ECONOMIC PERFORMANCE OF ORGANIC CROPPING SYSTEMS FOR VEGETABLES IN THE NORTHEAST

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by
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ABSTRACT

Between 1980 and 2010, organic farming has become one of the fastest growing segments in agriculture in the United States. Although a national standard for organic agriculture was established by the USDA in 1997 and amended in 2005, organic farming systems are extremely heterogeneous compared to conventional farming methods. A variety of strategies that comply with the USDA guidelines of organic production practices can be applied ranging from high input systems to those with greater reliance on internal processes.

This thesis examines the economics of four alternative organic cropping systems that comply with USDA guidelines. The analysis compares the profitability and land management capability of four different organic cropping systems used to produce winter squash, cabbage, potatoes and lettuce. Interactive crop budgets were developed to document both production costs and income streams for each cropping system. The analysis using data from trials between 2005 and 2009 indicate that different systems generate different economic outcomes across the crops, and sometimes the differences are substantial.

The ridge-tillage system that relied on cover crops for nitrogen (System 4) yielded the highest revenues for squash production, while System 1, which relies on compost for nitrogen, occasional cover crops and uses conventional tillage, had the highest revenues for cabbage. The economic analysis used here develops a framework to outline the financial implications of adopting each of the four organic cropping systems. When the economics for a full crop rotation across the systems are examined as a whole, large differences are not detected. However, individual crops do respond differently to the different systems, but overall, the high intensity system generated the highest profits.

BIOGRAPHICAL SKETCH

Stephanie Chan was born in New York, NY. Despite her suburban upbringing in Oceanside, NY, she has dreamed of living and working on a farm. She received her bachelors of arts' degree with honors from Boston University in 2004, where she majored in Economics and minored in Applied Statistics. In 2011, she became a certified sustainable farmer. Upon completion of her thesis, Stephanie plans to graduate from Cornell with a Master's of Science degree in Applied Economics and Management, explore urban agriculture, continue promoting local foods, and start an organic homestead.

dedicated to my family

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LIST OF ABBREVIATIONS

AMS	Agriculture Marketing Services
CSA	Community Supported Agriculture
ERS	Economic Research Service
NASS	National Agricultural Statistics Services
NOP	National Organic Program
OCS	Organic Cropping System
OREI	Organic Agriculture Research and Extension Initiative
OTA	Organic Trade Association
UN	United Nations
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

1.1 Introduction

Consumer demand for organic food has grown tremendously in recent years creating new market opportunities for producers while transforming the organic food industry. Once a niche product sold in a limited number of retail outlets, organic foods can now be found in nearly 20,000 natural food stores and in 73% of conventional grocery stores (USDA-ERS, 2008). Since the 1990s, certified organic acreage in the United States has increased as producers endeavor to meet increasing demand for organic produce. The U.S. government has responded to the dramatic growth of the industry by instituting policies to facilitate organic produce marketing and support research and education on organic farming systems.

The development and success of the United States Department of Agriculture’s organic regulatory program and label is partially responsible for the increase in consumer demand. Although a national standard for organic agriculture was established by the USDA in 1997 and amended by the USDA in 2005 (USDA-NOP, 2010), organic vegetable farming systems are extremely heterogeneous compared to their conventional counterparts. A variety of strategies that comply with the USDA guidelines of organic production practices can be applied ranging from high input systems to those with greater reliance on internal processes.

In this research, I examine four such systems that comply with USDA guidelines utilizing long-term on-farm data. Organic producers have many options regarding tillage, cropping intensity, cover crops, labor, methods of weed control, and harvesting of crops. Of these factors, cover crops, fertility inputs, weed management and tillage are closely examined here because these activities have important economic and ecological implications in vegetable production. Long-term cropping systems studies that accurately simulate organic farms provide a means for analyzing how different management practices influence agronomic conditions and profitability.

1.2 Organic Vegetable Production in New York State

Vegetables are an important component of total agricultural production in the Northeast, and notably in New York State. New York ranks 5th nationally in area harvested of principal fresh market vegetables (USDA-NASS, 2011). For instance, New York is the 3rd largest producer of fresh and processing cabbage in the United States, ranks 6th in lettuce production, 12th in potatoes and 6th in squash (USDA-NASS, 2007). In New York State, vegetable production totaled $361 million in 2010 (USDA-NASS, 2011).

Spurred by an interest in exploring alternative agricultural systems, the “Back to the Land Movement” in the 1960s and 1970’s drew organic farmers to rural Upstate New York. The establishment of a New York chapter of the Northeast Organic Farming Association (NOFA-NY) in 1983 provided farmers with formal organic certification as well as educational and marketing opportunities (NOFA-NY, 2011). The New York State Department of Agriculture and Markets has created an organic farming resource center to provide farmers with networking opportunities, educational resources and financial assistance. It also administers an organic certification fee reimbursement programs to help producers transition from conventional to organic farming. The agency has reported that 809 certified organic producers applied for grants from this program in 2008 and expects that the number of applications will continue to rise (New York State Department of Agriculture and Markets, 2011).

Through the efforts of farmers, NOFA-NY and state and federal support, New York ranked 6th in the country for number of certified organic operations accounting for 5% of total

U.S. certified operations in 2005 (New York State Department of Agriculture and Markets, 2011). In New York State, approximately 190 farms produced $9.5 million worth of organic vegetables on 1,534 acres in 2008. These data suggest that the average organic farm in New York State has about 8 acres in vegetable production; however, a large share of organic vegetable farms have less than 3 acres in production (Henehan and Li, 2010). In 2008, as part of the USDA Census of Agriculture, an Organic Survey was conducted on a national level and broken down by state. Cabbage, lettuce, potatoes and squash were amongst the vegetables with the highest production level and sales. In 2008, 48 New York farms produced 3,351 hundredweight of cabbage worth $247,082 in sales. Lettuce sales totaled $648,277 averaging $106.38 per hundredweight. Total production of potatoes was 96,400 hundredweight in New York with total sales of $405,999. Squash production had the highest yield and total sales. There were 84 New York farms that produced 8,858 hundredweight of squash with a value of $897,087. National statistics suggest that an increasing share of vegetables grown in the United States is produced following USDA organic guidelines (USDA-Census of Agriculture, 2008).

Given the growing importance of organic production in New York agriculture, the objective of this thesis is to examine the profitability of contrasting approaches for producing organic vegetables on small farms. Organic farming can offer small to mid-sized farms in New York State an enterprise option that could improve farm and community economic viability and environmental sustainability.

1.3 Organic Farming

Organic farming methods have been utilized since the beginning of human civilization. The Green Revolution of the 1940’s ushered in a new era of industrialized agricultural production reliant on pesticides, herbicides, synthetic fertilizer, increased dependence on petroleum and the resulting disadoption of organic technology. British agriculturalist, Walter Ernest Christopher James, 4th Baron Northbourne, is credited with coining the term organic farming. The term is derived from his notion of "the farm as organism," which he describes as a self-contained and self-sustaining environment. Conversely, conventional farming relies on "imported fertility" and "cannot be self-sufficient nor an organic whole" (Heckman, 2006).

In 1947, J. I. Rodale, an American organic pioneer, founded the Rodale Institute which promoted the term organic and organic growing methods. Rodale is quoted as writing, "Organics is not a fad. It has been a long-established practice – much more firmly grounded than the current chemical flair. Present agricultural practices are leading us downhill." (Rodale Institute, 2011). Rachel Carson, a prominent scientist and naturalist supported this idea with her novel, *Silent Spring*, which chronicled the harmful effects of DDT and other synthetic pesticides. *Silent Spring*, a best seller, is often credited for launching the environmental movement which influence reaches to the founding of the Environmental Defense Fund, the ban of DDT, and the creation of the Environmental Protection Agency (Beyl, 1991). Awareness of the consequences of modern farm practices created growing consumer demand for food grown without chemicals. As the market for organic foods grew, so did the need for standards, certification, and regulation. Private organizations began developing organic certification standards in the 1970s to support organic farming and prevent consumer fraud. Nonprofit groups such as the Rodale Institute, established voluntary standards and certification programs in 1972. Some states began offering organic certification services for similar reasons. The Rodale Institute helped set up the California Certified Organic Farmers and the Oregon-Washington Tilth Organic Producers Association in the early 1970s to promote and support organic food and act as certification organization for organic farmers (Rodale Institute, 2011). The resulting patchwork of standards in the various certification programs caused a variety of marketing issues. Congress passed the Organic Foods Production Act of 1990 to establish national standards for organically produced commodities.

The USDA National Organic Standards Board (NOSB), which sets national standards for the producing, handling and processing of organically grown agricultural products, defines "organic" as:

- "Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony.
- "'Organic' is a labeling term that denotes products produced under the authority of the Organic Foods Production Act. The principal guidelines for organic production are to use materials and practices that enhance the ecological balance of natural systems and that integrate the parts of the farming system into an ecological whole.
- "Organic agriculture practices cannot ensure that products are completely free of residues; however, methods are used to minimize pollution from air, soil and water.
- "Organic food handlers, processors and retailers adhere to standards that maintain the integrity of organic agricultural products. The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals and people."

Essentially, organic farming standards involve a commitment to two guiding principles: ecological production and maintaining product integrity. Ecological production involves building soil quality, minimizing pollution, use of natural pest management, and development of a diverse agroecosystem. These goals can be achieved through a range of management practices, including diverse crop rotations, reduced tillage, cover crops, green manures, compost, and biological and mineral pest control products. The second requirement, maintaining organic integrity, involves actions that prevent the contamination of organic produce with prohibited materials and taking steps that prevent the accidental commingling of organic and conventional products.

Furthermore, compared to many other labels used for food products (such as “natural” or “local”), use of the term “organic” is highly regulated in the United States. To be in compliance, farmers cannot use synthetic fertilizers and pesticides; they must also take precautions against pesticide drift from neighboring farms and other sources of contamination. Typically, equipment and storage areas employed in organic fruit and vegetable farming are dedicated solely to organic use. Farmers seeking to transition from conventional farming to organic farming must by law keep the land free from synthetic fertilizer, pesticides and other prohibited substances for three years prior to the harvest of the first “certified organic” crop (USDA-NOP, 2010).

Since 1980, organic farming has been one of the fastest growing segments of U.S. agriculture (USDA-ERS, 2008). The increase in sales of organic food has been driven mainly by repeated food safety scares, animal welfare concerns, general health concerns, and broader concerns regarding the impact of industrial agriculture on the environment. In addition, the organic food movement is reaching a more mainstream audience and organic consumers now include a wider range of socioeconomic groups (James, Rickard, and Rossman, 2009). Many organic farmers have identified personal health and environmental concerns as motivating factors in their decision to farm organically (Johnson and Toensmeier, 2009). Producers have responded to the boom in consumer demand by increasing the number of organic products. The number of organic products available commercially has grown by 8,593 between 1986 and 2008 (USDA-ERS, 2008). Retail sales of organic foods have undergone a dramatic rise from $3.6 billion in 1997 to $24.8 billion in 2009 as show in Figure 1.1. Figure 1.2 shows that the number of organic fruit and vegetable products introduced annually increased over the same period, and exceeded 60 new products in 2007 and 2008. Fresh organic fruit and vegetable retail sales alone have increased fourfold between 1997 and 2009, and constitute about 38% of total organic sales (OTA, 2010). The USDA does not have consistent data on organic trade because organic product codes have not yet been added to international trade codes (USDA-ERS, 2008). Global organic sales reached $54.9 billion in 2009, up from $50.9 billion in 2008 with the largest markets in the United States, Germany, and France (OTA, 2010). As the organic sector continues to grow, many producers, manufacturers and distributors are expected to continue to expand both nationally and globally (Dimitri, Jaenicke, and Oberholtzer, 2008).

