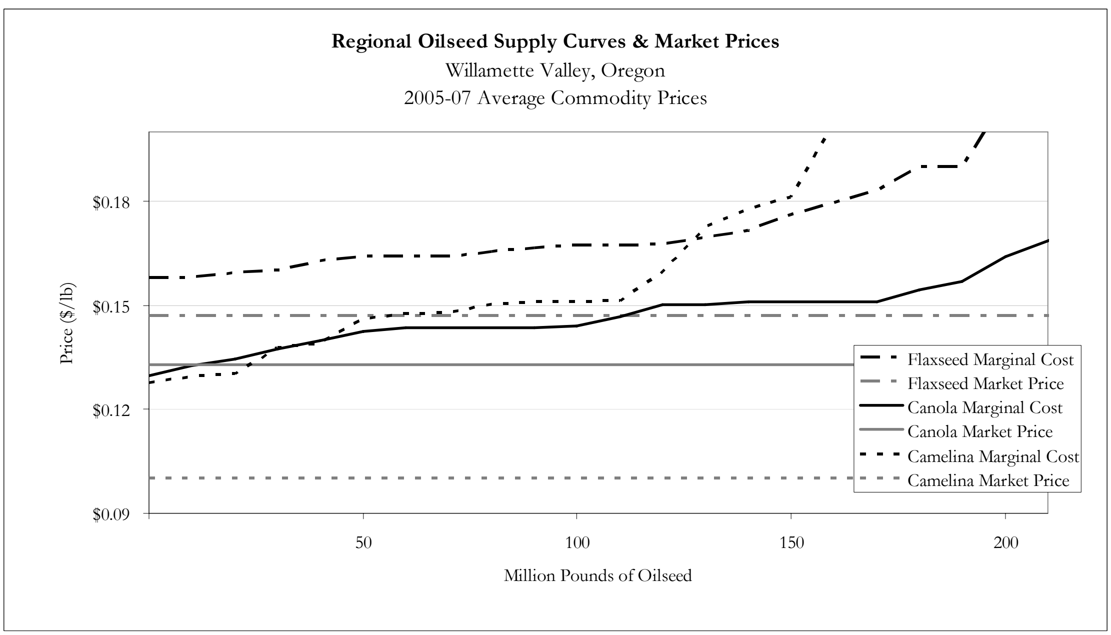


Figure 8 – Regional Oilseed Supply Curves and Market Price Levels

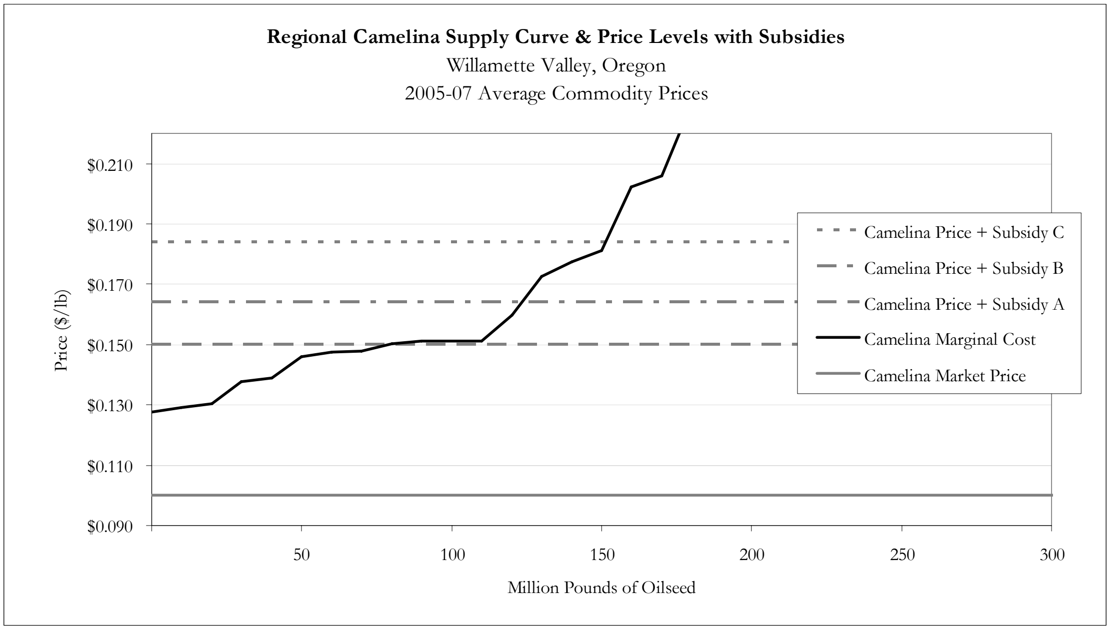


Figure 9 – Regional Camelina Supply Curve

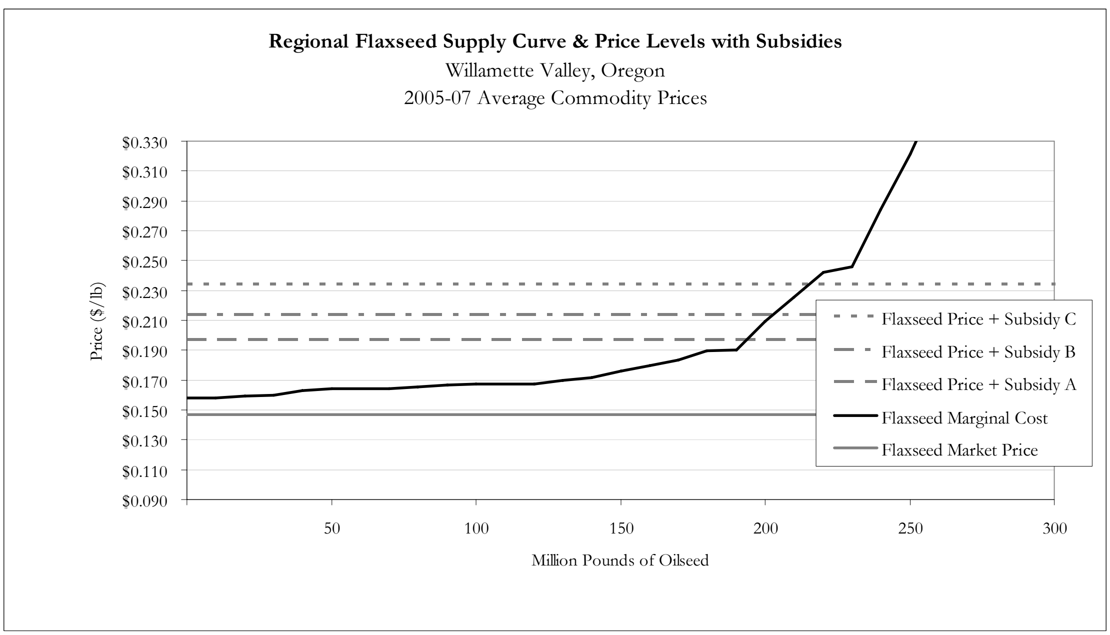


Figure 10 – Regional Flaxseed Supply Curve

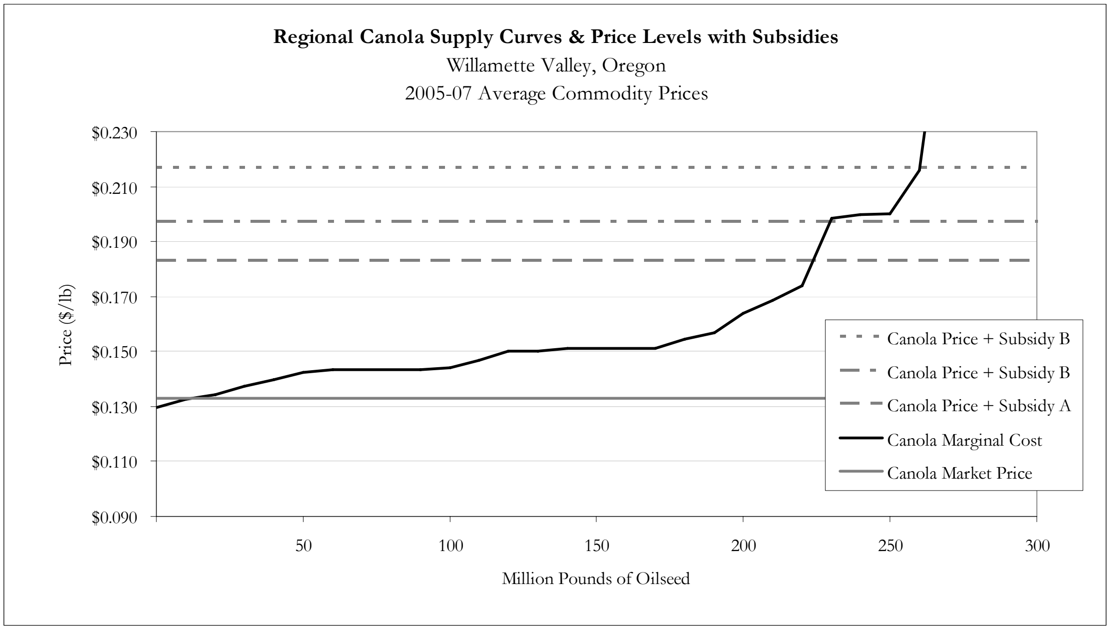


Figure 11 – Regional Canola Supply Curve

4.2. Subsidies' effect on the agricultural landscape

In order to evaluate how the subsidies affect the agricultural landscape, it is first necessary to see how total crop acreages change given different price/cost scenarios. Table 6 shows this information. It shows that the subsidies clearly induce oilseed production. Regardless of which oilseeds are coming in, wheat acreages drop significantly. (It is important to keep in mind that the assumed price of wheat in these simulations is the 2005-07 average of $4.60/hundredweight.) Vegetable crops such as snap beans and sweet corn don't appear to compete well with the canola crop and they show reductions with subsidies in simulations where canola production is an option. Red clover acreage declines in all cases, suggesting oilseeds are replacing it as a rotation crop. It is important to note how, at higher subsidy levels (B and C), flaxseed competes with canola and enters into production.

Table 6 – Simulation Results by Oilseed Restriction and Subsidy Levels

Unit: *1000s of acres*	**All Oilseeds with Subsidies**				**Flax & Camelina with Subsidies Only**			**Camelina with Subsidies Only**		
	N	A	B	C	A	B	C	A	B	C
Canola	6	70	51	63						
Pounds (millions):	*18*	*223*	*162*	*189*						
Flaxseed			38	39	86	91	95			
Pounds (millions):			*82*	*84*	*192*	*203*	*212*			
Camelina								47	72	83
Pounds (millions):								*78*	*121*	*144*
Fallow	8	8	8	8	8	8	8	8	8	8
Winter Wheat	148	96	90	85	83	81	82	109	93	85
Alfalfa	20	20	20	20	18	18	18	20	17	18
Alfalfa Est.	4	4	4	4	4	4	4	4	3	4
Grass Hay	85	83	83	82	83	83	82	85	84	83
Pasture	107	107	107	107	107	107	107	107	107	107
Corn Silage	13	13	13	13	13	13	13	13	13	13
Snap Beans	20	19	15	14	19	19	19	20	19	19
Sweet Corn	20	19	15	14	19	19	19	20	19	19
Redclover	17	14	13	12	15	14	12	17	16	15
Chewings Fescue	8	7	7	7	7	7	7	8	8	7
Orchardgrass	14	13	13	14	13	13	13	13	13	13
Annual Ryegrass	111	108	106	104	108	106	105	111	110	108
Perennial Ryegrass	171	169	169	168	170	170	170	171	169	169
Tall Fescue	147	146	145	145	146	145	145	147	147	146

Secondly, one can evaluate how crop placement (across broad soil categories) changes according to different levels of the subsidy. Appendix D contains tables detailing all of these results. The only noticeable change is that orchard grass shifted production in foothill soils to higher quality soils. This occurs because oilseeds takeadvantage of the lower-valued foothill soils. Figure 12 shows how crop composition minimally changes given the four pricing scenarios. The scenarios are ordered from the center in the following way: baseline (no incentives), scenario A, scenario B, and scenario C, which has the highest level of subsidy. The model shows that most of the land-use change lies in the production of wheat acres which diminish by about a half. The figures in Appendix I show how different levels of production for each oilseed affect the crop composition in the Valley assuming each crop comes into production at various levels with a concordantly higher price. These figures show that oilseed production pressures wheat acres out of production until it reaches levels of 175, 225, and 250 million pounds of camelina, flaxseed, or canola production, respectively. At that point, oilseeds begin to replace clovers as rotation crops. Then, grass and hay production scales back as the more quickly rotating wheat crop increases its acreages. It is worth mentioning that when simulations were run with a previous version of the model—which resulted in higher fallow acres to begin with—oilseed acreage first replaced fallow acres rather than wheat. This isn't surprising considering the fact that wheat generally generates a profit whereas fallow acres do not (i.e. profitable oilseeds compete more easily with fallow acres). Finally, the decrease in canola acreage and increase in flaxseed acreage when moving from simulation A to B is indicative of the fact that since subsidies are high enough to induce profitable flaxseed production and canola can only be grown once every four years, flaxseed comes into production every third year for the shorter vegetable and wheat rotations.