The majority of U.S. farmers interested in converting from conventional farming to organic production have faced barriers to entry because of the high costs associated with conversion and lack of technical knowledge (Wiswall, 2009). During the required three-year transitional period, farmers incur steep upfront costs, but do not receive the price premium of growing a certified organic crop. The upfront costs include potential losses due to high production expenses, reduced yields and reduced prices for lower quality products. Overall, the two major limitations to organic production are time and land, and this thesis will explore the returns to both factors in the analysis.

Despite the rigorous certification process, producers are turning to certified organic farming systems as a way to decrease input costs, lower reliance on nonrenewable resources, capture high-value markets with premium prices, and thereby increase farm income. Consequently the area used to produce certified organic vegetable crops in the United States is increasing rapidly (see Figure 1.3); organic farmland for vegetables has more than doubled in the United States between 1997 and 2005 and anecdotal evidence suggests that it could double again in the next decade. However, production has not kept pace with consumer demand creating periodic shortages of organic produce (USDA-AMS, 2010).

1.4 Purpose and Objectives

The use of systems thinking and integrated management strategies is fundamental to organic agriculture. A variety of strategies that comply with the USDA guidelines of organic production practices can be applied ranging from high input systems to those with greater reliance on internal processes. This thesis examines the economics of four alternative organic cropping systems that comply with USDA guidelines. This analysis compares the profitability and land management capability of four different organic cropping systems used to produce winter squash, cabbage, potatoes and lettuce.

The main objectives are:

- Build interactive crop budgets for each crop
- Compile crop data by system to evaluate whole system profitability and allow for comparisons
- Perform sensitivity analysis on key parameters and determine probability of net returns given different yield distributions

Interactive crop budgets were developed to document both production costs and income streams for each system. I use five years of data from an on-going experiment to analyze the economic effects of four organic cropping systems on yield, farm receipts, production costs, and net returns for cabbage, lettuce, potatoes and squash grown in New York State. The results indicate that individual crops respond differently to the different systems, indicating that a mixed-system approach for various vegetable crops might yield the greatest economic returns. Subsequent sensitivity analyses were performed across a range of key parameters, and the results indicated that profitability was most impacted by income variables. Monte Carlo simulations were run to determine the probability density function of net returns with yields under a normal, gamma and beta distribution. Lastly, this thesis looks at possible commercial applications of the OCS project.

1.5 Summary

Consumer demand for organic food has experienced double digit growth for over a decade for a variety of reasons and continues to grow in New York State and nationally. Fresh fruits and vegetables lead the organically grown food category and continue to outsell other categories. Organic farming can provide vegetable growers in New York State with an enterprise option that can improve economic viability and environmental sustainability. This research seeks to assess the economics of four alternative organic cropping systems that comply with USDA guidelines.

In Chapter 2, I provide a review of the literature with a focus on issues surrounding organic production. Chapter 3 describes the Organic Cropping Systems project and subsequent analysis. The results are presented in Chapter 4, along with findings from the sensitivity analysis. Chapter 5 takes a look at applications of the OCS on small farms, commercial farms, farms employing direct marketing approaches, and urban agriculture. Lastly, Chapter 6 summarizes conclusions and areas for future research.

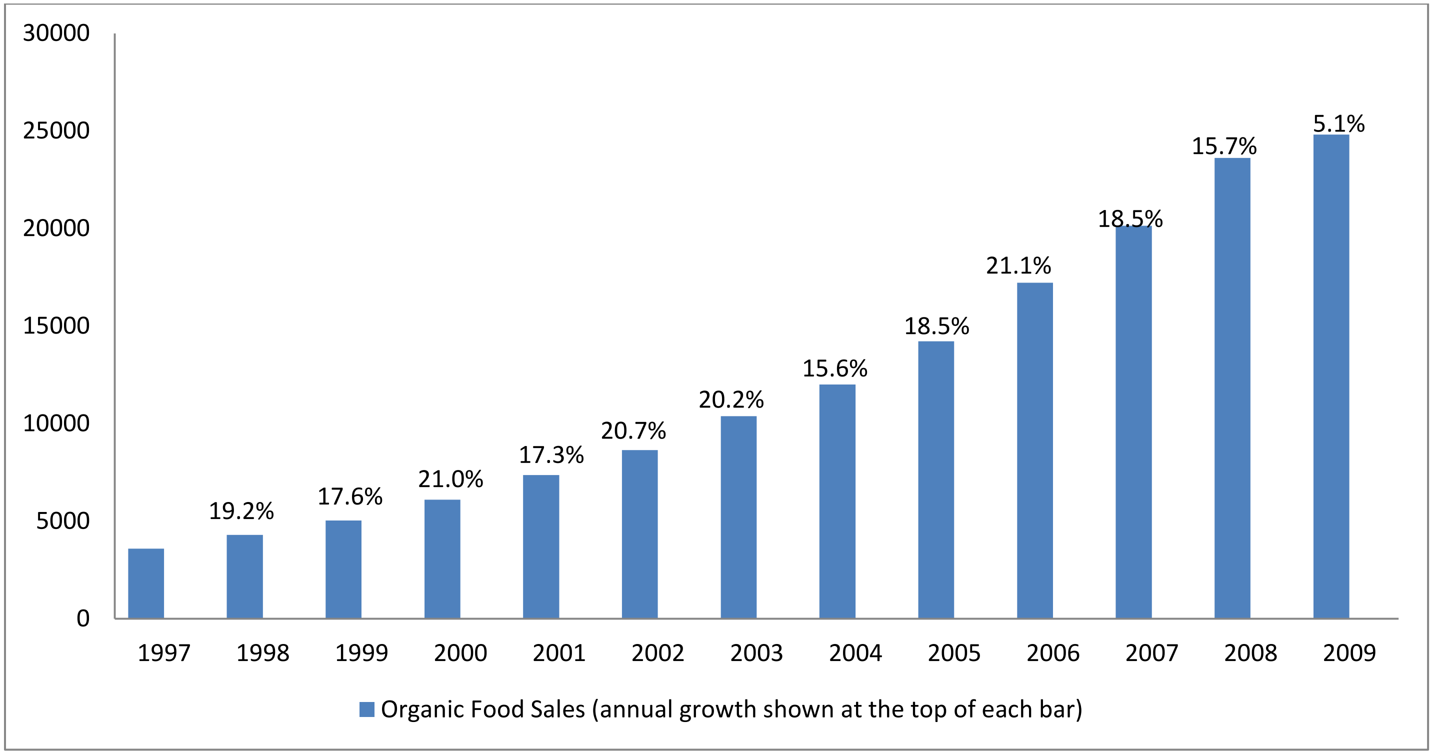


Figure 1.1: U.S. Organic Food Sales: 1997 to 2009 (in millions of dollars)

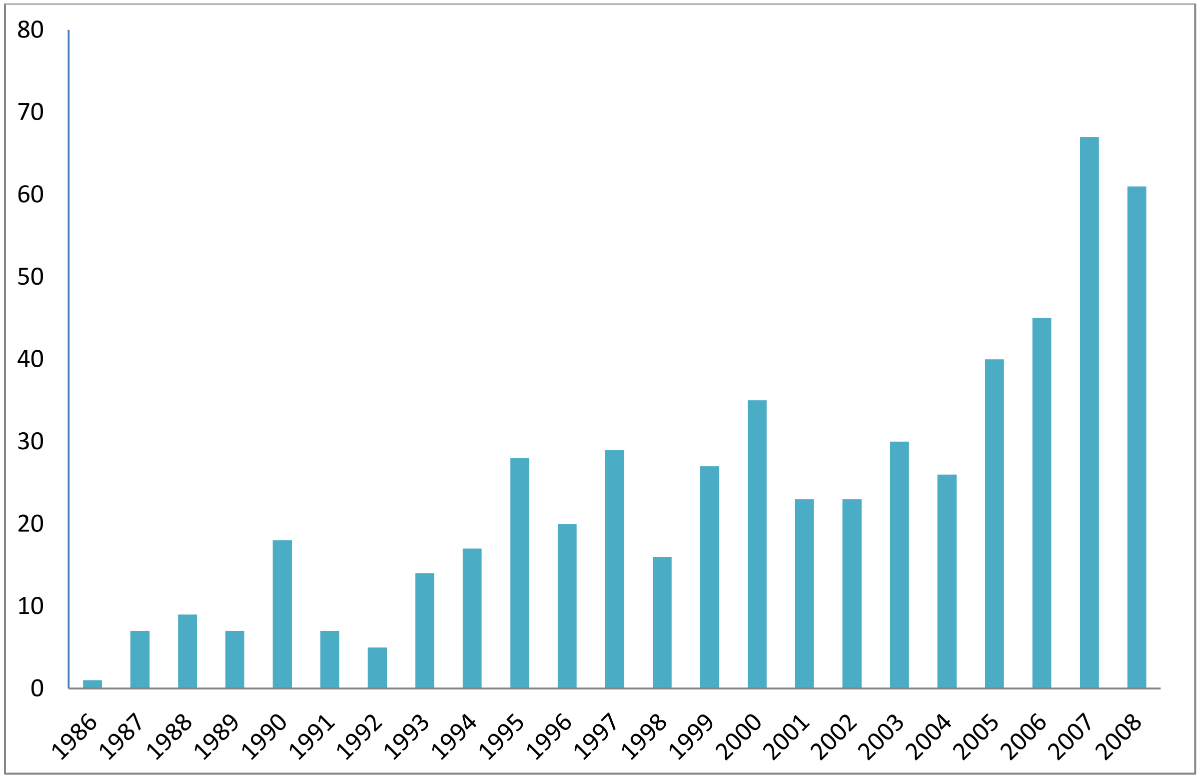


Figure 1.2: The number of new organic fruit and vegetable product introductions in the U.S. retail market: 1986 to 2008

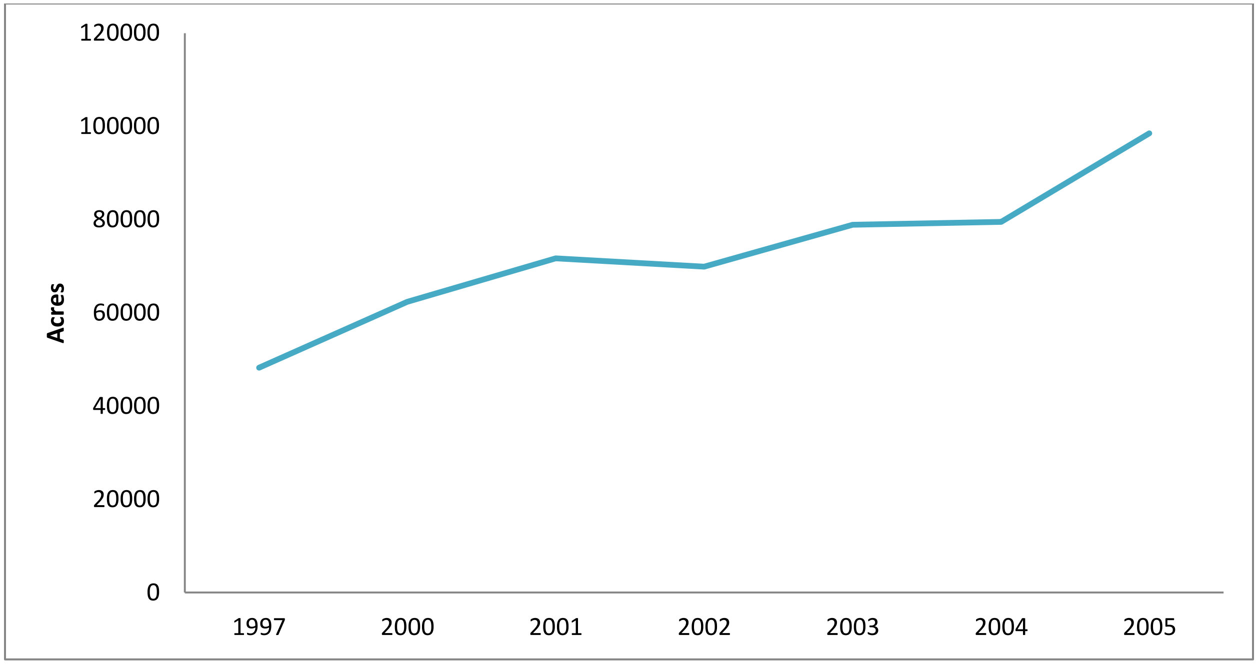


Figure 1.3: Land used for certified organic vegetable crops in the United States: 1997 and 2000 to 2005

CHAPTER 2

LITERATURE REVIEW

Growing interest in organic agriculture has prompted numerous studies in various academic fields characterizing differences between organic and conventional systems in terms of ecological, environmental, nutritional, health and economic conditions. A fraction of these studies are focused on improving organic production systems. Of those studies, most research topics are focused on component processes such as weed suppression rather than a holistic approach analyzing both the production and economic conditions for the individual cropping systems. This paper will place an emphasis on probing into the production economic issues of organic farming.

2.1 Soil Organic Matter and Organic Agriculture

Farming begins with the soil, and generating profit requires managing soil for optimal health, fertility and weed management. Organic practices such as crop rotations build and maintain soil fertility and prevent pest and weed problems. Crop rotation is the practice of growing various crops in the same area to prevent the accumulation of pathogens that develop with monoculture. In addition, the rotation of crops replenishes nitrogen levels and improves soil structure and fertility. After a cash crop is harvested, cover crops are utilized to reduce soil erosion and conserve soil organic matter. Legumes are commonly used as cover crops because they contribute nitrogen to the soil. Soil quality improves proportionally with grass, legume and other cover crops (Johnson and Toensmeier, 2009). Crop rotation is an important agricultural management practice necessary to preserve and improve sustainability, productivity, and resilience of agroecosystems and is central in designing of the organic vegetable cropping experiment.

Maintaining high levels of soil organic matter is especially beneficial and critical on organic farms. Compared to conventional systems, organic cropping systems generally increase soil organic matter, which in turn improves aggregate stability and soil structure, enhances biological nutrient cycling processes and increases bacteria and fungi (Johnson and Toensmeier, 2009). Studies indicate that the amount of soil organic matter is significantly higher on organic farms than in conventional systems on average (Korschens, Weigel and Schulz 1998; Maeder et al. 2002; Shepherd, Harrison, and Webb, 2002). For example, soil organic matter averages 3% to 4% on a non-organic farm, while the organic soil has organic matter between 5.2% to 5.5% (Studdert and Echeverria, 2000). Soil organic matter improves water percolation and infiltration, which reduces soil erosion from surface runoff. In addition, the improved water management diversifies soil food webs and assists in the cycling of nitrogen from biological sources within the soil (Lowenfels and Lewis, 2006). A well balanced soil system plays the dual role of meeting nutrition demands while maintaining the soil organic matter supply to continue the aerobic decomposition process. Soil and rhizosphere microorganisms that thrive in this environment regulate nutrient cycling, organic matter turnover and suppress plant pathogens (Franzlubbers and Haney, 2006).

Soil organic matter not only provides an important source of soil nutrients, but helps increase biodiversity, which in turn provides many essential ecological services such as pest resistance. Earthworms and arthropods construct vertical holes in the soil that facilitate the percolation of water into the soil. The biomass and numbers of arthropods and earthworms are reported to be more than two times prevalent in organic farms than in conventional farms

(Hansen, Alroe and Steen, 2001). The diverse living conditions created from intercropping and crop rotation in organic farms provides a range of housing, breeding and nutritional supply that supports diverse wildlife habitats. Organic farms were found to contain 85% more place species, 33% more bats, 17% more spiders and 5% more birds (Fuller et al., 2005). Pesticides can be extremely toxic to non-target organisms ranging from pollinating bees and insects that provide food to birds, fish and earthworms (Kremen, Williams and Thorp, 2002). Studies suggest that high intensity organic farming is the least detrimental farming system with respect to wildlife conservation and preservation of landscapes (Krebs et al., 1999; Green et al., 2005). Contact zones for neighboring habitats have better protection from pesticide and other off farm drift inputs with organic systems (Bengtsson, Ahnstrom, and Weibull, 2005). Consequently, there are higher levels of biodiversity of floral and faunal surrounding organic farms when compared to their conventional counterparts.

Good soil health is the crux of a well-functioning ecosystem. Within a self-sustaining system managed with organic methods, organic farming provides the backdrop for floral, faunal, habitat, landscape diversity that conventional methods are unable to create.

2.2 Environmental Impacts of Organic Agriculture

In addition to the ecological benefits, organic cropping systems also have environmental benefits. Global climate change is at the forefront of the world’s environmental problems. The main greenhouse gases contributing to global warming include carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Agriculture generates 10% to 12% of anthropogenic greenhouse gases (Niggli et al., 2009). Energy-related CO_2 emissions, resulting from the combustion of petroleum, coal, and natural gas represent the majority of greenhouse gases emissions. Agricultural CO_2 emission comes from energy consumption for the production of fertilizers, transportation of goods, and creating and application of pesticides. Quantitative research conducted by Stolze et al. (2000) estimates that CO_2 emissions are 40% to 60% lower for organic farming systems on a per-hectare scale. Similarly, the Rodale Institute found that organic farming uses 45% less energy than conventional systems which produce 40% more greenhouse gases. Organic agriculture has the ability to sequester carbon and acts as a CO_2 sink via the fixation of crops and creation of soil organic matter. The Rodale Farming Systems Trial found that the organic system sequestered CO_2 more than 4 times the rate of conventional systems. In addition, N_2O and CH_4 emissions are lower on organic farms than conventional farms (Flessa, et al., 2002; Petersen et al., 2006). Soils managed organically with crop rations are more aerated with better soil structure and have significantly lower mobile nitrogen concentrations.

Organic farming techniques also have a less harmful impact on source and groundwater pollution. Agricultural runoff leads to eutrophication and marine ecosystem damage, which creates problems with drinking water and fisheries alike. Empirical studies have demonstrated that organic farms have up to 57% less leaching rates when compared to conventional fields. The percentage can be further increased by improvements in system management including factors such as timing legume removal properly and crop rotation selection (Pacini et al., 2002).

In addition, the environmental effects of soil erosion can be limited by farm management practices. Soil is directly linked to environmental quality through water and air quality, global warming, and production energy uses. Moderate to severe soil degradation are the consequences of traditional soil and crop management practices (Green et al., 2005). While there are off-site, topography and climate conditions that can affect the level of fertile topsoil, changes in soil water dynamics, nutrient levels and amount of soil organic matter, organic farming can reduce soil erosion risks. Some strategies include diverse crop rotation with a high percentage of legume cover crops, year round growing with a high percentage of intercrops, and reducing the number of row crops (e.g. cotton, maize, peanuts).

Based on the literature, organic farming improves upon conventional farming in terms of its effects on climate change, water pollution and soil erosion. A European study whose definition of organic follows the same guiding principles as the U.S. definition concluded, "an increase in the area of organic farming would clearly improve the total environmental and resource use performance of agriculture" (Stolze et al., 2000).

2.3 Health and Organic Agriculture

While there is substantial evidence supporting the environmental benefits of organic food production, there continues to be a debate over its nutritional quality. Secretary Glickman, U.S. Secretary of Agriculture, is quoted as stating, "The organic label is a marketing tool. It is not a statement about food safety. Nor is 'organic' a value judgment about nutrition or quality" (Pollan, 2006, p. 179). However, a study conducted by the European Commission Research found that organic fruits and vegetables contain up to 40% more antioxidants than their conventionally grown counterparts (European Commission Research, 2009). The daily consumption of antioxidants support human health by neutralizing cell damage inflicted by free radicals. Organic farming methods can increase concentrations of antioxidants in fruits, vegetables and grain products and increase in antioxidant intake without the proportional increase in calories. Similarly, Asami et al. (2003) verified these results and added the discovery that organically grown produce have consistently higher levels of vitamin C and polyphenols. Polyphenols play a role in preventing or fighting cancer and exhibit antimicrobial properties. It is theorized that organic plants are products of evolution and produce these compounds to defend against pest, disease and other pathogens (O'Riordan and Cobb, 2000). Other research suggests that chemical fertilizers do not supply the necessary soil matter to synthesize vitamin and antioxidant production. Overall, studies indicate that organic fruits and vegetables contribute more of necessary nutrition and vitamins to support a healthy lifestyle and diet.

Organic systems may not only provide more nutrition, but may also prevent problems from consuming food contaminated with chemicals or other unknown substances. Heavy agricultural reliance on synthetic-chemical fertilizers and pesticides can have serious impacts on public health. Public health concerns, animal poisonings/deaths, damage to adjacent crops, environmental problems and many other factors contribute to a social cost of more than $12 billion in addition to the $10 billion spent on application of pesticides (Pimentel, 2005). Synthetic pesticide exposure has been identified as a major risk factor in the development of neurological conditions including ADHD, autism, and Alzheimer's disease. The toxicity of pesticides is also linked with impairment of immune functions and other health problems that can take years to develop. Children are particularly susceptible to poisoning because they cannot detoxify pesticides at the same rates as adults. The risk of synthetic pesticide exposure is greatly reduced with organic farming because it is a prohibited input and care is taken to prevent the mixing of conventional and organic goods. Consequently, consumers can minimize pesticide dietary exposure through the consumption of organic food. The new proteins in non-organic food could potentially act as allergens or toxins or alter the metabolism of the plant or animal creating a cycle of new toxin and allergy production (Altieri and Rosset, 1999).

2.4 Organic Agriculture and Yields

While organic foods appear to be safer, the production levels of marketable yields are often questioned. Another main criticism of organic agriculture claims that organic farming cannot produce comparable conventional farming yields to ensure the global food security. Badgley et al. (2006) found that the average yield ratio for organic:non-organic food ranged from 0.816 to 3.995 globally. Organic fruit and vegetable production more than doubled yields from conventional farming in developing countries, while the ratio was slightly less than one in developed countries. The research suggests that countries most susceptible to food insecurity may stand to gain the greatest benefits from implementing organic cropping methods. Overall, the world ratio for vegetables was estimated to be 1.064 and 2.080 supporting the idea that organic farming of these essential crops would be more than sufficient to feed the growing world population. In addition, the researchers believe that their calculations underestimate actual output from organic farms because they do not take into account polycultures and multiple cropping systems, which would result in higher production per unit when compared to monoculture.

Similar findings in the Rodale Institute's Farming Systems Trial, a study comparing organic and chemical agriculture since 1981, showed that organic yields matched those of nonorganic crops and production levels were greater in periods of drought (Rodale Institute, 2011). One of the longest running organic trials, the Broadbalk experiment at the Rothhamsted Experiment Station have found that wheat yields were higher in organic plots than plots receiving chemical fertilizers. The increase in yield could be attributed to improved soil quality based on greater accumulation of soil carbon (Johnston, Poulton, and Coleman, 2009). Organic practices would also improve soil fertility and biological pest management. Perfecto and Badgley (2007) found that organic farming can yield up to three times as much food as conventional farming on the same amount of land. These yields were made possible by the use of cover crops, which provide enough nitrogen to farm with organic methods instead of synthetic fertilizer (Perfecto and Badgely, 2007). Another United Nations (UN) supported report complied by 400 international experts concluded that radical change in current food systems are necessary to meet future demand. The report called for governments to focus on small scale farmers and sustainable practices, including organic farming (United Nations, 2009). Yield levels were estimated to be higher on smaller farms than on larger farms, which suggest that increasing the number of smaller farms would lead to an increase in food production. In the United States, small and medium sized farmers represent more than 90% of total farm numbers and manage about half of U.S. farmland. Several studies conducted by the UN also found that organic and transitioning to organic farms (including farms transitioning to organic farming) saw yield increases of more than 100% utilizing low cost and locally available technologies and inputs (United Nations, 2007). Another UN report found that organic farming and other agroecological approaches can raise productivity at the field level, improve nutrition and reduce rural poverty (United Nations, 2010). Organic farming is more labor intensive than conventional farming, and mass adoption could assist with alleviation of rural unemployment over the growing season. On-farm fertility generation reduces reliance on external input, state subsidies and moneylenders, which reduces input costs for the farm manager. The results of these studies and many others show that organic farming is a viable and sustainable alternative to conventional farming.