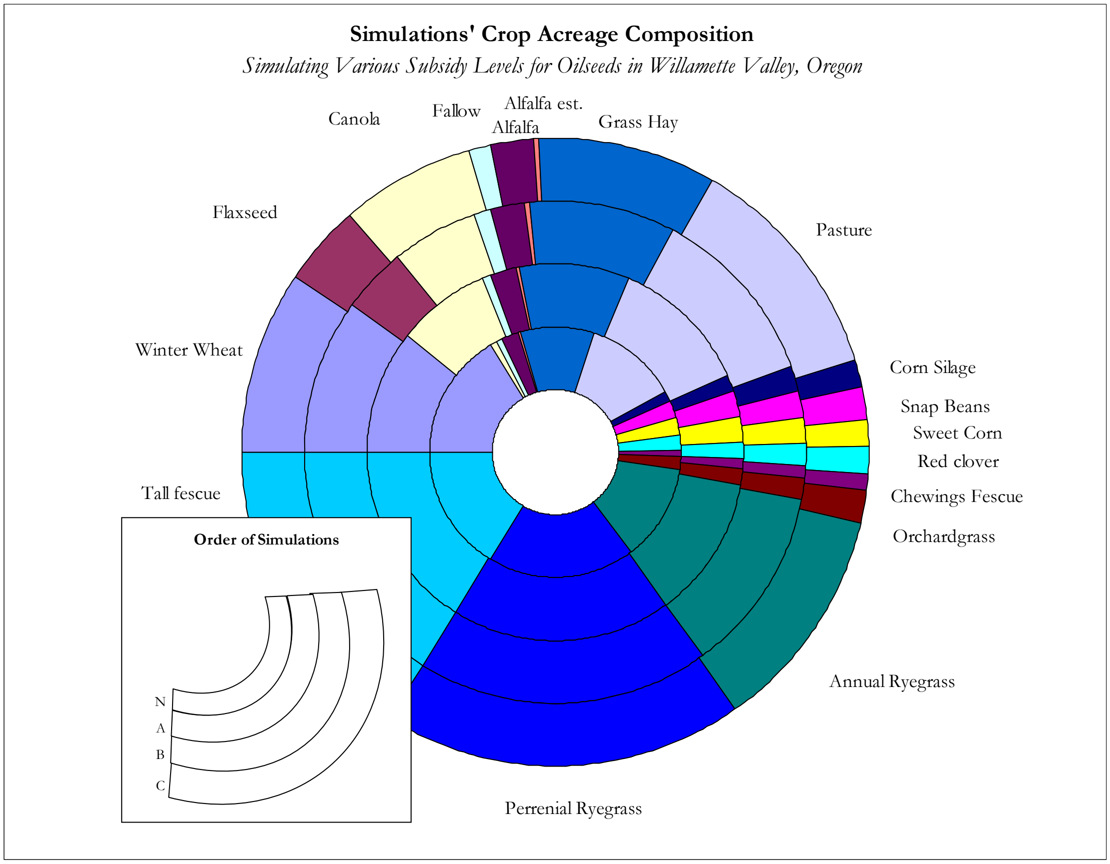


Figure 12 – Simulations' Crop Acreage Composition

4.3. Pressure on the Central Region of the Willamette Valley

Two main sources of data from the model may give an indication as to how much the central region of the Willamette Valley is valued if restricted: shadow prices and a general acreage comparison. Shadow prices show that if canola production were disallowed in the central region, forcing one acre of land in the central region to grow canola would, in simulation A, increase profits by 66 dollars. Under simulation C, an acre in the central region would increase profits by 92 dollars. By comparison, if canola were disallowed in the northern or southern regions, the value of an acre in each region would be about 63 or 89 dollars for simulations A and C, respectively. If flaxseed were restricted from the central region, on the other hand, it would *cost* money (about 1 dollar) or at best increase profits by only 13 dollars to get the first acre of flaxseed into production in the central region (for simulations A and C respectively). Clearly, there is a greater potential benefit from growing canola in the central region rather than flaxseed or camelina. Table 7 shows how, while non-oilseed crops only slightly adjust (probably because oilseed crops are rotation crops), flaxseed is substantially grown, instead of canola, on the central region acres. This all appears to support the idea that flax can substitute for canola to meet production levels as long as there is a demand for flax with its higher price. It also, however, shows that by disallowing canola from the central region there is a fairly substantial opportunity cost.

Table 7 – Central Region Constraint Effects on Crop Distribution Assuming Subsidies

Unit: 1000s of Acres	**No Canola Restriction**			**No Canola in Central Region**	
	Baseline	*Simulation A*	*Simulation C*	*Simulation A*	*Simulation C*
Canola	6	70	63	29	35
Flaxseed	0	0	39	50	65
Fallow	8	8	8	8	8
Winter Wheat	148	96	85	87	73
Alfalfa	20	20	20	19	19
Alfalfa Est.	4	4	4	4	4
Grass Hay	85	83	82	84	83
Pasture	107	107	107	107	107
Corn Silage	13	13	13	13	13
Snap Beans	20	19	14	19	19
Sweet Corn	20	19	14	19	19
Red Clover	17	14	12	15	12
Chewings Fescue	8	7	7	8	7
Orchardgrass	14	13	14	13	13
Annual Ryegrass	111	108	104	108	106
Perennial Ryegrass	171	169	168	170	170
Tall Fescue	147	146	145	146	145

4.4. Relaxing the Oilseed Rotational Constraint

In all previous simulations it was assumed that oilseed crops came in solely as rotation crops for other main crops (e.g. wheat or grasses). In this simulation it is assumed that flax and camelina can be planted two years in a row with a rotation crop following. Because the Willamette Valley is a restricted area and due to disease problems, it is simply impractical to grow canola more than once every four years. Flaxseed and camelina may, however, prove different and be grown for two consecutive years with a rotation crop. Table 8 below shows that when simulations A and C are run for all oilseeds given the new constraints, flaxseed production soars in response to the subsidies. Of note are the substantial reductions in beans, corn, red clover, and those of lesser, yet still noteworthy, degree: red clover and annual grass. Figure 13 through Figure 16 show how higher levels of production are possible under this arrangement but not without more drastic changes to the crop production mix in the Valley. Of note is the fact that although grains (wheat acres) are replaced by flax and camelina initially, after about 450 or 350 million pounds (for flaxseed and camelina, respectively) grains don't factor back in. This is because grains no longer have the advantage of rotating out more quickly. Higher-valued grasses are used as a rotation instead. It is noteworthy that a dramatic change in the landscape already takes place given the basic subsidy level (A). By allowing flax and camelina to grow for two-years in a row before requiring a rotation crop of their own, oilseed acreage essentially doubles compared to when all oilseeds may only be grow as a rotation crop for other crops.

Table 8 – Simulation Results when Including a Flax/Camelina Rotation

Unit: 1000s of acres	**All Oilseeds with Flax/Camelina Rotation**		
	N	A	C
Canola	6	30	22
Pounds (millions):	*18*	*101*	*75*
Flaxseed		180	226
Pounds (millions):		*388*	*495*
Camelina			
Pounds (millions):			
Fallow	8	8	8
Winter Wheat	148	2	0
Alfalfa	20	20	20
Alfalfa Est.	4	4	4
Grass Hay	85	81	77
Pasture	107	107	107
Corn Silage	13	13	0
Snap Beans	20	0	0
Sweet Corn	20	0	0
Redclover	17	15	14
Chewings Fescue	8	7	7
Orchardgrass	14	15	15
Annual Ryegrass	111	104	97
Perennial Ryegrass	171	167	161
Tall Fescue	147	144	141

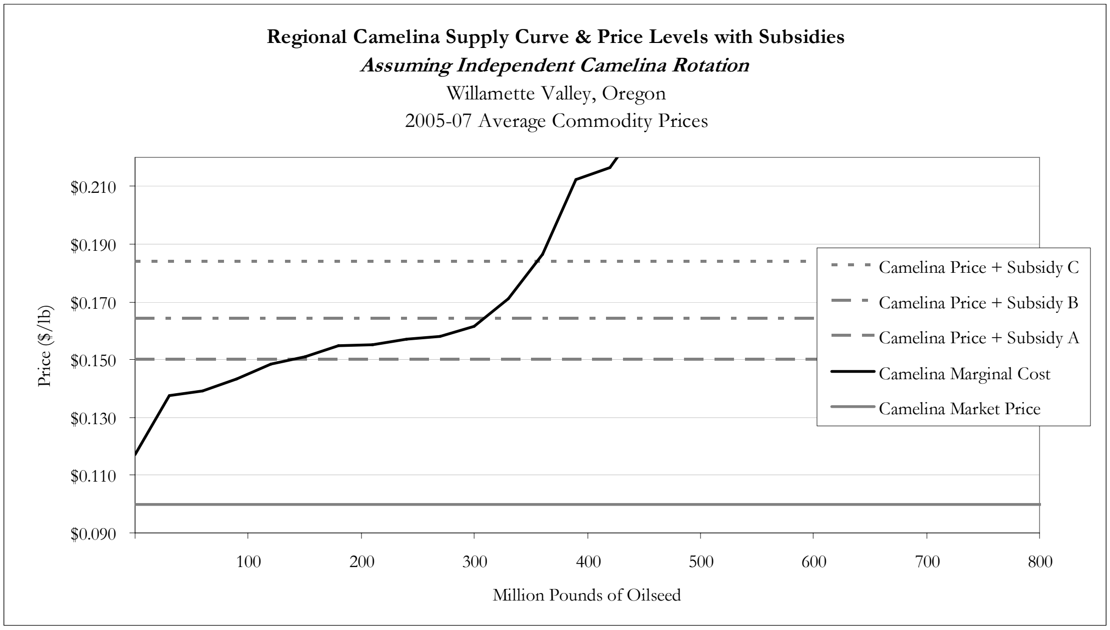


Figure 13 – Willamette Valley Camelina Supply Curve, Assuming it has its Own Rotation