With trade and the continual improvement of technology, organic food systems may be able to produce more yields than conventional farms, but may do so in a more sustainable process. Organic agricultural methods can help preserve small family farms, increase farm productivity, connect local sustainable distribution networks and ultimately improve food security globally.

Long-term experiments have demonstrated that organic yields are at least comparable to conventional yields. The higher yields can be attributed to organic management practices such as crop rotation, cover crops and improved soil organic matter. The OCS simulates real farms that follow differing approaches to organic management with the objective of measuring the effect of these systems on economics.

2.5 The Economics of Organic Agriculture

Several studies have examined various production issues related to organic agriculture and agricultural systems that use fewer pesticides and chemicals (e.g., Olesen et al., 2002; Schoofs et al., 2005). Of those focused on improving organic systems, most investigate one component such as fertility management or weed suppression rather than whole system properties including profitability and the economic effects of alternative farm management practices.

Much of the economic literature concerning organic agriculture focuses on consumers' willingness to pay for organic produce relative to conventional food products (e.g., Loureiro, McCluskey, and Mittelhammer, 2001; Giraud, Bond, and Bond, 2005; Hu, Woods, and Bastin, 2009). Organic food often sells for higher prices than conventionally produced produce. The price premium is the culmination of higher production costs as well as the consumer's willingness to pay extra for the organic label. High price premiums usually indicate high demand, attracting more producers to the organic sector. The USDA-ERS (2008) found that the price premium was 30% or less for the majority of organic produce when compared to their conventional counterparts. The demographic of the organic consumer is as diverse as organic marketing channels. The public and private sectors have conducted several surveys to identify the purchasing habits of consumers of organic food products. While results have varied depending on sample size, geographic coverage and the type of survey used, many studies indicate that organic foods are becoming more mainstream. According to the research of Dettman and Dimitri (2010), consumers with higher levels of education and higher income were more likely to purchase organic vegetables. Their findings determined that the percentage of organic expenditures increased with higher education levels, while increases to household income decreased spending on organic vegetables proportionate to overall vegetable purchases. Conversely, African Americans and consumers over the age of 50 were less likely to purchase organic vegetables (Dettmann and Dimitri, 2010).

Also, a growing body of literature investigates a wide range of consumer issues in organic and other niche markets (e.g. Umberger, Thilmany-McFadden, and Smith, 2009; Wang, Curtis, and Moeltner, 2011). These studies analyze the social dimensions of organic in comparison to other ecofriendly labels. Niche market terms such as food miles, local, and biodynamic are not formally regulated leading to different interpretations by consumers. While consumer perception on the importance of organic in relation to other niche market labels is debatable, studies tend to agree that demand for organic will continue to rise and consumers will continue to pay a price premium for productions containing the organic label.

Much less work has examined the economics of producing organic crops, and the economics of transitioning into organic production. Most of the economic research in this area has focused on grain crops (e.g., Delate et al. 2003; Cavigelli et al. 2009; McBride and Greene, 2009) rather than vegetables crops. This thesis begins to address this imbalance as it specifically examines the costs and benefits of four contrasting approaches to small-scale organic vegetable production.

2.6 Enterprise Budgets

A better understanding of the effect of management practices on income and costs is critical in assisting farmers with making decisions. This thesis calculates crop receipts, costs, net returns to land, and returns to labor for vegetable crops under four alternative cropping systems. Results from our crop budgets highlight potential returns across the systems; in addition, a sensitivity analysis is used to examine how small changes in prices, yields, and input costs impact farm profitability.

There are many examples of enterprise budgets for conventional vegetable production in the United States (e.g., Delate et al., 2003; Molinar et al., 2005; Tourte et al., 2009); however, the results typically rely on survey information from producers in a single year. Variations in profitability among different crop budgets are mostly attributable to labor costs and regional costs of growing these crops. In addition, different estimates for retail and wholesale prices contributed to variation in net returns. Conner and Rangarajan (2009) studied costs in two differently managed organic farming systems and their results indicated that costs per acre differed greatly due to crop rotation, scale, marketing, and production costs. Similarly, Ogbuchiekwe et al. (2004) found that lettuce and cantaloupe yield and net return were greatly affected by crop management practices. Jacobsen, Escalante and Jordan (2010) analyzed 10 different organic production systems in the Southeast in terms of productivity, profitability and carbon sequestration potential and found that while yields differences were not significant, the difference in returns was economically significant. This thesis extends the analyses in these studies to compare different organic production methods across different years and crops in New York, and specifically targets such questions for small-scale farms. Our approach accounts for crop rotation schedules and diverse organic management systems, and sheds some new light on profitability questions for organic vegetable producers in the Northeast. This research should aid both established organic producers and those who are considering a shift to organic production.

Researchers have used enterprise budgets to address profitability questions in agriculture, and to track how changes in inputs affect yields and ultimately farm-level revenue. Delate, Cambardella, and McKern (2008) compared conventional and organic bell pepper growth and yields using strip-tilled or fully incorporated cover crops. Burket, Hemphill and Dick (1997) investigated the effect of cover crops and crop rotation on vegetable productivity. Another study evaluated agroecological and economic effects of “integrated” and organic fruit production (Peck, Merwin and Brown, 2010). In addition, a series of studies examining costs of production for organic crops have been done by researchers at the University of California, Davis (e.g., Tourte et al., 2009), yet these typically focus on large farming operations that include both organic and conventional production methods. Building on these past models, this paper will follow a similar methodology, but with the additional goal of analyzing the effect of differing inputs and practices on yield and profitability for organic vegetable crops.

2.7 Sensitivity Analysis

Enterprise budgets enable researchers to easily conduct a sensitivity analysis to gain more insight about profitability conditions. Vegetable production is characterized by a high level of risk due to yield and price variability. Previous studies (Musser et al., 1981; Hanson et al., 1993) have developed a safety-first criterion, which focuses on the probability of achieving a target minimum level of returns. In other words, this approach is equivalent to maximizing expected profits, where the profits are a proxy for utility. A risk averse farmer would expect returns to fall below a lower limit or confidence interval. Once a baseline set of results have been calculated, a sensitivity analysis will be performed. A commonly used type of sensitivity analysis is independent parameter perturbation in which parameters are varied individually by a fixed percentage around a base value (Ferreira et al., 1995). Here I look at both upper and lower bounds of several production inputs to estimate the possible range of net returns. In addition, key parameters in the model will be identified and variations in how those parameters impact profitability will be measured.

Important results in statistical analyses assume that the sample population is normally distributed, has a common variance and additive error structure. Farm level yield data is often limited and complicated by the correlation of yields across farms due to environmental factors. As such, several studies have addressed the distribution of crop yield with conflicting results in terms of positive and negative skewness (Day, 1965; Anderson, 1974; Swinton and King, 1991; Ramirez, Misra and Field, 2001). In contrast, Just and Weninger (1999) prescribe a normal distribution to the distribution of residual farm variability and argue that previous studies failed to adjust for yield trends and indicated other statistical testing problems. In these studies, parametric approaches are usually preferred due to small samples. A Monte Carlo simulation model can be used to estimate the economic impacts of each cropping system with a distribution of possible crop yields to generate a distribution of potential net incomes based on historical data. From these different distributions, the probability of the ranges determined in the sensitivity analysis can be calculated. Monte Carlo simulations are frequently utilized in the crop insurance literature, which assume normality. Since a consensus has not been reached, this thesis will model normal distributions and selected non-normal distributions.

2.8 Summary

In summary, the vast literature suggests that organic cropping systems are able to maintain ecological integrity, contribute to environmental stewardship, and provide economic benefits. Within the realm of organic production systems a variety of strategies can be applied. I seek to enable producers to assess their profitability in organic markets by developing cost studies that outline the financial implications of adopting each of the system examined in the project. Following the framework used in the past, enterprise budgets will be created. To improve upon static models that are currently available to growers, these models are designed to dynamically incorporate differences in field operations, inputs and crop performance. Finally, parametric sensitivity analyses will be performed on the baseline results to determine a range of possible net operator returns.

This thesis seeks to build upon on the literature by facilitating development of organic agriculture production for vegetables, evaluating the potential economic benefits to producers who use organic methods and conduct advanced on farm research. There is a knowledge gap in the role of various organic management strategies in determining crop yields. There are a number of systems experiments in a variety of climatic regimes that address either grain or, less frequently, vegetable systems, but none that simulated the novel farm innovations included in this study. Understanding the impact of management systems on yields as well as production costs of crops is critical for farm production and pricing decisions. This long-term holistic approach can shed some light on farmer issues by analyzing synergies and tradeoffs among rotations, cover crops, soil fertility, weeds, pests and economics. Organic farmers are continuously seeking new ways to improve their cropping systems with alternative management options and new cover crops. The results from this research can inform organic farmers to develop viable and profitable farm plans to meet NOP organic certification requirements.

CHAPTER 3

THE ORGANIC CROPPING SYSTEMS PROJECT

With the increasing demand for organic produce, there is a critical need for long-term cropping systems that accurately simulate organic farming systems. Only through this type of experimental design can we analyze how different management practices changes soil, which ultimately determines crop quality, yields and economic returns.

3.1 A Description of the Cropping Systems

From its inception, the project has been a collaborative multidisciplinary effort between farmers and researchers. The organic cropping systems (OCS) used in this experiment were developed by scientists and farmers in the Northeast to represent well-managed but contrasting organic vegetable production systems. The expert farmers manage farms that achieve consistently good yields and have low weed, insect and pathogen problems, despite minimal off-farm inputs. Four systems are described and analyzed here. Three systems use easily adopted methods for mass replication by commercial organic growers, while one uses highly specialized equipment that is not commercially available. The experiment is conducted on a gravelly loam soil on a certified organic experiment station farm near Freeville, New York.

The OCS were designed to emulate real-world producer decisions and practices, and consisted of four distinctive systems. In the experiment, environmental factors (soil and climate) are held constant, as are pest management, crop varieties and irrigation. The four systems varied in terms of their use of land and labor, and this thesis will explicitly measure returns to both factors of production in the analysis. The experiment uses a randomized split-plot design with four cropping systems as the main plot factor, two entry points into the four-year crop rotation as the split-plot factor, and four replicate blocks for a total of 32 plots. Each plot is 25 feet by 65 feet. The systems follow a similar basic rotation of cash crops involving cabbage, lettuce, potatoes, and winter squash (as shown in Figure 3.1). Sweet corn was originally one of the four vegetable crops included in the experiment, but was replaced with squash after the crop on 2005 to better reflect organic vegetable production patterns in the Northeast. Some additional short season crops are interpolated into one system and fallow and cover crops are substituted for certain crops in another system.

System 1 is the High Intensity Cropping System. This simulates farms with limited arable land and focuses on maximizing income via intensive cropping. In addition to cabbage, lettuce, potatoes, and winter squash, this system includes two additional cash crops. Snap peas are grown before cabbage and spinach is grown after lettuce for a total of six crops in four years. Compost is the primary nutrient source. Moldboard plow, rotary tiller, chisel plow, and harrows are used for tillage. Weeds are controlled primarily by cultivation.

System 2 is the Intermediate Intensity Cropping System. It simulates a relatively land-limited farm, but obtains most of its nitrogen from legume cover crops. A single cash crop is grown annually. Similar to System 1 (High Intensity), weed competition is limited by cultivation, but additional preventative weed management measures are also used.