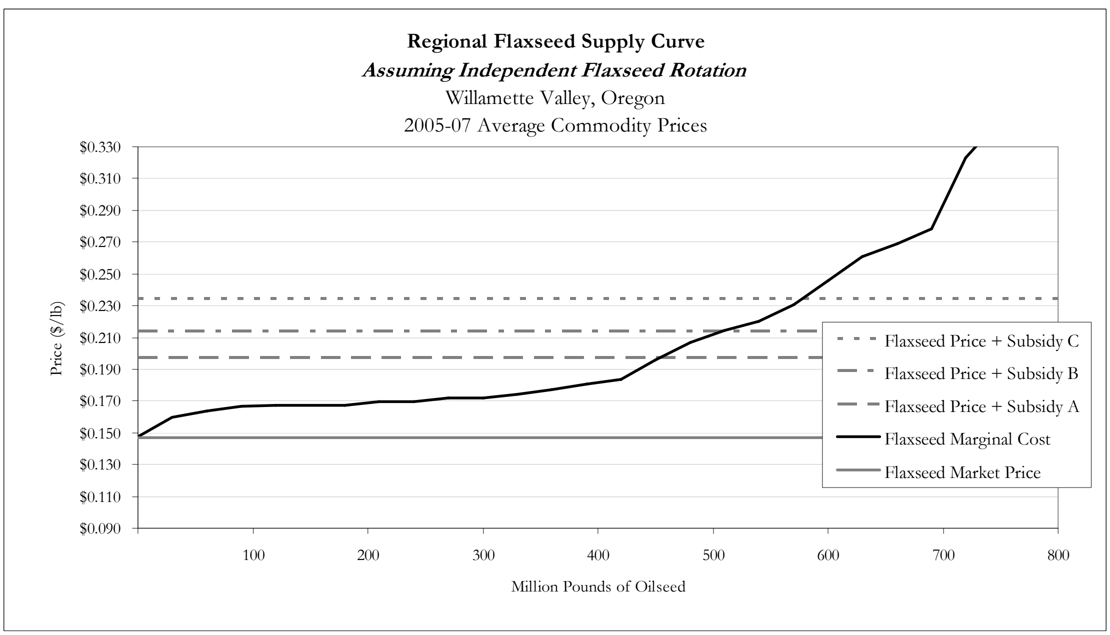


Figure 14 – Willamette Valley Flaxseed Supply Curve, Assuming it has its Own Rotation

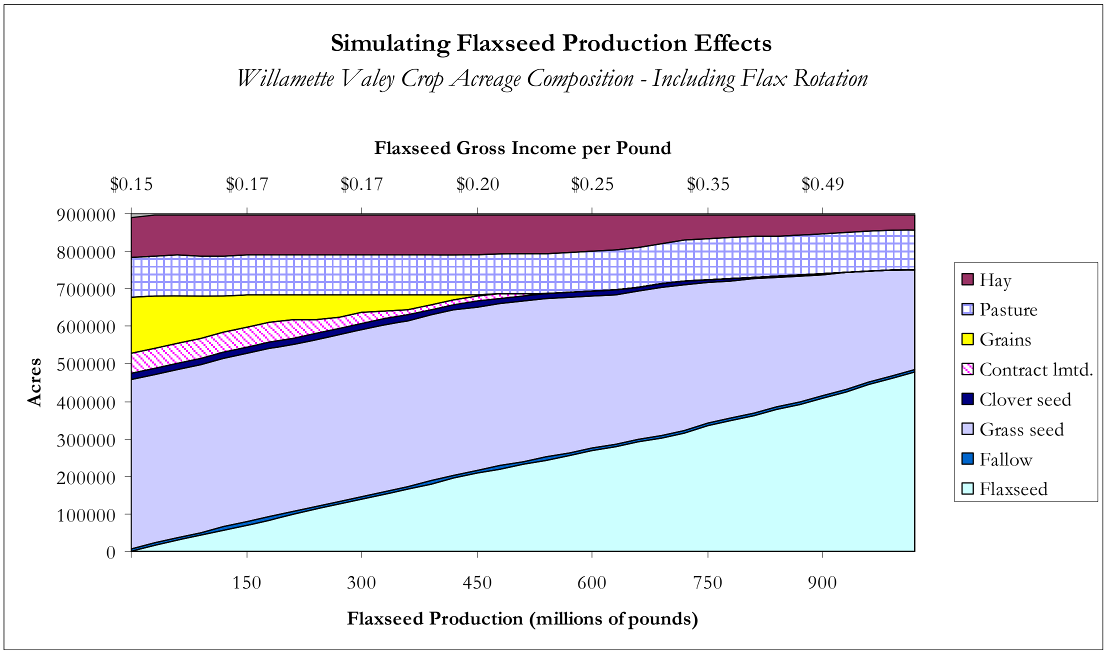


Figure 15 – Willamette Valley Crop Distribution Given Various Levels of Flaxseed Gross Profit, Assuming it has its Own Rotation

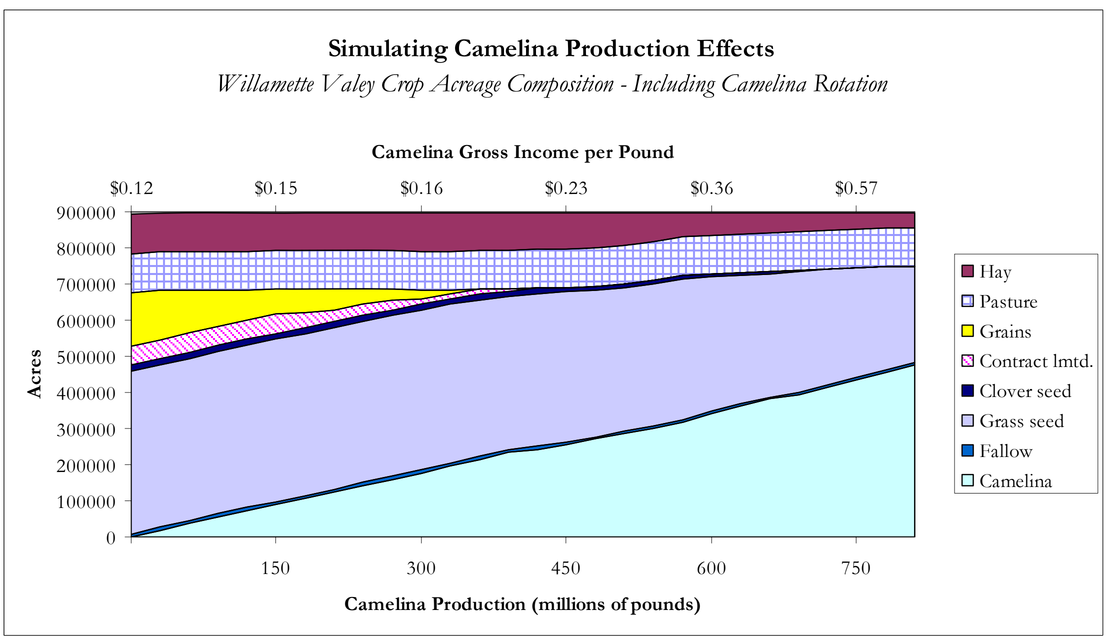


Figure 16 – Willamette Valley Crop Distribution Given Various Levels of Camelina Gross Profit, Assuming it has its Own Rotation

5. Discussion

In summary, the results demonstrate from model simulations that although incentives appear sufficient to induce oilseed production and no major changes are anticipated from that level of production, the total oilseed poundage can produce only a nominal amount of biodiesel. With incentives totaling approximately 5 to 7 cents per pound of oilseed, all three oilseed crops are profitable and enter into production. State incentives induce about 223 million pounds of canola, 162/82 of canola/flax, and 189/84 of canola/flax in cases A, B, C respectively[31]. 240 million pounds (an approximate average to the aforementioned values) would produce approximately eight million gallons of diesel or about 1% of Oregon's diesel consumption.

The results also demonstrate that production practices in the Valley change depending on the extent of oilseed production and the kinds of rotations they can fit into. If the model had fallow acres in its baseline, oilseed crops would have initially shifted those fallow acres into production. However, since prices are high in the baseline simulation nearly all acres are put into production (i.e. there are relatively few fallow acres) and simulated oilseed production gradually initially shifts acres of *wheat* out of production instead. Producing any more than 175, 225, or 250 million pounds of camelina, flaxseed, or canola, respectively, causes a shift away from clover seed acreage, followed by an increase in wheat and a decrease in grass seed production. It's important to note that gross profits would have to reach 21, 25, or 20 cents per pound (subsidy levels of 11, 10 or 7 cents/lb) for camelina, flaxseed, or canola, respectively. If canola were restricted from the central region flaxseed would come into production in its stead. It did so, however, at a higher cost because canola was more profitable. Finally, the results suggest how important the rotational constraint is in terms of how subsidies affect oilseed production in the Valley. If oilseed crops were assumed to be a rotation crop to the various major crops in the model (wheat, grasses, vegetables) then production was kept in check up to a point (as

[31] This translates into a cost of approximately 15 million dollars in subsidies alone per year.

discussed above). However, when flaxseed and camelina were permitted to grow for two years before needing a rotation crop for at least a year flaxseed had an advantage over canola and production soared. The lowest subsidy level (only the 5-cent per pound tax credit), for example, resulted in a production level of about 450 million pounds of flaxseed whereas before relaxing the rotation constraint it yielded less than 200 million. Land use change was significant as well. At the 450 million pound level flaxseed replaces nearly all of the wheat acreage and a portion of the vegetable acreage in the Valley.

The issue of there being a seed crushing and oil processing market to absorb all of the oilseed production theorized in the model must be examined. The basic premise in this study is that a market exists to absorb all the oilseed produced and that it is located in the heart of the Willamette Valley, specifically in Rickreal. The crusher in Rickreal, in fact, has a limit of processing up to 100 million pounds. According to simulations this capacity level is a bit short of potential production projected in this study. Capacity issues may be a moot point, however, since new crushers may startup in the medium or long term to meet the upsurge in supply. Of greater importance is the issue of pricing for oilseeds to be used for biodiesel production. All of the results presented in this thesis presume that oilseed crushers are willing to pay 10 to 15 cents per pound of oilseed (i.e. the prices used in the model). If we assume that gross profit from selling biodiesel is $5 per gallon ($3.50/gallon price plus $1.50 in total incentives) and that a maximum of 80% of biodiesel production costs come from purchasing the seed[32], then the seed cannot cost more than $4 per gallon or $0.16 per pound of seed (assuming an optimistic 25 lb/gallon conversion ratio). A more conservative estimate might modify the percentage of seed costs to 70% and change the conversion ratio to 30 lb/gallon to account for lower oil-yielding seed. If this is the case, a maximum price of $0.12 per pound of oilseed would be required. Using the midpoint ($0.14 per pound) as a maximum price, only camelina and canola will be purchased since flax is too expensive. Recent price figures from the

[32] These are reasonable estimates given previous research, (Jaeger & Siegel, 2008)

National Agricultural Statistical Service (2002) indicate that even canola is too expensive given a maximum price of 14 cents (see Figure 17 below). It may be that camelina is the only reasonable crop to be grown for biodiesel due to pricing and growing limitations (i.e. Brassica exclusion zones). This is, in fact, the only crop for which the local Willamette Biomass Processors currently offer a contract on their website (Willamette Biomass Processors, 2008).

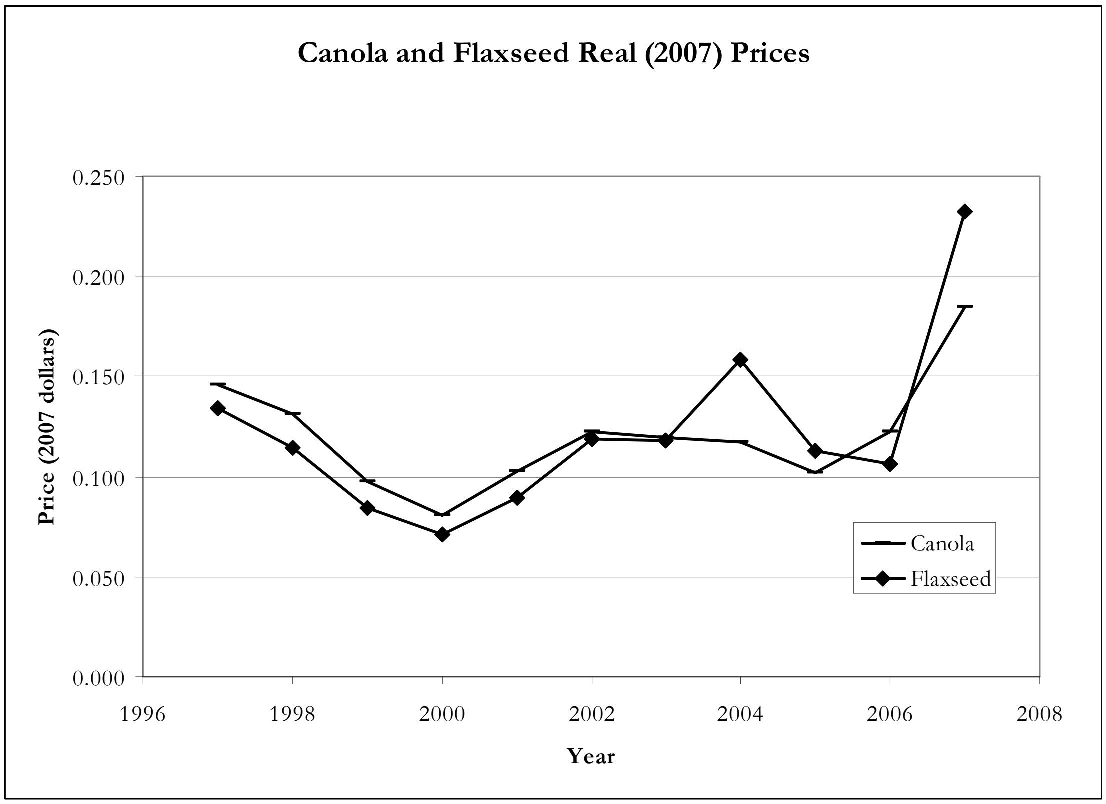


Figure 17 – Canola and Flaxseed Historical Prices

One other market consideration has to do with seed meal. Drawing from the results from simulations A, B, and C for all oilseeds approximately 145, 160, or 177 million pounds of meal will become available, respectively. This is enough to feed approximately 80-100,000 cows for a year which hovers around the approximately 90,000 confined cows estimated to be in Oregon in recent years[33]. While canola and flax meal have GRAS and AAFCO status thereby permitting their use for humans or animals, camelina does not yet have either status. Assuming camelina achieves GRAS and AAFCO status, it could be used as a feed. Otherwise, that loss in value will make it much more difficult for total biodiesel production costs to break even.

Growers' decisions are not fully modeled, however, and there may be other reasons to grow or avoid oilseed crops. One major reason growers regard oilseed crops as beneficial is because they can serve as rotation crops. Although the author could find no study comprehensively evaluating rotation benefits relevant to this study, it is generally accepted that rotating crops is beneficial for the soil, pest management, subsequent crops, and the general ecosystem. This potential added value may imply lowering the supply curve to account for this externality and increase production, especially in the face of subsidies. However, given the fact that crop yield estimates are already taking into account current rotations, oilseeds would have to provide even greater benefits than current rotation crops to result in a positive externality. Conversely, the lack of information on canola, flaxseed, and camelina production potential in the Valley can keep growers from growing crops. Oregon State University is working on this aspect and has already conducted trials to investigate yield potential and seed shatter for subsequent crops on the same soil. While it was their data that helped set the oilseed yields for this model, very little was known regarding lower-quality and/or poorly-drained soils. For this reason, a wheat yield-index was used to derive estimates for the oilseed crop yields. If yields turn out to be different on particularly lower-quality soils, there may be more pronounced changes by soil use for other crops. Production costs used in the model were also based on estimates produced by a variety of agronomists consulting together. It may be that costs are actually higher due to added herbicidal costs in a rotation or lower due to more efficient production practices. Finally, Oregon's 5 cent/lb subsidy is set to expire the first day of

[33] These figures are derived using parameters from: Jaeger, Cross, & Egelkraut, 2007.

2013. This gives growers approximately four years to consider growing oilseed crops. Although it may appear like a long time, the subsidies probably have to be guaranteed for a period longer than that so that growers feel that the expected benefits over time from growing a new crop is worth the effort and risk today. However, judging from the author's conversations with extension agents, many growers are innovators and are constantly trying new methods to improve production. The experience these innovators gain may be what help other growers in the Valley learn if and how oilseed crops should be produced in the area.

6. Conclusion

This thesis sought to understand the effects of subsidies enacted by the State of Oregon on the Willamette Valley Agriculture. The first objective was to evaluate whether or not the subsidies induced production of oilseeds. The second was to evaluate what level of subsidy would be required to induce oilseed production if it was found that oilseeds were not produced with current subsidy levels. The third objective aimed at examining how agricultural production practices changed across soil types and at the aggregate level with the subsidy. The fourth objective was to evaluate whether or not the subsidies put pressure on specialty-seed growing areas mostly concentrated in the center of the Willamette Valley. In order to achieve these objectives the author made use of mathematical programming techniques to simulate price changes and their effects on the Willamette Valley's major agricultural markets and land.

The model shows that if growers take advantage of the current 5 cent/lb subsidy, oilseed production becomes viable in the Valley. If growers take advantage of the capital credit and benefit from the incidence of the subsidy to crushers and processors they will likely produce even more oilseeds. Rotation constraints affect results significantly. If flax and camelina can be grown for two years in a row before needing only one year of rotation, production levels double given subsidies. Regardless of rotation, the first acres to give way to oilseeds are fallow acres (if available) and then wheat acres. Also, distribution across broad soil groupings does not appear to change significantly for the subsidy levels examined. If oilseeds can be grown only as rotation crops, then at extremely high gross net profit levels (above $0.30 per lb) red clover is replaced as a rotation crop and grass seed production reduces to accommodate the dramatic increase in oilseed and wheat acreage—tied to each other due to wheat's shorter rotation. If flax and camelina can grow for two years in a row then a gross net profit of about 20 cents per lb would induce production of 350 to 450 million pounds of oilseed and would entirely take over wheat acreages. This is dependent, however, on the price of wheat averaging $4.60 per bushel as it did from 2005 through 2007. Finally, were canola production limited to the northern and southern parts of the Willamette Valley, flaxseed would come into production in the central region to take advantage of subsidies.

Although the timing of the study makes for an interesting confluence of factors there is insight to be gained. The model is dependent on prices and costs which are, for the most part increasing. Wheat, hay, and corn prices are reaching unanticipated levels due to regional, national, and world market forces. Fertilizer costs are dramatically increasing as are fuel costs which can account for a large portion of growing costs. Oilseed prices drastically increased in 2007 but may be indicative of its cyclical nature. Therefore, the model uses averages for the last three years to project perhaps more reasonable estimates into the future. As a result, the model still yields insights. Subsidies appear substantial enough to induce enough production to meet 1% of current diesel use. The subsequent change in the landscape does not appear very significant as long as oilseeds are used as a rotation crop and are not grown for two years in a row with their own third-year rotation crop. Also, the model shows that the sizeable market share of the grass seed industry in the Valley has a dominating effect on the acreages of other crops (i.e. it isn't until oilseed prices reach substantially high levels that grass acres decrease). Finally, although higher prices or gross profit per pound may definitely increase oilseed production it is doubtful that biodiesel processors can afford oilseed prices as high as they have been in 2007 (over fifteen cents). This hypothesis, however, falls apart if energy prices continue to increase, making higher-costing oilseed feedstocks for biodiesel more competitive. Camelina may be the only hope for a low-cost oilseed that biodiesel processors could even afford depending on the price competitiveness of biodiesel with petroleum-based diesel.

The model developed in this thesis could serve as the foundation for other research work. As more information is gained on oilseeds' yield per acre and oil content in the Valley, the model could be run analyzing not only total pounds produced but total potential oil produced. This may result in a more accurate analysis displaying the relative merits of each oilseed. The model could be expanded to include more areas of the state, or even the northwestern states (Washington, Oregon, and Idaho), in order to evaluate how marginal costs for oilseed might vary depending on region. This may show what areas are relatively more suitable for oilseed production. The model might be augmented to include greenhouse gas accounting, or chemical leaching, for example, in order to conduct a benefit-cost analysis. Alternatively, the effects of subsidies on other raw materials for biofuels, such as grass straw for ethanol, may be examined.

BIBLIOGRAPHY

Ainslie, B., Dowlatabadi, H., Ellis, N., Ries, F., Rouhany, M., & Schreier, H. (2006). *A Review of Environmental Assessments of Biodiesel Displacing Fossil Diesel*. Retrieved March 29, 2008, from http://www.canola-council.org/uploads/Environmental_Analysis_FINAL-July-8.pdf

Berglund, D.R., McKay, K., & Knodel J. (2007). *Canola Production, NDSU A-686 (revised)*. Retrieved March 29, 2008, from http://www.ag.ndsu.edu/pubs/plantsci/crops/a686w.htm

Brown, M. (2008, February 23). Fuel-maker offers more for camelina. *Billings Gazette*. Retrieved March 29, 2008, from http://billingsgazette.net/articles/2008/02/23/news/state/23-camelina.txt

Christensen, N.W. & Hart, J.M. (1993). *Combatting take-all of winter wheat in western Oregon, EC1423*. Retrieved. March 29, 2008, from http://extension.oregonstate.edu/catalog/html/ec/ec1423/

Crutzen, P. J., Mosier, A. R., Smith, K. A., & Winiwarter, W. (2008). N2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels. *Atmos. Chem. Phys., 8, 389–395*. Retrieved March 29, 2008, from http://www.atmos-chem-phys.net/8/389/2008/acp-8-389-2008.pdf

De la Torre Ugarte, D.G., (2006). *Bioenergy and Agriculture: Promises and Challenges, Developing Bioenergy: Economic and Social Issues*. Retrieved March 29, 2008, from http://www.ifpri.org/2020/focus/focus14/focus14_02.pdf

Ehrensing, D. (2007a). *Dryland Cropping Systems: Camelina (draft report)*. Unpublished Manuscript, Oregon State University, Corvallis, OR.

Ehrensing, D. (2007b). *Dryland Cropping Systems: Flax (draft report)*. Unpublished Manuscript, Oregon State University, Corvallis, OR.

Energy Information Administration. (2007a). *AEO2008 Overview*. Retrieved March 29, 2008, from http://www.eia.doe.gov/oiaf/aeo/pdf/earlyrelease.pdf

Energy Information Administration. (2007b). *Annual Energy Review* (Report No. DOE/EIA-0384). Retrieved. March 29, 2008, from http://www.eia.doe.gov/emeu/aer/

Energy Information Administration. (2007c). Biofuels in the U.S. Transportation Sector. Retrieved March 29, 2008, from http://www.eia.doe.gov/oiaf/analysispaper/biomass.html

Energy Information Administration. (2007d). *Weekly Retail Gasoline and Diesel Prices.* Retrieved March 29, 2008, from http://tonto.eia.doe.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm

Environmental Protection Agency (2006). *U.S. Greenhouse Gas Inventory, Executive Summary*. Retrieved March 29, 2008, from http://www.epa.gov/climatechange/emissions/downloads06/07ES.pdf

Etter, L. (2007, November 28). Ethanol Craze Cools As Doubts Multiply. *Wall Street Journal*. Retrieved March 29, 2008, from http://online.wsj.com/public/article/SB119621238761706021-WyAp6f_YynWmwFH2YHQ3bn6VEp4_20071228.html?mod=tff_main_tff_top

Frondel, M. & Peters, J. (2007). Biodiesel: A new Oildorado? *Energy Policy, 35, 1675–1684*. Retrieved March 29, 2008, from ScienceDirect database.