System 3 is the Bio-extensive Cropping System in which cash crops are grown every other year. In the alternate years, cover crops and fallow periods build soil organic matter and are used to reduce the weed seed bank. Nitrogen is primarily derived from legume cover crops. Shallow plowing and rotary tilling are used to reduce tillage. This system flushes weeds out of the weed seed bank and prevents further weed seed production by hand rogueing weeds that escape cultivation. It simulates a farm that is substituting land for other inputs and is modeled after a well-established farm in Pennsylvania (Nordell and Nordell, 2007).

System 4 is the Ridge-till Cropping System, which uses ridge tillage instead of plowing. One crop is grown each year, and cover cropping practices are similar to the Intermediate Intensity Cropping System. Ridges are built with a potato hiller after crop harvest, and the cover crops are scraped into the valleys prior to planting the next crop (see Figure 3.2). This system reduces the degree of soil disturbance and the energy used for tillage relative to other systems. The ridge bases are undisturbed by tillage or wheel traffic to improve soil quality in the crop row. Nitrogen is provided mostly from cover crops. Ridge tillage is not a typical practice in vegetable production, and ridge scraping equipment, while simple, is not widely used.

The cropping systems differ in tillage methods, cover crops, cropping intensity, applied nutrients, and weed management strategies. Legume cover crops include hairy vetch, red clover, field peas and bell beans. Non-legume cover crops including rye, wheat and buckwheat are also grown in the experiment. Compost applications very based on the estimated nitrogen input derived from cover crops and the nitrogen needs on the cash crop. Environmental factors such as soil and climate are held constant, as are pest management, crop varieties and irrigation. This study seeks to retain the weed management, nutrient, and soil quality benefits of System 3 (Bio-extensive) but investigate ways or growing more frequent cash crops. Cropping intensities vary across the four systems. System 1 (High Intensity) produces six crops in four years, System 2 (Intermediate Intensity) and System 4 (Ridge-till) produce one cash crop per year, and System 3 (Bio-extensive) produces two cash crops in four years. The degree of inversion during tillage is highest in System 1 (High Intensity) and lowest in System 4 (Ridge-till). Pairwise comparisons of System 2 (Intermediate Intensity) and System 3 (Bio-extensive) provide insight into the benefits of fallowing for weed control and soil quality. Comparing System 1 (High Intensity) and System 2 (Intermediate Intensity) yields information on the effect of nutrient inputs on various soil parameters and biological populations. The comparison between System 2 (Intermediate Intensity) and System 4 (Ridge-till) allows for a test of the benefits of reduced tillage on the development of soil quality, and possible reductions in labor and energy usage.

3.2 The Agronomy of the OCS

The organic cropping rotation began with transplanting cabbage as the main cash crop in 2005 utilizing System 1 (High Intensity), System 2 (Intermediate Intensity) and System 4 (Ridge-till) in Entry Point 1. The cabbage was transplanted in mid-July. It should be noted that plants in System 1 (High Intensity) were visibly smaller for several weeks. System 1 (High Intensity) produced 51,700 pounds per acre of marketable cabbage. System 2 (Intermediate Intensity) and 4 produced 54,100 and 51,300 pounds of cabbage per acre respectively. In 2005, sweet corn was planted in Entry Point 2, but in 2009 was replaced with squash, a more suitable crop for the region, in a unanimous decision made by the research team and farm advisory group.

In the following year, lettuce transplants were grown as the main crop in an organically managed plastic greenhouse to be planted in all four systems. Two varieties of lettuce were grown; Ermosa, a green butterhead lettuce, and New Red Fire, a red leaf, was seeded in early April and harvested in late June through early July. System 1 (High Intensity) yielded 21,400 marketable heads of New Red Fire lettuce per acre and 21,800 marketable heads of Ermosa. A cover crop was not planted over the winter, but the plots had residue from the previous years late cabbage crop and overwintered chickweed, which was plowed under and disced in mid-April. Three tons of compost per acre was applied in early May. After the lettuce cultivation, melody spinach was planted, which produced 9,600 marketable pounds per acre. System 2 (Intermediate

Intensity), an early lettuce main crop followed by a field pea/soybean cover crop produced more New Red Fire lettuce but less Ermosa lettuce compared to System 1 (High Intensity). In 2006, 23,200 marketable heads of New Red Fire lettuce and 18,200 marketable heads per acre of Ermosa lettuce were harvested from System 2 (Intermediate Intensity). The plots had a cover crop of winterkilled bell beans and residue from the previous cabbage crop and chickweed. Pre-plant tillage, planting, cultivation and hoeing were identical to the process used in System 1 (High Intensity). System 3 (Bio-extensive) yielded less New Red Fire (19,100 marketable heads per acre) and Ermosa lettuce (16,200 marketable heads per acre) than the other systems that year. The System 3 (Bio-extensive) cash crop was lettuce, followed by a planting of rye and vetch cover crops. Cabbage was not planted in the previous spring and instead, oats and field peas were used to improve soil fertility. Three fresh tons per acre of compost was applied to the field in mid-April. After the lettuce was cultivated, rye and hairy vetch cover cropped for the next season. System 4 (Ridge-till) had the lowest lettuce yield of all the systems in 2006. System 4 (Ridge-till), an early lettuce main crop followed by field pea/soybean cover crops, yielded 17,200 marketable heads per acre of New Red Fire lettuce and 15,000 marketable heads per acre of Ermosa lettuce. These plots begin in the spring with low ridges covered by cabbage and bell bean residue with some chickweed plants. The chickweed between the rides was flame weeded in mid-April. The ridges were reformed shortly after then seeded with soybeans and field peas. The stand of peas and soybeans grew well and outperformed that of System 2 (Intermediate Intensity), which was not ridged.

In 2006, cabbage was the main crop grown in entry point 2. As with the previous year, Farao cabbage transplants were grown in an organically managed plastic greenhouse. They were seeded in early June without fertilizer. The cabbage yield data was collected in early October and the yields were very similar to the results in 2005. System 1 (High Intensity) produced 7,200 marketable pounds per acre of snap peas and 37,000 marketable pounds per acre of cabbage. These plots were covered with winter rye before planting. The peas were seeded in late April and harvested two months later. Cabbage was transplanted in mid-July about a week after the other systems. The cabbage crop was cultivated in early September. System 2 (Intermediate Intensity) had a comparable cabbage yield of 36,200 marketable pounds per acre. System two had a cover crop of hairy vetch and wheat. Both crops grew strongly, producing 5,200 pounds per acre and 1,000 pounds per acre respectively. As with System 1 (High Intensity), the cabbage was transplanted in July and the final cultivation of the cabbage was in early September. Bell beans were interseeded with the cabbage. System 3 (Bio-extensive) was fallow for this rotation. These plots had a mix of rye and spelt cover crops over the winter. The cover crops were flail mowed then seeded with oats and peas in preparation for next year's lettuce crop. System 4 (Ridge-till) produced the highest marketable yield of cabbage in 2006 with 39,700 pounds per acre. Hairy vetch and oats covered the field and grew strongly before it was fail mowed. The ridges were scrapped in the end of June, reformed in early July and scraped again in mid-July. The extra ridging helped to control weeds. Cabbage was transplanted after the last scrapping. The cabbage was cultivated from the plots in September, which were then seeded with bell beans.

In 2007, potatoes were the main cash crop for the organic systems vegetable trial in Entry Point 1. The potatoes were planted and cut by hand in early May. The potatoes emerged slowly due to the cool and dry weather and were harvested by mid-August. System 1 (High Intensity) yielded 18,100 marketable pounds per acre of Yukon Gold potatoes, 411 dry pounds per acre of rye spring cover crop and 2,382 dry pounds per acre of rye fall cover crop. The rye cover crop was planted late the previous fall and remained over winter. System 2 (Intermediate Intensity) had additional cover crops including wheat and hairy vetch. This system produced 14,400 marketable pounds of potatoes per acre, 475 dry pounds per acre of rye, 1,759 dry pounds per acre of wheat and 487 dry pounds per acre of hairy vetch. Rye was planted instead of field pea and soybeans because of chickweed pressure. System 3 (Bio-extensive) was fallow for this rotation. Rye, buckwheat and red clover were used as cover crops for the spring, summer and fall respectively. System 4 (Ridge-till) consisted of ridge till potatoes, and cover crops of oats and hairy vetch. System 4 (Ridge-till) under performed System 1 (High Intensity) and System 2 (Intermediate Intensity), and had a marketable yield of 10,600 pounds of potatoes per acre. Field peas and soybeans covered the ridge plots over the winter and were scraped off in early May. System 4 (Ridge-till) also yielded 2,307 dry pounds per acre of oats and 259 dry pounds per acre of hairy vetch.

The main crop of Entry Point 2 in 2007 was lettuce. Ermosa and New Red Fire lettuce varieties were seeded in an organically managed greenhouse in mid-April and harvested in July. The cover crops were handled differently for each system. System 1 (High Intensity) produced 10,283 marketable heads of Ermosa lettuce and 6,499 heads of New Red Fire lettuce per acre. In addition, 3,978 pounds per acre of spinach was harvested. Residue cabbage and chickweed covered the plots over the winter. This year the stand was poor which was probably attributed to excessive temperatures. System 2 (Intermediate Intensity) had a higher marketable yield of Ermosa lettuce (9,991 heads per acre), but a lower yield of New Red Fire lettuce (11,176 heads per acre) when compared to System 1 (High Intensity). The lettuce cash crop was followed by a buckwheat and red clover cover crop. As with System 1 (High Intensity), residual cabbage and chickweed with the addition of bell bean covered the plots over the winter. After the lettuce was harvested, a cover crop of buckwheat was planted. System 3 (Bio-extensive) grew lettuce followed by buckwheat and rye. System 3 (Bio-extensive) was the most successful in growing New Red Fire in this trial. In this system, 14,255 heads of Ermosa were marketable per acre, while 10,579 heads of New Red Fire was produced. Rye covered the plots over the winter. The crop was grown and harvested in a similar fashion as the other systems. System 4 (Ridge-till) produced the most Ermosa lettuce with 14,772 marketable heads per acre. The New Red Fire crop was also successful and 10,201 heads per acre were produced. Remaining cabbage, bell bean and chickweed covered the plots over the winter. The plots were re-ridged in early May and scraped at the end of the month. Three tons per acre of compost was applied. The lettuce was also transplanted at the end of May. The ridges were then scrapped in mid-August for planting of oats and peas.

The vegetable crops grown in 2008 completed a full crop rotation. The cash crop for Entry Point 1 was Delicata winter squash. The squash was planted in a certified organic greenhouse in mid-May and transplanted into the field in early June. System 1 (High Intensity) was transplanted into black plastic and the others into pre-made furrows. The harvest data was collected in mid-September. System 1(High Intensity) had no fall cover crop, but a spring cover crop of rye which coved the plots over the winter. System 1 (High Intensity) produced the lowest yield, 6,302 pounds of marketable squash and 74,000 pounds of rye per acre. System 2 (Intermediate Intensity), which was a squash crop followed by oats and peas, yielded more produce. 10,157 marketable pounds per acre of squash was harvested along with 2,944 dry pounds of wheat and 2,146 dry pounds of hairy vetch. Wheat and hairy vetch provided a cover crop over the winter. The crop was grown in the same manner as System 1 (High Intensity). The oats and peas were planted in October. System 3 (Bio-extensive) improved on the marketable yield compared to the previous systems and had the highest cash crop yield this year. In this year, 12,750 marketable pounds of squash was produced per acre. Medium red clover served as a cover crop over the winter, which yielded 1,759 dry pounds per acre. Rye was planted as a fall cover crop in November. In System 4 (Ridge-till), ridge till squash followed by oats and peas, did not fare as well, and produced 7,113 marketable pounds of squash per acre. The spring cover crops of hairy vetch produced 2,144 dry pounds per acre while the oats yielded 2,307 dry pounds, which was removed in late May. The ridges were then scraped in early June and areas between rows were ridged at the end of the month. The ridges were scraped again in July. The squash was otherwise grown under the same conditions as the rest of the systems. The oats and peas were planted in early October, which was earlier than the accepted optimal planting dates and re-ridged.