González, A. (2007, August 16). Biodiesel plant stirs hopes in Grays Harbor. *The Seattle Times*. Retrieved March 29, 2008, from http://seattletimes.nwsource.com/html/businesstechnology/2003838495_imperium16.html

Governor's Advisory Group on Global Warming. (2004). *Oregon Strategy for Greenhouse Gas Reductions*. Retrieved March 29, 2008, from http://www.oregon.gov/ENERGY/GBLWRM/docs/GWReport-FInal.pdf

Hahn, R., & Cecot, C. (2007). The Benefits and Costs of Ethanol. *AEI-Brookings Joint Center Working Paper No. 07-17*. Retrieved March 29, 2008, from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1027692

Herring, P. (2006, September 5). OSU and ODA examine potential for canola as an oil crop. *Extension Service News*. Retrieved March 29, 2008, from http://extension.oregonstate.edu/news/story.php?S_No=399&storyType=news

Hill G.K., & Learn S. (2007, October 21). Canola's golden promise loses luster. *The Oregonian*. Retrieved March 29, 2008, from http://www.oregonlive.com/news/oregonian/index.ssf?/base/news/119285615573440.xml&coll=7&thispage=1

Hill, J., Nelson, E., Tilman, D., Polasky, S., and Tiffany, D. (2006). Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels.

Proceedings of the National Academy of Sciences, 103, 11206-11210. Retrieved March 29, 2008, from http://www.pnas.org/cgi/reprint/103/30/11206

Institute for a Sustainable Environment. (1999). *SSURGO and STATSGO Soils for the Willamette River Basin*. Retrieved March 29, 2008, from http://www.fsl.orst.edu/pnwerc/wrb/access.html

Institute for a Sustainable Environment. (2005). *Willamette Valley Ecoregion Land Use and Land Cover ca. 2000*. Retrieved March 29, 2008, from http://www.fsl.orst.edu/pnwerc/wrb/access.html

Intergovernmental Panel on Climate Change (2007). *Climate Change 2007: Synthesis Report*. Retrieved March 29, 2008, from http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

International Energy Agency. (2007a). *IEA Energy Technology Essentials*. Retrieved March 29, 2008, from http://www.iea.org/textbase/techno/essentials2.pdf

International Energy Agency. (2007b). *World Energy Outlook, Executive Summary*. Retrieved March 29, 2008, from http://www.iea.org/Textbase/npsum/WEO2007SUM.pdf

Jaeger, W. K., & Siegel, R. W. (2008). *Economic Dimensions of Oilseed Crops and Their Biodiesel Potential in Oregon's Willamette Valley*. Manuscript submitted for publication.

Jaeger, W. K., Cross, R., & Egelkraut, T. M., (2007). Biofuel Potential in Oregon: Background and Evaluation of Options. *Oregon State University Extension Service, Special Report 1078*. Retrieved March 29, 2008, from http://extension.oregonstate.edu/catalog/pdf/sr/sr1078.pdf

Kish, M. (2007, April 13). New firm serves up biofuels to go. *Portland Business Journal*. Retrieved March 29, 2008, from http://www.bizjournals.com/portland/stories/2007/04/16/story5.html

Lies, M. (2007, November 30). Growers make voices heard at canola hearing. *Capital Press*. Retrieved March 29, 2008, from http://www.capitalpress.info/main.asp?SectionID=67&SubSectionID=792&ArticleID=37329&TM=7918.916

McCarl, B., & Spreen, T.H. (1980). Price Endogenous Mathematical Programming as a Tool for Sector Analysis. *American Journal of Agricultural Economics, 62(1), 87-102*. Retrieved March 29, 2008, from EBSCOhost.

McVay, K.A., and Lamb, P.F. (2007). *Camelina Production in Montana, MT200701AG*. Retrieved March 29, 2008, from http://www.montana.edu/wwwpb/pubs/mt200701AG.pdf

National Agricultural Statistical Service. (2002). *2002 Census of Agriculture - Volume 1 Geographic Area Series Census, US - State Data*. Retrieved March 29, 2008, from http://www.nass.usda.gov/Census/Create_Census_US.jsp

Natural Resources Conservation Service. (2008). *Soil Data Mart*. Retrieved March 29, 2008, from http://soildatamart.nrcs.usda.gov/

Nicholson, W. (2005). Microeconomic Theory, Basic Principles and Extensions (9th ed.). Ohio: Thomson South-Western.

NORPAC. (2005). *Processing & Warehouse Locations*. Retrieved March 29, 2008, from http://www.norpac.com/Plant_Location_Map.pdf

Oregon Agricultural Information Network (OAIN). (2007). *OAIN Database*. Retrieved March 29, 2008, from http://oregonstate.edu/oain/Database/SignInDCS.asp

Oregon Department of Agriculture. (2006). *2005-2006 Oregon Agriculture & Fisheries Statistics*. Retrieved March 29, 2008, from http://www.nass.usda.gov/Statistics_by_State/Oregon/Publications/Annual_Statistical_Bulletin/2006%20Bulletin/bulletin06.pdf

Oregon Department of Agriculture. (2007). *The Agriculture Quarterly, Issue 364*. Retrieved March 29, 2008, from http://www.oregon.gov/ODA/docs/pdf/pub_0612br.pdf

Oregon Department of Agriculture. (2008). *ODA Plant Division Rapeseed Control Areas*. Retrieved March 29, 2008, from http://www.oregon.gov/ODA/PLANT/canola_rapeseed.shtml

Oregon Department of Energy. (2007). *House Bill 2210 Enrolled: Biofuels Bill, Section by Section Summary*. Retrieved March 29, 2008, from http://oregon.gov/ENERGY/docs/HB2210--Biofuels.pdf

Oregon Environmental Council. (2007). *Fueling Oregon with Sustainable Biofuels*. Retrieved March 29, 2008, from http://www.oeconline.org/economy/sustainablebiofuels

Oregon Water Resources Department. (2006). *Oregon Water Right Places of Use (POUs), by administrative basin*. Retrieved. March 29, 2008, from http://www.oregon.gov/OWRD/MAPS/index.shtml

Radich, A. (2004). *Biodiesel Performance, Costs, and Use*. Retrieved March 29, 2008, from http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/

Rose, M. (2007, December 15). Breaking ground for fuel. *Statesman Journal*. Retrieved January 20, 2008, from http://www.statesmanjournal.com/apps/pbcs.dll/article?AID=/20071215/NEWS/712150328/1001

SeQuential. (2007). *SeQuential Biofuels :: About Us*. Retrieved March 29, 2008, from http://www.sqbiofuels.com/about_us.htm

US Department of Energy. (2007a). *Alternative Fuel Price Report*. Retrieved March 29, 2008, from http://www.eere.energy.gov/afdc/price_report.html

US Department of Energy. (2007b). *State & Federal Incentives & Laws, Alternative Fuel Infrastructure Tax Credit*. Retrieved March 29, 2008, from http://www.eere.energy.gov/afdc/progs/view_ind_fed.php/afdc/351/0

US Department of Energy. (2007c). *State & Federal Incentives & Laws, Renewable Energy Systems and Energy Efficiency Improvements Grant*. Retrieved March 29, 2008, from http://www.eere.energy.gov/afdc/progs/view_ind_fed.php/afdc/327/0

Willamette Biomass Processors. (2008). *Grower Page*. Retrieved March 29, 2008, from http://www.willamettebiomass.com/grower_page.html

APPENDICES

Appendix A General Soil Categories for the Willamette Valley and their Respective Soil Series Names

Description	Code	Soil Series Names Included
Excellent WD bottomland soils	NEWB	Newberg, Sifton, Chehalis, Cloquato, Chapman, Mcbee, Evans
Average PD bottomland soils	BASH	Bashaw, Brand, Labish, Wapato, Waldo, Verboort, Cove, Sauvie, Faloma, Waldo - c, Sauvie - c, Sauvie - cas, Rafton
Excellent WD terrace soils	WILL	Willamette, Quafeno, Abiqua, Malabon, Hillsboro, Salem
Excellent MWD terrace soils	WOOD	Carlton, Mcalpin, Woodburn, Quatama, Jimbo, Saturn, Sawtell, Coburg, Helvetia, Santiam
Poor EWD bottomland soils	BRIE	Camas, Haploxeroids, Briedwell, Pilchuck, Xerofluvents, Canderly, Burlington
Excellent SWPD terrace soils	AMIT	Clackamas, Chehalem, Amity, Redbell, Aloha, Holcomb, Oxley
Average PD terrace soils	DAYT	Dayton, Concord, Noti, Conser, Huberly, Natroy - cas, Natroy, Courtney, Awbrig
Good WD foothills soils	JORY	Jory, Cottrell, Cottrell - cas, Cazadero, Jory - cas, Windygap, Laurelwood, Cornelius, Alspaugh, Alspaugh - cas, Bull run, Melbourne, Bateman, Molalla - cas, Rosehaven, Peavine - c, Molalla, Saum, Springwater, Kinton
Somewhat shallow WD foothills soils	NEKA	Nekia, Salkum, Silverton, Hullt, Mccully, Bellpine, Veneta, Yamhill, Willakenzie, Bacona, Bornstedt, Steiwer
Good SWPD foothills soils	HAZL	Hazelair, Mershon, Mershon - cas, Stayton, Suver, Sutherlin, Cornelius - c, Delena - c, Delena, Hardscrabble, Panther, Powell, Powell - cas, Dupee, Dupee -cas, Witham, Cascade, Pengra, Helmick, Peavine
Shallow foothills soils	PHIL	Philomath, Oakland, Dixonville, Rickreall, Witzel, Dickerson, Climax, Ritner, Nonpareil, Chehulpum
Good PD bottomland soils of Coastal Valleys	NEST	Nestucca, Brallier, Nestucca, Linslaw, Wauna
Good WD bottomland soils of Coastal Valleys	NEHL	Nehalem, Gauldy, Meda, Mues, Logsden, Kirkendall, Eilertsen
Good WD terrace soils of Coastal Valleys	COQU	Coquille, Brenner, Chetco, Chismore, Clatsop, Chitwood, Blacklock, Crims, Hebo, Pyburn, Gleneden, Willanch, Ginger, Hapludalfs, Langlois, Locoda, Quosatana
Good WD terrace soils of Oregon Coast	KNAP	Knappa, Mcnulty, Quillayute, Briedwell, Bagness, Bullards, Klooqueh, Gardiner, Mcalpin, Winchuck, Grindbrook, Walluski, Knappa, Mcalpin, Ferrelo
Mountainous soils of Coast Range	ETEL	Etelka, Apt, Astoria, Atring, Bacona, Blachly, Bohannon, Bullgulch, Burnthill, Crater lake, Crutchfield, Cunniff, Dement, Digger, Ecola, Alcot - cas, Goble, Goble, Hembre, Honeygrove, Honeygrove - v, Hooskanaden, Horseprairie, Hunterscove, Kenusky, Klootchie, Loeb, Loneranch, Mcginnis, Millicoma, Mowako, Natal, Neskowin, Preacher, Reedsport, Rinearson, Sibannac, Skipanon, Skookumhouse, Slickrock, Svenson, Templeton, Treharne, Wedderburn, Whaleshead, Whobrey, Winema, Xerochrepts, Zwagg

Appendix B Assumed Yields for Willamette Valley Mathematical Programming Model across General Soil Categories

	Unit	WILL	WOOD	AMIT	NEWB	BRIE	BASH	SAUV	DAYT	JORY	NEKA	HAZL	PHIL	NEST	NEHL	COQU	KNAP	ETEL
Spring Oats	bushels	93.00	89.13	69.75	77.50	38.75	31.00		34.88			31.00						
Soft white winter wheat	bushels	110.00	110.00	95.00	100.00	70.00	70.00		75.00	90.00	90.00	90.00						
Crimson clover	1000 lbs	0.70	0.70	0.70	0.70													
Red clover	1000 lbs	0.60	0.60	0.60	0.60													
Generic Fine Fescue Grass	1000 lbs									1.00	1.00	1.00						
Orchard grass	1000 lbs	1.00	0.95	0.80	0.80					0.75		0.75						
Annual rye grass	1000 lbs			2.00	2.00	1.80	1.80	1.90	1.95									
Tall fescue grass	1000 lbs	1.90	1.80	1.50	1.30	1.30	1.30	1.30	1.40	1.40								
Tall fescue grass (irrig.)	1000 lbs	1.90	1.80		1.90	1.70												
Perrenial rye grass	1000 lbs	1.60	1.60	1.40	1.30	1.10	1.00	1.10	1.35	1.20	1.20	1.20						
Perrenial rye grass (irrig.)	1000 lbs	1.90	1.80		1.90	1.60												
Snap beans, proc (irrig.)	tons	6.00	6.00	5.30	6.00	4.00	3.70											
Sweet corn, proc (irrig.)	tons	9.00	9.00	8.00	9.00	6.00	5.50	6.50										
Corn for silage (irrig.)	tons	28.00	28.00	25.00	28.00	20.00												
Oilseed flax	1000 lbs	2.50	2.50	2.16	2.27	1.59	1.59		1.70	2.05	2.05	2.05						
Camelina	1000 lbs	2.00	2.00	1.73	1.82	1.27	1.27		1.36	1.64	1.64	1.64						
Canola	1000 lbs	3.50	3.50	3.02	3.18	2.23	2.23		2.39	2.86	2.86	2.86						
Alfalfa hay	tons	5.77	5.58	4.00	4.75	2.94		4.20		4.28	4.14							
Alfalfa hay (irrig.)	tons	7.20	7.00		6.56	5.12		5.20		6.00	4.40	6.00						4.50
Alfalfa hay establishment	tons	1.50	1.45	1.04	1.24	0.76		1.09		1.11	1.08							
Alfalfa hay est. (irrig.)	tons	2.00	1.94		1.82	1.42		1.44		1.67	1.22	1.67						1.25
Grass hay	tons	5.50	5.50	5.00	4.50	2.50	2.50	3.00	2.50	2.50		2.50	0.90	2.20	2.20	2.20		
Pasture production (dry)	tons	10.80	11.10	10.12	12.08	5.83	7.11	8.00	8.02	8.86	7.00	6.29	4.20	8.13	12.50	5.88	8.56	8.15
Pasture production (irrig.)	tons	17.27	16.77	15.19	16.13	12.73	13.16	15.62	11.92	15.19	14.56	9.92	9.37	14.03	16.38	8.00	14.00	16.00

Appendix C Summarized Crop Expenses from Various Enterprise Budgets

Crop	Spring Oats	Winter Wheat Conv. Till	Crimson Clover	Red Clover (Average)	Red Clover (Year 2)	Red Clover (Year 1)	Fine Fescue Silverton	Orchardgrass	Annual Ryegrass Conv. Till	Tall Fescue South	Tall Fescue (Irrig)	Perennial Ryegrass	Perennial Ryegrass (Irrig)
Unit	bu	bu	lb	lb	lb	lb	lb	lb	lb	lb	lb	lb	lb
Fertilizer	75.20	65.10	75.44	0.00	60.66	81.91	90.87	106.10	97.45	123.60	123.60	126.18	126.18
Chemical	0.00	0.00	0.00	0.00	2.92	10.00	32.19	25.75	0.00	25.75	25.75	67.86	67.86
Herbicide	4.95	29.53	16.36	0.00	8.76	70.54	47.07	57.77	31.18	43.17	43.17	25.59	25.59
Fungicide	0.00	22.50	0.00	0.00	0.00	0.00	17.94	15.94	0.00	35.88	35.88	0.00	0.00
Pesticide	0.00	13.50	24.30	0.00	13.05	33.30	0.00	0.00	0.00	0.00	0.00	4.73	4.73
Other	138.94	136.99	280.09	327.68	96.49	277.72	205.01	119.41	188.16	116.42	154.99	162.74	201.31
Fixed Costs (no land rent)	71.08	80.98	129.12	108.72	82.12	135.33	245.81	164.66	131.62	219.59	412.23	86.24	278.88
Custom per unit	0.00	0.00	0.09	0.11	0.11	0.11	0.11	0.09	0.03	0.06	0.06	0.08	0.08
Total Costs (no yield)	290.17	348.60	525.31	436.40	264.00	608.80	638.89	489.63	448.41	564.41	795.62	473.34	692.06

Crop	Sweet Corn for Processing	Snap Beans for Processing	Corn Silage	Winter Flax	Spring Camelina	Winter Canola	Alfalfa Hay (Non-Irrigated)	Alfalfa Hay (Irrigated)	Alfalfa Hay Est. (Irrigated)	Alfalfa Hay Est. (dry)	Grass Hay	Dry Pasture Production	Irrig Pasture Production
Unit	Ton	Ton	ton	lb	lb	lb	ton	ton	ton	ton	ton	AUMS	AUMS
Fertilizer	185.83	163.75	58.50	45.60	14.50	80.35	93.30	93.30	21.00	21.00	50.85	84.23	84.23
Chemical	0.00	0.00	0.00	0.47	10.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Herbicide	26.40	65.66	23.00	21.50	7.25	12.75	17.61	17.61	38.00	38.00	0.00	0.00	0.00
Fungicide	0.00	50.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pesticide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	359.00	393.51	366.06	131.05	77.45	173.39	100.26	138.83	284.10	258.41	69.07	28.49	67.06
Fixed Costs (no land rent)	165.20	153.95	215.11	96.29	74.38	108.44	44.17	236.81	244.34	51.70	104.16	81.78	274.42
Custom per unit	8.00	8.00	0.00	0.00	0.00	0.00	17.00	17.00	17.00	0.00	17.00	2.81	2.81
Total Costs (no yield)	736.43	827.86	662.67	294.91	184.21	374.93	255.34	486.55	587.44	369.11	224.08	194.50	425.71

Appendix D Assumed Costs for Willamette Valley Mathematical Programming Model

	unit	Basic Cost ($/ac)	Yield-Based Cost ($/unit)	Transportation Costs ($/unit) No.	Cent.	Sth.
Spring Oats	bushels	290.17		0.14	0.38	0.45
Soft white winter wheat	bushels	348.60		0.14	0.38	0.45
Crimson clover	1000 lbs	525.31	85.40			
Red clover	1000 lbs	436.40	106.00			
Generic Fine Fescue Grass	1000 lbs	638.89	105.20			
Orchard grass	1000 lbs	489.63	91.90			
Annual rye grass	1000 lbs	448.41	32.30			
Tall fescue grass	1000 lbs	564.41	61.36			
Tall fescue grass (irrig.)	1000 lbs	795.62	61.36			
Perrenial rye grass	1000 lbs	473.34	83.00			
Perrenial rye grass (irrig.)	1000 lbs	692.06	83.00			
Snap beans, proc (irrig.)	tons	827.86	8.00	12.00	8.00	12.00
Sweet corn, proc (irrig.)	tons	736.43	8.00	12.00	8.00	12.00
Corn for silage (irrig.)	tons	662.67				
Oilseed flax	1000 lbs	294.91		4.76	2.16	4.76
Camelina	1000 lbs	184.21		4.76	2.16	4.76
Canola	1000 lbs	374.93		4.76	2.16	4.76
Alfalfa hay	tons	255.34	32.00			
Alfalfa hay (irrig.)	tons	486.55	32.00			
Alfalfa hay establishment	tons	369.11	32.00			
Alfalfa hay est. (irrig.)	tons	587.44	32.00			
Grass hay	tons	224.08	17.00			
Pasture production (dry)	AUMS	194.50	2.81			
Pasture production (irrig.)	AUMS	425.71				
Fallow land	na					
Fallow land (irrig.)	na					

Appendix E Assumed Prices for Baseline Willamette Valley Mathematical Programming Model Simulation

		Unit	Price	Quantity	Flexibility	Elasticity	Current Pr.	Current Qty
Price Endogenous	*Crimson Clover*	1000 lbs	432.0	4,860	-0.50		712.9	3,722
	Red Clover	1000 lbs	875.0	6,137	-0.63		1114.4	8,230
	Chewings Fescue	1000 lbs	793.0	14,578	-1.49		722.2	8,314
	Orchardgrass	1000 lbs	550.0	14,829		-0.08	1007.1	12,616
	Annual Ryegrass	1000 lbs	191.0	184,935	-1.64		273.3	221,701
	Tall Fescue	1000 lbs	404.0	87,284	-1.28		646.3	227,925
	Perrenial Ryegrass	1000 lbs	462.0	112,127	-2.63		633.3	234,722
	Alfalfa	Ton	100.2	4,723,000		-1.38	167.4	49,268
	Grass Hay	Ton	62.5	620,000	-5.26		115.7	282,480
Price Exogenous	*Spring Oats*	Bushel	2.2					
	Winter Wheat	Bushel	4.6					
	Snap Beans	Ton	190.0					
	Sweet Corn	Ton	93.9					
	Corn Silage	Ton	29.0					
	Flaxseed	1000 lbs	147.0					
	Camelina	1000 lbs	100.0					
	Canola	1000 lbs	133.0					
	Alfalfa Est.	Ton	153.7					
	Pasture	AUMS	12.0					
	Fallow	na	0.0					

Appendix F Objective Function Formulation for Price-Endogenous Crops

Basic economic theory predicts that in a perfectly competitive market firms behave as price-takers and maximize profits. Profits can be represented mathematically as

$$\pi = R(q) - C(q)$$

Where…

π	=	Profits
q	=	Quantity produced
p*	=	Optimal price
C(q)	=	Cost (aggregate) as a function of quantity produced
R(q)	=	Revenue as a function of quantity produced
MC	=	Marginal cost (partial derivative of cost with respect to quantity)

When firms are price-takers they will maximize profits with a given price. Calculus is used to maximize profits by taking the partial derivative of the function with respect to the choice variables and setting them equal to zero. This is because at the maxima (or minima) the slope of the function with respect to every choice variable must be zero. Mathematically, it can be shown that:

$$Max \pi = R(q) - C(q)$$

$$R(q) = p^* q$$

$$\frac{\partial \pi}{\partial q} = \frac{\partial R(q)}{\partial q} - \frac{\partial C(q)}{\partial q} = 0$$

$$\frac{\partial \pi}{\partial q} = p^* - \frac{\partial C(q)}{\partial q} = 0$$

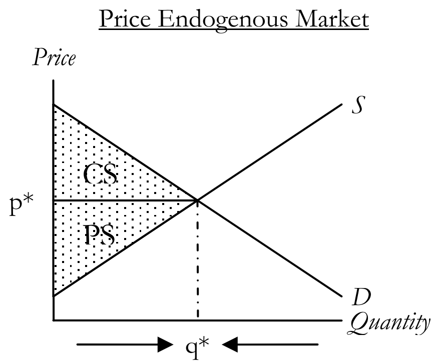
$\therefore p^* = MC$ at the profit maxizing point

However, when prices become endogenous the revenue function becomes:

$$R(q) = p_D(q)q - C(q)$$

Where $p_D(q)$ is the demand function relating how prices change given shifts in price. Assuming a linear demand function $p_D(q)$ can take the form $p_D(q) = \alpha - \beta q$. Mistakenly maximizing profit (π) as was done before with this endogenous price function would yield a monopoly result where the thousands of firms behave as one firm. This is clearly not the case. However, some prices are endogenous to the model.