Potatoes were planted as the main crop in the second Entry Point in 2008. The potatoes were planted and cut by hand in mid-May. As with the previous year, the potatoes were slow to emerge because of the dry and cool weather conditions. The potatoes were cultivated in mid-June and hilled in early July then harvested in early September. System 1 (High Intensity) had a rye cover crop on the plots over winter, which was planted late the previous fall. In early May, 11.6 tons per acre of compost was and 13,200 pounds of potatoes per acre were marketable. The spring cover crop of rye yielded 365 dry pounds per acre. System 2 (Intermediate Intensity) had the highest marketable yield of potatoes per acre (20,300). The system followed the harvesting of potatoes with the planting of wheat and hairy vetch. In the spring there was a good cover crop of red clover, which was plowed in May. Compost was spread at 5.8 tons per acre in early May. The potato management followed the previous system. The wheat and hairy vetch was planted in early September. System 3 (Bio-extensive) was fallow with a spring cover crop of rye and a summer/fall cover crop of buckwheat. As with the other systems, rye was planted in the previous fall and a disc was used to turn the crop at the end of July. At this time, buckwheat was broad cast and flail mowed in early September. Red clover was planted in its place. An estimated 4,000 dry pounds per acre of rye was produced and 1,500 dry pounds of buckwheat under System 3 (Bio-extensive). The ridge till potato System 4 (Ridge-till) had the lowest marketable potato yield (11,900 pounds per acre). This system had a spring cover crop of oats and peas that covered the plots over the winter. The ridges were scraped in early May and 5.8 tons of compost was applied. The ridges were reformed in early September and planted with oats and hair vetch.

In 2009, the 6th year of the study, cabbage was the main cash crop planted in the first rotation entry point. System 1 (High Intensity) yielded 63,476 marketable pounds per acre of cabbage; these plots were bare over winter after the 2008 squash harvest and seeded in early spring with inoculated ‘Sugar Sprint’ snap peas. However, the stand was poor and the plots were replanted to ‘Renegade’ spinach. The cabbage crop was transplanted after spinach harvest in early July, and harvested in mid-October. System 2 (Intermediate Intensity) followed a similar regime of transplanting, cultivation, and hand hoeing for cabbage, but was preceded by a cover crop of oats and peas. It yielded less marketable pounds of cabbage per acre than System 1 (High Intensity). System 3 (Bio-extensive) deviated from the previous two systems because 2009 was a fallow year and the cabbage cash crop was not grown, therefore the results will not be presented for cabbage production for this system. In the 2009 trial, System 4 (Ridge-till) yielded the lowest marketable pounds per acre of cabbage. Similar to System 3 (Bio-extensive), a spring cover crop of oats and peas were utilized in System 4 (Ridge-till).

The cash crop for the second rotation entry point in 2009 was winter squash. Plants were transplanted into black plastic in System 1 (High Intensity) in early June following a spring cover crop of rye, and harvested in mid-September. System 1 (High Intensity) yielded 11,002 marketable pounds per acre of squash. System 2 (Intermediate Intensity) had a lower yield of squash than System 1 (High Intensity), with 7,909 marketable pounds per acre, following a cover crop of wheat and hairy vetch. System 3 (Bio-extensive) had a higher total marketable yield per acre of 12,156 than System 2 (Intermediate Intensity), following a cover crop of red clover. System 4 (Ridge-till), the ridge tillage squash, had the highest total yield of 12,820 marketable pounds per acre following a fall-planted cover crop of hairy vetch and fall oats covering the plots over the winter.

The OCS is an ongoing experiment; it is replicating the rotation described above between 2009 and 2012. In order to analyze the systems in complete crop rotations, the incomplete data from the OCS for the third and fourth rotations between 2009 and 2013 has been omitted from this study.

3.3 Approach to Comparing Organic Management Systems

Farmers, extension agents, and economists working with agricultural production often use and present data in the form of an enterprise budget. An enterprise budget is an interactive tool which allows the user to enter input levels. Most enterprise budgets are modeled with one crop; however, this experiment will create an enterprise budget for organic farmers who employ crop rotation. This will allow the user to model differences in field operations, inputs and crop performance interactively. For example, lower yields will be adjusted for lower costs. The economic analysis used here develops a framework to outline the financial implications of adopting each of the organic cropping systems for the crop rotation using field-level data between 2005 and 2009. The first entry point began in 2005 producing cabbage, and it followed with the production of lettuce in 2006. A second entry point was introduced in 2006 and it also began producing cabbage. This analysis enables a comparison of the effect of different crop management treatments on yield, total receipts, three cost categories, and net returns.

Costs and receipts are based on a small scale farm with some mechanization, in which the operator performs all labor and crops are marketed at retail prices. Total costs are subdivided into mechanical costs, material costs and marketing costs. For simplicity, it is assumed that marketing costs are equal to 20% of gross receipts (this assumption will be explored in detail in Chapter 5). Receipts are based on yields observed in the OCS experiment and prices reported by members of the farm advisory team and published regional reports that survey prices at local farm markets. Prices used here reflect average prices received at local farmer’s markets. The total receipts reported in the analysis assume that 90% of the observed yields are actually sold; this is done to account for a portion of the crop that is commonly not harvested on retail-oriented vegetable farms. The prices used here are considered to be conservative by the advisory team, but the analysis uses these prices so as not to overestimate the potential net returns. As organic produce becomes more common, the price differential between organic and conventional prices will likely fall, and this is another reason to use conservative prices in the analysis. However, the analysis also considers the effects of higher and lower prices on net returns in a sensitivity analysis. In the analysis, the average costs are calculated to produce each crop in each system using the two years of data collected; this was done to reduce year-to-year fluctuations that were observed. The analysis also averaged yields. For example, yield and cost data for cabbage from 2005 and 2006 were averaged.

System 1 (High Intensity) and System 3 (Bio-extensive) required special attention since they had more and less than one cash crop per season, respectively. In the case of System 1 (High Intensity), the second cash crop receipts and expenses were averaged and added to those of the main cash crop each year. So, income and costs for spinach were combined with those for lettuce, and similarly, income and costs for snap peas were combined with those for cabbage. System 3 (Bio-extensive) was more complicated. Two-year averaged receipts and expenses for 0.05 acres of the cash crop plus average expenses for 0.05 acres of the previous fallow year were added together to assess the economics for 0.1 acres of managed area needed to produce the cash crop.

A key advantage of the model is that it is integrated; information on costs related to field operations, inputs and crop performance are inter-connected, and are used to calculate net returns. A lower yield for a crop will result in an associated decrease in labor costs for harvesting, washing, and packaging activities. These lower costs will partially offset the reduction in net returns due to lower yields.

3.4 Examining Returns to Labor and Land

The OCS for vegetables were designed to emulate real-world producer decisions and practices, and consist of four unique strategies (treatments). The assumptions in the enterprise budget model, place an emphasis on small scale operations which represents the production operations and materials typical of organic farmers in the Western New York region. The analysis also include calculations to highlight the returns to labor as part of the analysis, and here it is assume that an operator has 1500 hours available per season. To simulate real small farms, the farm operator is also assumed to be the only full time farm worker; therefore there is no additional paid labor. The farm operators' labor hours are divided between growing, harvesting and packing each vegetable crop.

For each crop in each system I track and report the total operator hours required for 0.1 acres. Dividing 1500 hours by the total operator hours for a crop yields the number of 0.1 acre units that can be produced per season; dividing this result by 10 yields the number of acres that can be managed with 1500 hours per season. The calculation of net returns per season given 1500 hours of labor is based on total receipts, total costs (machinery, materials, and marketing) plus the acreage-adjusted overhead charges for equipment, land and buildings. The net return per operator hour is simply the net return per season divided by the 1500 hours of available labor.

3.5 Additional Sensitivity Analyses

Employing a Monte Carlo simulation provides another means of estimating the expected mean net income and income variability for each system. In the simulation, crop yields are stochastic variables with distributions defined by historical data. The yield distributions for all crops in the rotation were truncated at levels 5% below or 5% above their historical minimum and maximums to improve the model's realism. As the literature supports both normal and non-normal distributions, both types of distributions were assumed for yield variables.

The data used in the model was analyzed using the @Risk fit distribution module to model the range of low yields to bumper crops. A normal distribution was selected as well as gamma distributions for positive skewness and a beta distribution for negative skewness. The @Risk distributions are defined with sample means and variance. The program is run with 10,000 iterations to estimate a probability density function, which describes the relative likelihood for this random variable to occur at a given point. Since continuous probability functions are defined for an infinite number of points over a continuous interval, the probability at a single point is always zero. Probabilities are measured over intervals, not single points. Therefore, the area under the curve between two distinct points defines the probability for that interval. In this analysis, the points will be represented by the yield ranges from the sensitivity analysis. Accordingly, the area under the curve between the net revenue ranges will be the probability of obtaining the net revenue given a 10% increase or decrease in yield. These calculations will be carried out under the three possible yield distributions highlighted in the literature review. The method of moment parameters are transformed for the gamma and beta distributions. As with the previous sensitivity analysis, the Monte Carlo simulations results will be summarized as whole cropping systems.

With proper implementation, randomized experiments provide a way to obtain unbiased estimates of treatment effects. Experimental data is widely used in agricultural studies conducted by economists and production scientists. There are many benefits in utilizing experimental data which include, known direction of causality, experiments are grounded on more plausible assumptions, results are easier to interpret and explain to a wider audience. However, there are also reasons experimental data can be disadvantageous. Controlled experiments are costly both monetarily and time wise. The OCS experiment results will improve as more crop rotations are completed and additional data is collected. As a result of these limitations, the experimental data derived from the OCS are used as inputs for Monte Carlo simulations to predict the response of net revenue for given yield distributions. The simulated events are then compared to the experimental data. Another interpretation is the theory of second-best data solutions. If one condition in the economic model cannot be satisfied, it is possible that the next best solution involves changing other variables away from the ones that were usually assumed to be optimal. Although the results from the OCS experiment show that adoption of a given system is profitable, if the conditions on the farm are sufficiently different from the experimental conditions, the results may be rendered unreliable for that farm's planning operations. While experimental conditions are not duplicated on the farm, the relationships within and between the systems should continue to hold. Second-best data solutions will be examined more closely in Chapter 5 by transitioning experimental results to implications for commercial marketing alternatives including various direct market opportunities.