An objective function that accounts for the price endogeneity and the competitive market can be developed using basic integral calculus. It was shown in figure 6 above that competitive equilibrium is reached when producer and consumer surplus are maximized in a market. An expression could be found, then, that maximizes this area while accounting for price endogeneity by maximizing the area between demand curve and the supply curve. The following graph and mathematics demonstrate this:



$$CS + PS = \int_0^{q*} p_D(q) - \int_0^{q*} p_S(q)$$

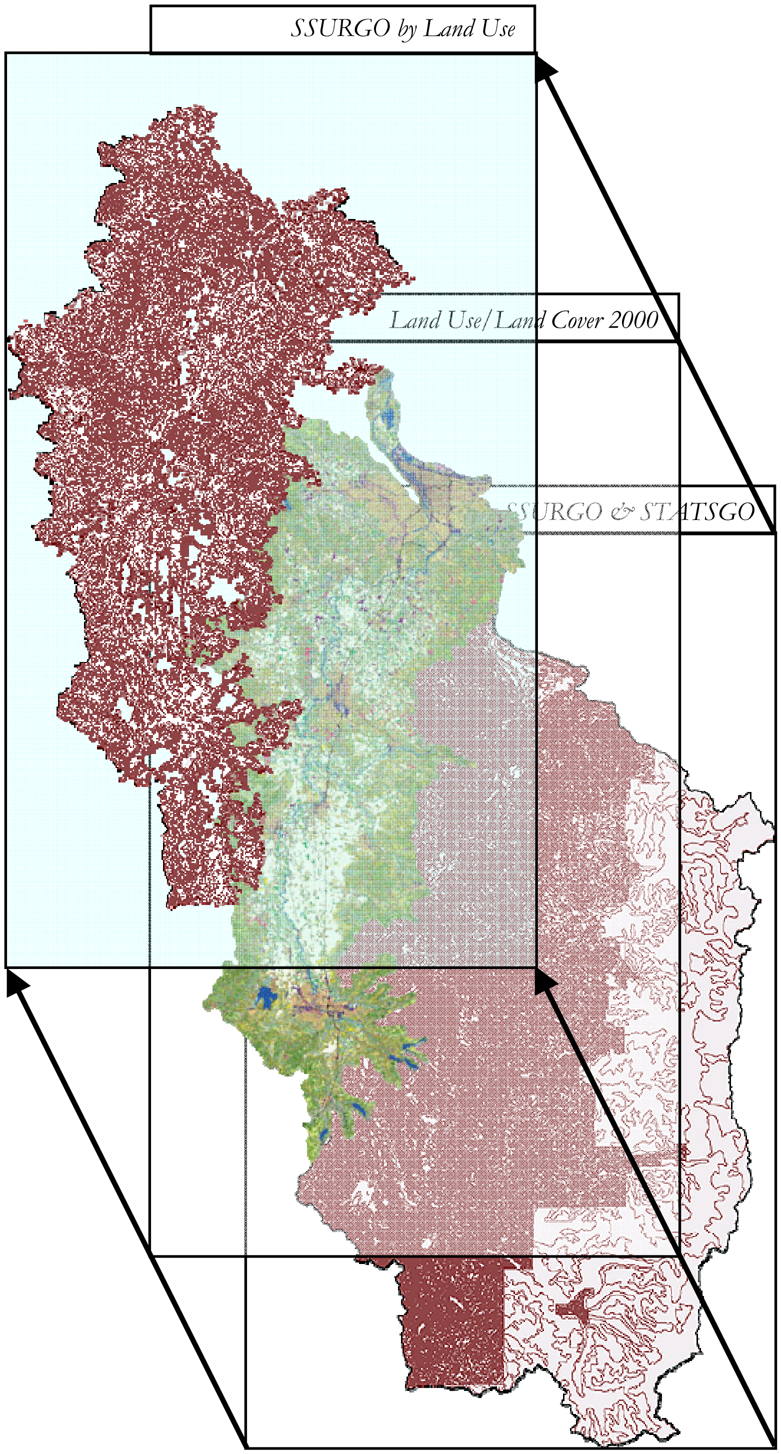
$$\ldots = \int_0^{q*} (\alpha - \beta q) - \int_0^{q*} MC(q)$$

$$\ldots = \left(\alpha q - \tfrac{1}{2}\beta q^2 + t\right) - \left(C(q) + t\right)$$

$$CS + PS = \left(\alpha - \tfrac{1}{2}\beta q\right)q - C(q)$$

The last expression, then, determines what the objective function should be for those crops whose price is determined endogenously.

Appendix G Graphical Representation of GIS Intersection



Appendix H Oilseed Various Subsidy Simulation Results

Trial **Baseline**

Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	10,968		8,687		19,655
ALFEST	2,194		1,737		3,931
ANNRYE	7,125	103,772			110,897
CANOLA			6,287		6,287
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,839		7,839
GRSHAY	60,041	9,628	14,898	315	84,882
ORCHGR	8,145		6,341		14,487
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	86,082	84,422			170,503
REDCLO	16,801				16,801
SNPBNP	20,000				20,000
SWCRNP	20,000				20,000
TALFES	125,012	22,061			147,073
WWHEAT	74,276		73,364		147,640
Grand Total	475,404	239,140	179,274	3,914	897,732

Trial **All Oilseeds A**

Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	7,419		12,795		20,214
ALFEST	1,484		2,559		4,043
ANNRYE	7,125	100,632			107,757
CANOLA	51,210		18,929		70,138
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,488		7,488
GRSHAY	58,593	9,628	14,898	315	83,434
ORCHGR	13,151				13,151
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	81,571	87,757			169,328
REDCLO	14,052				14,052
SNPBNP	19,410				19,410
SWCRNP	19,410				19,410
TALFES	123,903	21,865			145,768
WWHEAT	33,318		62,483		95,801
Grand Total	475,404	239,140	179,274	3,914	897,732

Trial	**All Oilseeds B**				
Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	7,374		12,848		20,222
ALFEST	1,475		2,570		4,044
ANNRYE	7,125	99,247			106,372
CANOLA	38,697	2,940	9,359		50,996
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,422		7,422
GRSHAY	58,059	9,628	14,898	315	82,900
ORCHGR	13,126				13,126
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	82,597	86,288			168,885
REDCLO	13,324				13,324
SNPBNP	15,113				15,113
SWCRNP	15,113				15,113
TALFES	123,421	21,780			145,201
WWHEAT	33,609		56,101		89,710
FLAXSD	21,613		15,956		37,568
Grand Total	475,404	239,140	179,274	3,914	897,732

Trial	**All Oilseeds C**				
Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	9,867		9,929		19,796
ALFEST	1,973		1,986		3,959
ANNRYE	7,125	97,374			104,499
CANOLA	38,591	14,887	9,045		62,523
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,309		7,309
GRSHAY	57,573	9,628	14,898	315	82,414
ORCHGR	9,951		3,930		13,881
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	91,703	76,315			168,018
REDCLO	11,931				11,931
SNPBNP	13,949				13,949
SWCRNP	13,949				13,949
TALFES	122,847	21,679			144,526
WWHEAT	28,444		56,101		84,545
FLAXSD	22,739		15,956		38,695
Grand Total	475,404	239,140	179,274	3,914	897,732

Trial **Flax/Camelina A**

Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	8,663		9,649		18,311
ALFEST	1,733		1,930		3,662
ANNRYE	7,125	100,524			107,649
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,492		7,492
GRSHAY	58,462	9,628	14,898	315	83,303
ORCHGR	13,160				13,160
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	82,228	87,887			170,115
REDCLO	14,797				14,797
SNPBNP	18,554				18,554
SWCRNP	18,554				18,554
TALFES	123,782	21,844			145,626
WWHEAT	27,566		55,004		82,570
FLAXSD	56,021		30,181		86,201
Grand Total	475,404	239,140	179,274	3,914	897,732

Trial **Flax/Camelina B**

Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	8,663		9,649		18,311
ALFEST	1,733		1,930		3,662
ANNRYE	7,125	99,225			106,350
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,383		7,383
GRSHAY	57,962	9,628	14,898	315	82,803
ORCHGR	13,138				13,138
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	83,038	87,062			170,100
REDCLO	13,772				13,772
SNPBNP	18,554				18,554
SWCRNP	18,554				18,554
TALFES	123,474	21,789			145,263
WWHEAT	25,529		55,084		80,613
FLAXSD	59,104	2,179	30,210		91,493
Grand Total	475,404	239,140	179,274	3,914	897,732

Trial **Flax/Camelina C**

Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	8,663		9,649		18,311
ALFEST	1,733		1,930		3,662
ANNRYE	7,125	97,791			104,916
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,251		7,251
GRSHAY	57,298	9,628	14,898	315	82,139
ORCHGR	13,107				13,107
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	81,249	88,592			169,841
REDCLO	12,411				12,411
SNPBNP	18,554				18,554
SWCRNP	18,554				18,554
TALFES	122,977	21,702			144,679
WWHEAT	26,360		55,181		81,541
FLAXSD	62,614	2,170	30,245		95,030
Grand Total	475,404	239,140	179,275	3,914	897,732

Trial **Camelina A**

Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	9,902		9,649		19,550
ALFEST	1,980		1,930		3,910
ANNRYE	7,125	103,772			110,897
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,628		7,628
GRSHAY	60,041	9,628	14,898	315	84,882
ORCHGR	13,218				13,218
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	86,082	84,422			170,503
REDCLO	16,801				16,801
SNPBNP	20,000				20,000
SWCRNP	20,000				20,000
TALFES	125,012	22,061			147,073
WWHEAT	53,707		54,904		108,611
CAMLNA	16,776		30,145		46,921
Grand Total	475,404	239,140	179,274	3,914	897,732

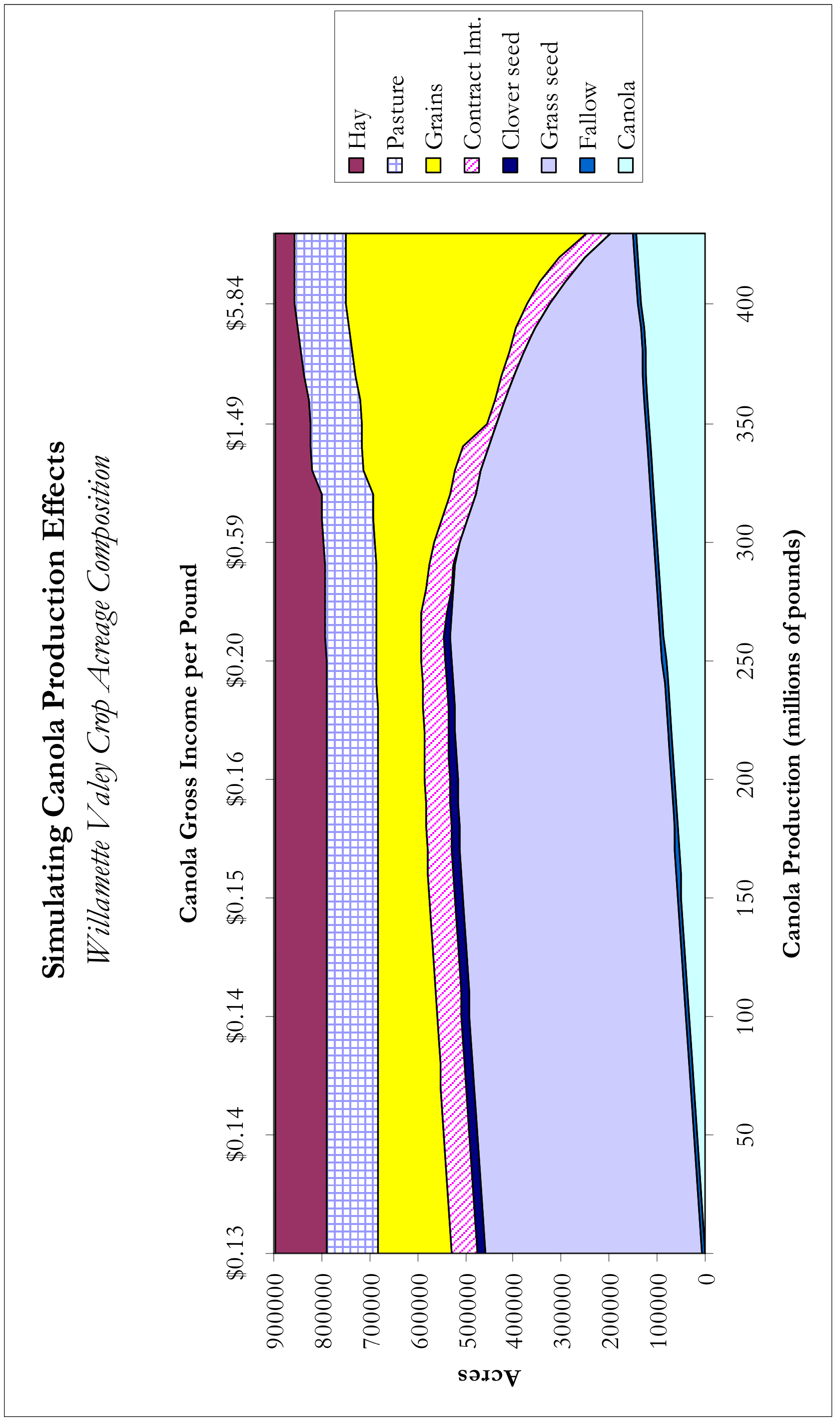
Trial **Camelina B**

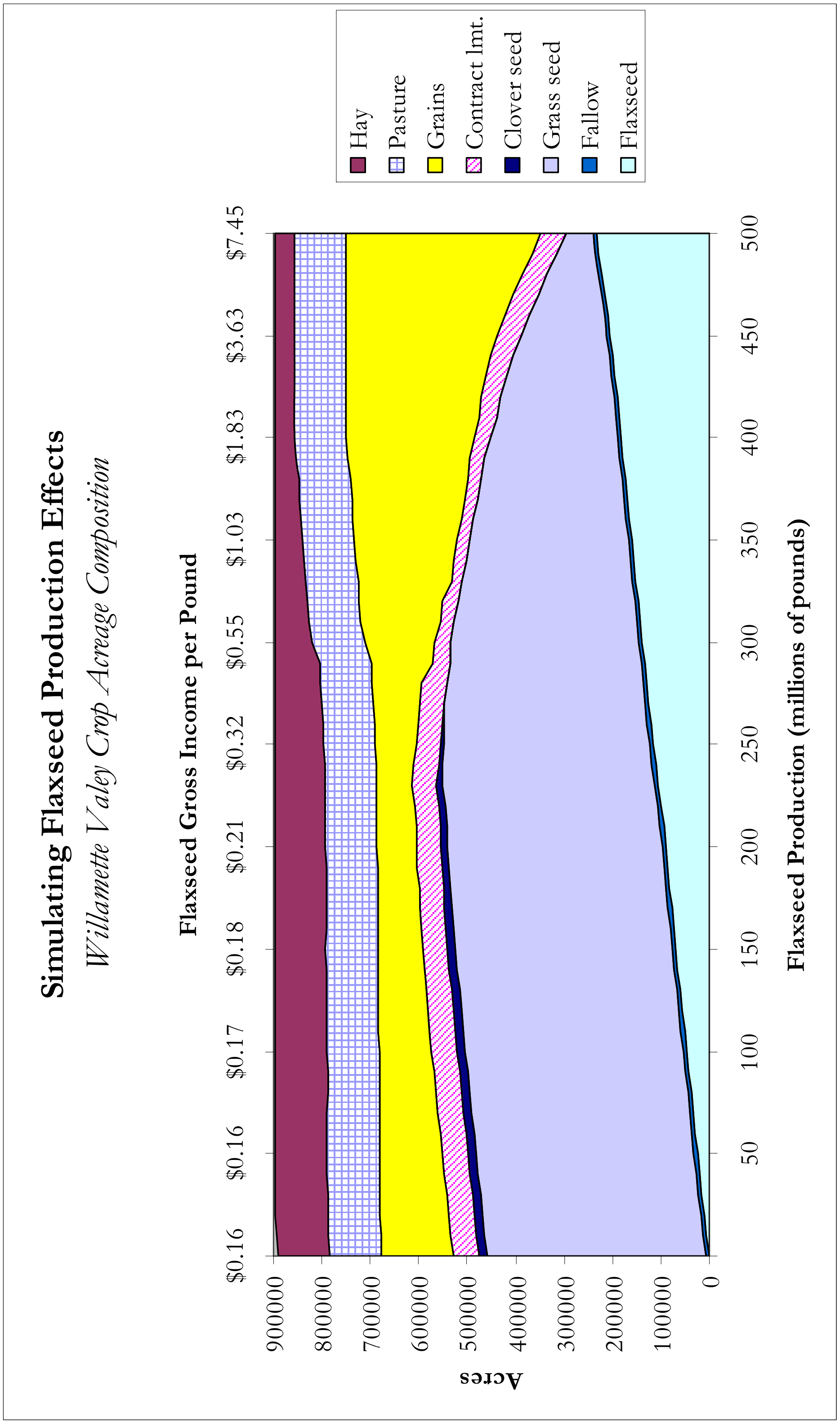
Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	13,627		3,183		16,810
ALFEST	2,725		637		3,362
ANNRYE	7,125	102,743			109,868
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,555		7,555
GRSHAY	59,657	9,628	14,898	315	84,498
ORCHGR	13,205				13,205
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	85,989	83,300			169,289
REDCLO	16,171				16,171
SNPBNP	18,554				18,554
SWCRNP	18,554				18,554
TALFES	124,724	22,010			146,734
WWHEAT	32,449		60,992		93,441
CAMLNA	37,865	2,201	31,888		71,954
Grand Total	475,404	239,140	179,274	3,914	897,732

Trial **Camelina C**

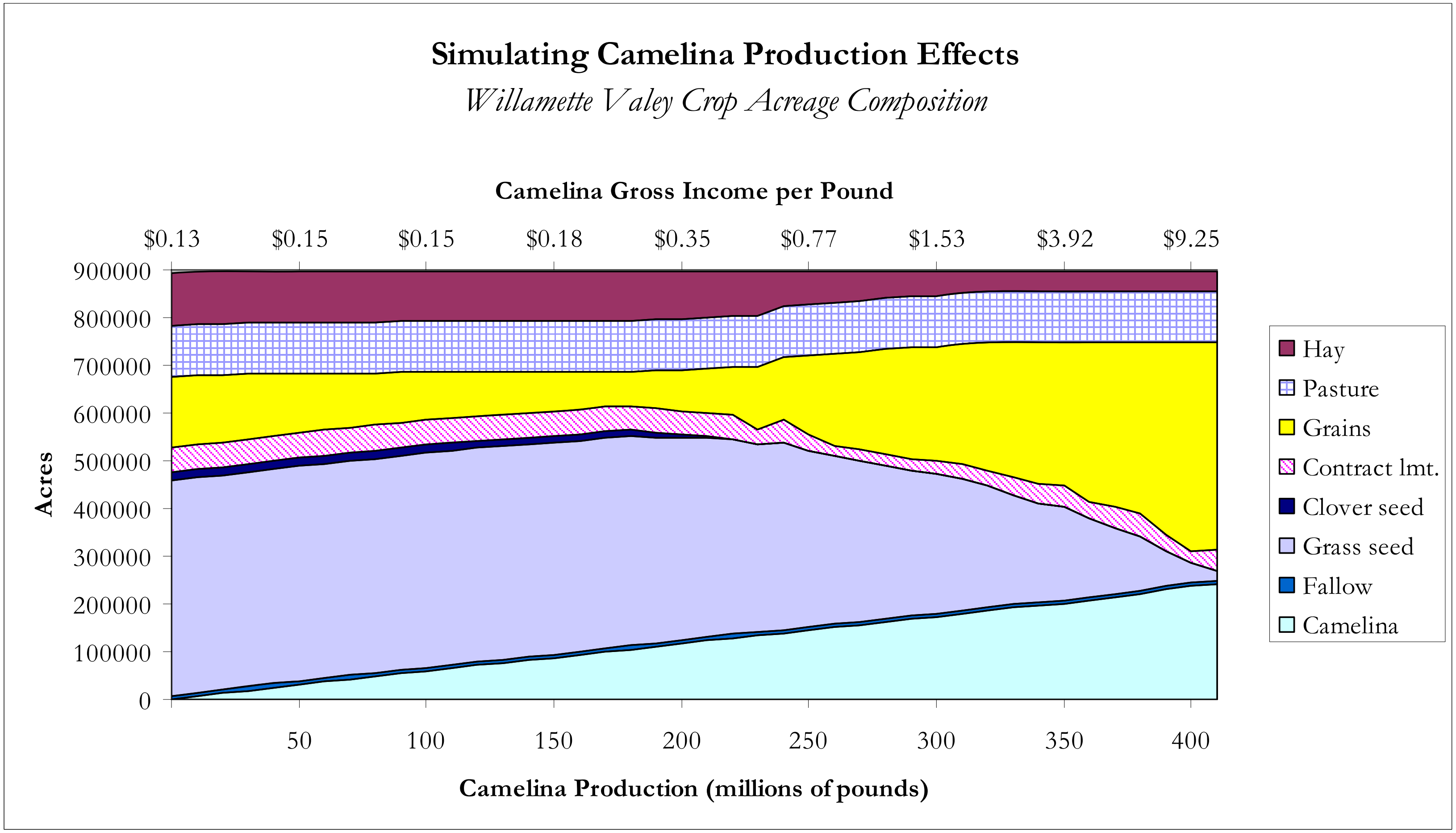
Sum of Acreage					
Crop	High Quality	Poorly Drained	Foothill	Coastal	Grand Total
ALFALF	8,663		9,649		18,311
ALFEST	1,733		1,930		3,662
ANNRYE	7,125	100,645			107,770
CSILGE	13,000				13,000
FALLOW			5,569	2,271	7,840
GENFSC			7,450		7,450
GRSHAY	58,619	9,628	14,898	315	83,460
ORCHGR	13,169				13,169
PASTUR	31,760	19,257	54,552	1,328	106,897
PERRYE	83,897	85,548			169,445
REDCLO	15,119				15,119
SNPBNP	18,554				18,554
SWCRNP	18,554				18,554
TALFES	123,959	21,875			145,834
WWHEAT	30,388		55,035		85,423
CAMLNA	50,866	2,188	30,192		83,245
Grand Total	475,404	239,140	179,274	3,914	897,732

Appendix I Willamette Valley Crop Composition Changes with Various Levels of Oilseed Subsidy and Production





Simulating Flaxseed Production Effects
Willamette Valey Crop Acreage Composition
Flaxseed Gross Income per Pound
$0.16
$0.16
$0.17
$0.18
$0.21
$0.32
$0.55
$1.03
$1.83
$3.63
$7.45
Acres
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
50
100
150
200
250
300
350
400
450
500
Flaxseed Production (millions of pounds)
Hay
Pasture
Grains
Contract lmt.
Clover seed
Grass seed
Fallow
Flaxseed



Simulating Camelina Production Effects
Willamette Valey Crop Acreage Composition
Camelina Gross Income per Pound
$0.13
$0.15
$0.15
$0.18
$0.35
$0.77
$1.53
$3.92
$9.25
Acres
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
50
100
150
200
250
300
350
400
Camelina Production (millions of pounds)
Hay
Pasture
Grains
Contract lmt.
Clover seed
Grass seed
Fallow
Camelina