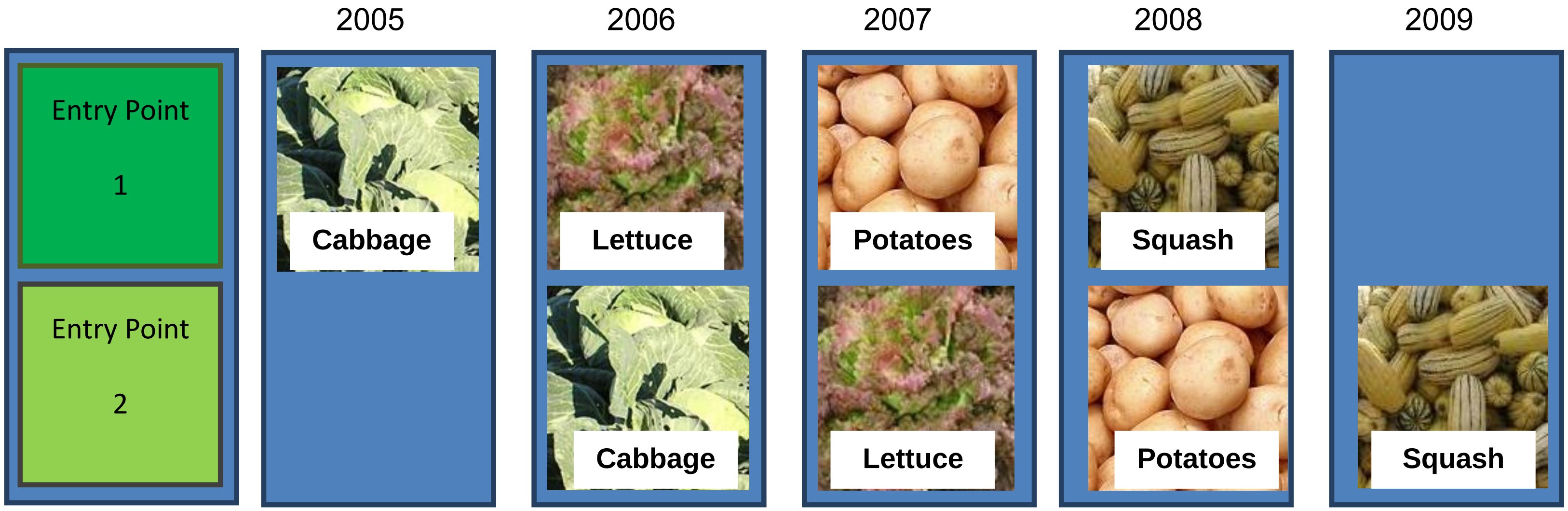


Figure 3.1: Illustration of crop rotation in the OCS vegetable experiments

Figure 3.2: System 4 (Ridge-till) scraping ridges with hairy vetch before planting cabbage

CHAPTER 4

RESULTS

4.1 Illustrative Example to Provide Detailed Results from the Framework

To illustrate how the results are calculated, Table 4.1 through Table 4.4 shows the details used to assess potential returns across the alternative systems for one crop, winter squash. The marketable yield of squash varied greatly among the different management systems. Cost varied also, but less than gross receipts since yields varied substantially. The average net returns ranged from $351 to $609 per 0.1 acre given a (retail) squash price of $1.25 per pound. Table 4.1 shows that System 1 (High Intensity) had the highest aggregate costs and highest costs in the categories of machinery use, materials, fuel, and operator labor. System 4 (Ridge-till) had the highest net return per unit of land (Table 4.4). From the Table 4.3 results, System 3 (Bio-extensive) was characterized by low costs and low net returns. Yields were higher in System 3 (Bio-extensive) during the production years compared to the other systems, but because it required two years to obtain that yield, its average yield and gross receipts were low. Despite low average yield, it did not have the lowest net return per operator hour.

Results in Table 4.4 also show that System 4 (Ridge-till) provided the highest return to labor if the operator is growing only winter squash. An operator could manage the most acres for squash production (including the time in fallow) with System 3 (Bio-extensive), but this option would command lower net returns and lower returns on labor than System 4 (Ridge-till). A System 4 (Ridge-till) winter squash grower could manage 5.71 acres per season and would generate the highest overall return and return per operator hour. The return on labor generated by System 4 (Ridge-till) is approximately 30% higher than System 2 (Intermediate Intensity) and

System 3 (Bio-extensive), and over 80% higher than System 1 (High Intensity). For squash production, it is found that System 4 (Ridge-till) yielded the best overall economic results.

4.2 Baseline Results

The method of analysis described above was used to examine the economics of producing all of the vegetable crops produced in the OCS, and the baseline results are summarized in Table 4.5 through Table 4.8. The results are structured to show an enterprise with 0.4 acres; this includes 0.1 acres of each of the crops in the rotation. Spinach and cabbage were the first cash crops grown in the rotation under System 1 (High Intensity); cabbage was the first cash crop grown in System 2 (Intermediate Intensity) and System 4 (Ridge-till). A cover crop was grown in System 3 (Bio-extensive) instead of cabbage. The marketable yield of cabbage varied little among the different systems (as shown in Table 4.7). From the Table 4.5 results, System 1 (High Intensity) also produced a second cash crop; 483 marketable pounds of snap peas were produced and the receipts and costs for the peas were included in the analysis. Overall, System 1 (High Intensity) had the highest costs in each cost category. Table 4.5 also shows that cabbage and peas grown under System 1 (High Intensity) would generate the greatest return to labor; this result is driven primarily by the additional revenue from selling the second cash crop of peas.

The next cash crop in the rotation is lettuce; in addition, spinach was grown after lettuce in System 1 (High Intensity). Lettuce yield in the production year ranged from 54 (24-head) cases in System 4 (Ridge-till) up to 59 cases in System 2 (Intermediate Intensity). Although System 3 (Bio-extensive) had a high yield in the production year (56 cases), because it required two years to produce this, its average yield was the lowest for any system (28 cases) as shown in Table 4.7. System 1 (High Intensity) generated the highest net return due to the second crop of spinach and the highest return to labor. System 1 (High Intensity) also had the highest total costs, which can be attributed to additional machinery and marketing costs associated with the second cash crop of spinach. Overall, System 1 (High Intensity) was the most profitable management system and required the greatest number of hours for growing and harvesting the crops.

Potatoes were the third cash crop in the rotation and were grown in System 1 (High Intensity), System 2 (Intermediate Intensity), and System 4 (Ridge-till). As with cabbage, System 3 (Bio-extensive) was fallow at this point in the rotation. Overall, potatoes were the least profitable crop in the OCS experiment, but they were included as they are a common crop on many organic vegetable farms in the Northeast. Marketable yield, which strongly influenced profitability, varied among systems in both years; the average marketable yield ranged from 1,013 pounds per 0.1 acre in System 4 (Ridge-till) to 1,562 pounds per 0.1 acre in System 2 (Intermediate Intensity). System 1 (High Intensity) had the highest machinery and material costs due to higher costs associated with compost application. The average net return per season for System 2 (Intermediate Intensity) was double that of System 4 (Ridge-till) and 12% higher than System 1 (High Intensity). The average total hours and acres managed per season were similar for System 1 (High Intensity) and System 2 (Intermediate Intensity). System 4 (Ridge-till) required fewer operator hours because of lower harvest labor, and a farmer could manage more acres under this system. System 2 (Intermediate Intensity) generated the highest return per operator hour for potatoes (as shown in Table 4.6).

Squash was the fourth vegetable grown in the rotation, and it was grown in all four systems. On average, System 4 (Ridge-till) yielded 834 marketable pounds of squash per 0.1 acre, followed by System 2 (Intermediate Intensity) with 703 marketable pounds of squash per

0.1 acre. System 4 (Ridge-till) had the highest average receipts and costs. Accordingly, System 4 (Ridge-till) had the highest return on operator labor. In addition, System 4 (Ridge-till) was the most efficient cropping system in terms of land and labor management. A farm operator could earn $17.12 dollars per operator hour using System 4 (Ridge-till), about 30% higher than under System 2 (Intermediate Intensity) or System 3 (Bio-extensive), and almost double the earnings under System 1 (High Intensity).

Because most vegetable producers in the Northeast grow several different crops each year, I also provide a more holistic analysis in which farms using each of the four systems produce all four phases of the crop rotation in a given year; the results are summarized in Table 4.9. This better mimics a commercial application of the OCS for farmers that grow cabbage, lettuce, potatoes and squash following the different management practices of the four systems. If a farm operator is seeking to maximize net returns, System 1 (High Intensity) should be used to grow the full rotation; this generated $7,300 in operator returns per 0.4 acres per season. System 1 (High Intensity) had higher costs than System 2 (Intermediate Intensity), but the additional two cash crop in System 1 (High Intensity) led to higher net returns. The labor and land management analysis in Table 3 shows that System 2 (Intermediate Intensity) had the second highest returns per operator hour. Remarkably, the highly experimental system, System 4 (Ridge-till) had only slightly lower overall returns and returns per hour of operator labor than System 1 (High Intensity) and System 2 (Intermediate Intensity), which are more traditional organic cropping systems.

Results in Table 4.9 show that System 1 (High Intensity) had the lowest ratios of machinery costs and material costs to total receipts, whereas System 3 (Bio-extensive) had the highest ratios of these costs to total receipts. System 3 (Bio-extensive) required the least labor—

97 hours for 0.4 acres compared to 241 hours, 184 hours, and 172 hours for the other systems. Thus, in addition to land, System 3 (Bio-extensive) also substituted machinery and materials for labor. This was due largely to the decreased labor requirement during the fallow periods. In fact, the labor requirements in System 3 (Bio-extensive) during the fallow year were typically less than 10% of that needed during the non-fallow years.

Since cabbage and potatoes were not grown in System 3 (Bio-extensive), comparing results for just lettuce and squash across the four systems is useful. Based on results in Tables 4.5 through 4.8, if 0.1 acres of lettuce and squash were grown in each system, net returns per hour would be \$22.12 in System 1 (High Intensity), \$21.41 in System 2 (Intermediate Intensity), \$17.72 in System 3 (Bio-extensive), and \$21.15 in System 4 (Ridge-till). These results for System 1 (High Intensity), System 2 (Intermediate Intensity), and System 4 (Ridge-till) are similar to those in Table 4.5 through Table 4.8, in which all cash crops are included.

Lastly this study also provides results for an operation that has the capacity to employ different systems for different crops in Table 4.10. A mixed-system approach could potentially be beneficial, but it also presents some challenges as some systems cannot fully mesh with each other. For example, System 1 (High Intensity) includes a secondary cash crop of spinach after lettuce that would conflict with cover crops needed for subsequent production of potatoes in other systems, including System 2 (Intermediate Intensity). Similarly, System 3 (Bio-extensive) requires a fallow period every other year, and this precludes the system's inclusion in a mixed-system approach. Thus we are limited to a mixed system analysis that examines the economics of an approach that includes System 2 (Intermediate Intensity) and System 4 (Ridge-till). A mixed-system approach that grows cabbage, lettuce, and potatoes using System 2 (Intermediate Intensity) and grows squash using System 4 (Ridge-till) generates returns that are 2.7% higher than those for System 2, the more profitable of the two component systems. This mixed system, however, provides lower net returns to land and labor than System 1 (High Intensity).

Overall net returns to land varied widely among systems. Returns to labor varied much less so. Net returns per labor hour were highest in System 2 (Intermediate Intensity) for potatoes, highest in System 4 (Ridge-till) for squash, and highest for cabbage (with snap peas) and lettuce (with spinach) in System 1 (High Intensity). If a farm were to adopt one system, then System 1 (High Intensity) would generate the highest total returns to land and labor, largely due to its extra crops of snap peas and spinach.

4.3 Sensitivity Analysis

The field trials indicated that different organic farm management systems will be best for different crops. The experiment is continuing to determine how crops in the four systems respond to variation in seasonal conditions and observe ecological changes in the systems. Additional research is needed to test how the economic results may change over time and how they would respond to different market conditions.

With the data at hand, however, we can explore how sensitive our results are to changes in the key parameters that are expected to change over time. In fact, many of the parameters for individual crops fluctuated between the two entry points, and data from early years of the second crop rotation of the experiment have shown additional variability in certain costs and yields. Changes in key parameters have the capacity to impact profitability of the several systems dramatically. Table 4.11 outlines results from an analysis to test how sensitive baseline system net returns in Table 4.5 through Table 4.8 are to small changes in yields, prices and selected input costs.

Yield is one of the most variable factors in the OCS experiment, and yields have an important effect on profitability (Sellen et al., 1996). We observed year-to-year yield fluctuations within systems from 5% to over 50% for crops in the experiment. Here I consider changes of 10% from the baseline yields in the sensitivity analysis. A 10% increase or decrease in the base marketable yield on a farm growing all crops leads to a roughly 12% increase or decrease in net returns in all systems. Thus, a change in yield has a disproportionately large effect on overall returns.

Retail vegetable prices have fluctuated over the years of the OCS experiment, and the study also considered the effects of small changes in retail prices in our sensitivity analysis. Results show that the percentage changes in net returns were greater than the percentage changes in price for all crops. For example, a 10% increase or decrease in the base price for all crops would change net returns by approximately 13% in all four systems and a 10% increase in price produced a similar increase in net returns. Across the range of prices used in the sensitivity analysis the results find that System 1 (High Intensity) maintained the highest net returns overall. All systems benefit from increases in prices; however, System 1 also had the most stable net return in the face of price changes.

Costs of producing vegetables, notably fuel costs, have changed substantially over the years of the OCS, and changes in fuel costs affect many of the individual machinery operation costs included in our analysis. However, changes in fuel costs led to very small shifts in net returns. For example, a 10% increase in fuel costs led to a decrease in net returns that was less than 1%. Fuel prices do not appear to have much impact on net returns because many organic farms are small, use a lot of manual labor, and use less machinery (and fuel) than conventional farms (Dalgaard, Halberg, and Porter, 2001).

Our baseline analysis assumed that marketing costs were 20% of gross receipts. As a result, any decrease in the marketing expenses will decrease the percentage of gross receipts assumed to be required for marketing. Overall, changes in marketing costs led to relatively small changes in net returns. Results in Table 4.11 display a 10% decrease in marketing costs across all systems leads to approximately a 3% increase in net returns across the various systems. Of course, if additional marketing efforts were used to promote organic vegetables differently, we might find a more responsive effect from changes in marketing expenses and the prices received.

In addition, an overall sensitivity analysis was conducted. In a worst case scenario, for each system marketable yields and prices fall by 10%, while fuel and marketing costs increase by 10%. In this case, net returns across all systems would decrease by 26% to 28% from the baseline results, and System 1 (High Intensity) maintained the highest net returns. Conversely, in the best case scenario, marketable yields and prices would increase by 10%, while fuel and marketing costs would decrease by 10%. Under these conditions, all systems would experience gains in net returns of 30% to 32% over those found in the baseline analysis. Net return of System 1 (High Intensity) is somewhat more stable under these scenarios than the others.

4.4 Monte Carlo Simulation

The sensitivity analysis identified yield as one of the key drivers of net revenue. This type of analysis enables for exploration of potential impacts and changes on the experimental farm results as well as capturing what might be observed in other Northeast locations. While the sensitivity analysis provides upper and lower bounds for net revenue on yields, it does not indicate the probability of net revenue falling within the given range. As yield is highly variable, the current literature does not have carefully measured distributions for vegetable yields. Several studies have tested whether yields are normally distributed, positively skewed and negatively skewed. This section utilizes all three distributions to plot out the probability density functions for each cropping system to provide a visual approximation of its distribution. Table 4.12 summarizes these simulation results shown in Figure 4.1 through Figure 4.12.

Figures 4.1 through 4.4 analyze a normally distributed yield and its corresponding net revenue for System 1 (High Intensity), System 2 (Intermediate Intensity), System 3 (Bio-extensive) and System 4 (Ridge-till) respectively. In probability theory, the normal distribution is a continuous probability distribution that has a bell-shaped probability density function. In this distribution, the data has less of a tendency to produce unusually extreme values, and therefore the distribution is concentrated around the central tendency. The curve is symmetric, or in other words, the probabilities of deviations from the mean are comparable in either direction. The normal probability density function is defined as:

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{4.1}$$

where parameter μ is the sample mean and σ^2 is the sample variance, and both are calculated from data in the OCS experiment. Utilizing @Risk and entering the sample mean and variance, the probability of a range of net revenue from a 10% increase and decrease (results from the previous sensitivity analysis) in revenue can be calculated. In addition, 90% of net revenue for yields under a normal distribution for each system is determined. This range is included to draw comparisons to extreme values and the best and worst case scenarios calculated earlier in Table 4.11. The results in Figure 4.1 indicate that probability that net revenue in System 1 (High Intensity) will be between \$6,411.85 and \$8,185.16 is 30.9%. In the event of very low yields, the net revenue is likely to not fall below \$3,630 per season. Similarly, for System 2 (Intermediate Intensity) Figure 4.2 shows that 38.4% of the time, net return will be in the range indicated in Table 4.11. Expanding the range from $2,930 to $7,110 will increase the probability of net revenue derived from normal yields to 90%. Figure 4.3 plots the probability density functions for yields under System 3 (Bio-extensive). According to historical data, there is a 44.7% probability that net revenue will be between $2,000 and $2,580, which corresponds to a 10% decrease and increase in yield. Unlike the previous systems, the variance between yields was smaller in System 4, therefore the area in which 90% of net revenue outcomes for normal yield distributions was very similar to the range utilized in the sensitivity analysis.

Continuing with the same approach, Figures 4.5 through 4.8 use gamma yield distributions to calculate ranges on net revenue for the four systems in sequential order. The probability density function of the gamma distribution can be expressed in terms of the gamma function parameterized in terms of a shape parameter k and scale parameter θ. Both k and θ will be positive values. The gamma distribution is positively skewed, with the probability density function:

$$f(x;k;\theta) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k \Gamma(k)} \text{ for x} \geq 0 \text{ and k,}\theta > 0 \qquad (4.2)$$

The mean is denoted as kθ and variance $k\theta^2$. The yield data is transformed using these parameters. With this yield distribution, the probability that net revenue is in the range determined in the sensitivity analysis is greater than that under a normal distribution. For example, the probability that net revenue in System 1 (High Intensity) will be between $6,411.85 and $8,185.16 has increased to 38.1%. In all systems, the lower bound has increased, while the upper bound has decreased in the 90% scenario. Notably, the range ($4,009.69; $5,197.52) for System 4 (Ridge-till) has a high probability of occurrence at 90.6%.

The last yield distribution to be examined is the beta distribution. The beta distribution is negatively skewed, with the following probability density function:

$$
\begin{aligned}
f(x,\alpha,\beta) &= \frac{x^{\alpha-1}(1-x)^{\beta-1}}{\int_0^1 u^{\alpha-1}(1-u)^{\beta-1}du} \\
&= \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1} \\
&= \frac{1}{B(\alpha,\beta)} x^{\alpha-1}(1-x)^{\beta-1}
\end{aligned}
\tag{4.3}
$$

where Γ(z) is the gamma function. The beta function, B , appears as a normalization constant to ensure that the total probability integrates to unity. A random variable X that is beta-distributed with shape α and β is denoted as X~ B (α,β).

$$\mu = \frac{\alpha}{\alpha+\beta}$$

$$Var(x) = \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)}$$

If $\bar{x}$ represents the sample mean and v represents the sample variance, the method of moments estimates of the parameters are calculated as:

$$\hat{\alpha} = \bar{x}\left(\frac{\bar{x}(1-\bar{x})}{v} - 1\right)$$

$$\hat{\beta} = (1-\bar{x})\left(\frac{\bar{x}(1-\bar{x})}{v} - 1\right)$$

The results are presented in Figure 4.9 through Figure 4.12 and are summarized in Table 4.12. In System 1 (High Intensity), the probability net revenue will be between \$6,411.85 and \$8,185.16 (or when baseline yields are increased and decreased by 10%), is 35.3%. Again, as demonstrated in Figure 4.12, this distribution encompasses the sensitivity analysis results 90.5% of the time in System 4 (Ridge-till).

Accurate modeling of crop yield typically requires longer time series observations than the current full rotation data available from the OCS project. The crop yield literature proposes various modeling approaches, and generally favors parametric approaches for small samples. The shape and scale parameters of the normal, gamma and beta distributions are defined by the sample mean and standard deviation using the method of moments. A theoretical distribution to represent simulation input data tends to smooth irregularities resulting from a limited number of sample values. Also, the theoretical distributions will generate values outside the range of observed values, often capturing values that may occur, but were missed in the sample process because they occur infrequently.

The Monte Carlo simulations provide some insight to the probability that net revenue will fall between certain ranges. In this analysis, the probability results from the sensitivity analysis are calculated. Afterwards, a larger range of 90% probability is calculated as a comparison and the best case and worst case scenarios developed in the sensitivity analysis are captured within this range. There does not appear to be any statistically significant differences under the different yield distributions. The gamma distribution captures a larger probability of the sensitivity results overall while the normal distribution captures the least. These probability density functions were estimated using data collected from only two rotations. More data is necessary to test for goodness-of-fit. However, based on the results of the Rodale and Broadbalk experiments, the beta distribution may the most appropriate distribution to characterize crop yields as there is evidence that yields increase as technology improves and more soil organic matter is accumulated. As the project continues and more data is collected, it will become easier to define the most appropriate distributions for yields of organic vegetable crops in the Northeast.

4.5 Summary of Results

Interactive enterprise budgets were developed for each crop and complete rotation information was aggregated by System. The yields and net revenue varied per crop and some systems outperformed others. For example, System 1 (High Intensity) generated the highest net returns for cabbage and lettuce, while overall net returns were highest for potatoes under System 2 (Intermediate Intensity) and squash net returns were maximized under System 4 (Ridge-till). Overall, System 1 (High Intensity) generated $7,300 in operator returns per 0.4 acres per season and had the highest net returns compared to the other systems. While System 1 (High Intensity) also had the highest cost inputs, the additional revenue generated by pea and spinach crops more than compensated for the higher costs. System 2 (Intermediate Intensity) had the second highest returns per operator hour. System 4 (Ridge-till), the most innovative cropping system, had only slightly lower overall returns and returns per hour of operator labor compared to the more traditional System 1 (High Intensity) and System 2 (Intermediate Intensity). A mixed system approach growing cabbage, lettuce and potato under System 2 (Intermediate Intensity) and squash under System 4(Ridge-till) generated higher net returns combined than each system individually. However, the mixed systems analysis showed that producing the entire crop rotation under System 1 (High Intensity) would generate the highest overall net returns.

After establishing a set of baseline results, a sensitivity analysis was performed to determine various “what if” scenarios, and to further examine how changes to the assumptions influenced profitability (including yields, prices, fuel costs and marketing expenses). A 10% decrease and increase to marketable yield and price were determined to have the largest effect on net return. Yields were further explored in Monte Carlo simulation that produced probability density functions for crop yields on net return under a normal, gamma and beta distribution. The probability of the ranges determined in the sensitivity analysis was between 30.9% to 90.6%. Additional data is necessary to assess the goodness-of-fit of the simulated distributions to historical yields. Previous studies have indicated that yields improved slowly over time, and it can be expected that this relationship would hold in this experiment as well over the long run.

Table 4.1: System 1 Costs and Returns for Squash (per 0.1 acre planting)[a]

		System 1 (High Intensity)
Receipts		
Marketable yield (lb)		**693**
Price ($/lb)		**1.25**
Total receipts ($)		**865.69**
Costs		
Machinery Costs ($)		**165.54**
	Flail mow	4.28
	Moldboard plow	3.58
	Rotary mow	8.56
	Disc	5.91
	Cultipacker	1.09
	Apply compost	2.89
	Cultivate squash	5.42
	Cultivate squash 2	5.42
	Irrigate	42.00
	Lay plastic	4.32
	Spray	0.93
	Remove and dispose of plastic	4.41
	Trap crop charge	9.69
	Miscellaneous support time	52.50
	Harvest machinery time	14.54
Material Costs ($)		**131.78**
	Compost	60.00
	Transplants	32.27
	Plastic	13.50
	Spray	15.05
	Trap crop	10.97
Marketing Costs ($)		**173.14**
Total Costs ($)		**470.46**
Net return ($/season)		**395.23**
Net return ($/lb)		**0.57**
Total operator hours required		25.68
Acres managed given 1500 operator hours		5.84
Net return given 1500 hours available ($/season)		14,149
Net return per operator hour ($/hour)[b]		9.43

[a] In this analysis it is assume that the farm operator performs all labor.

[b] This represents the returns per operator hour (assuming 1500 hours were used) and accounts for all expenses including overhead costs.

Table 4.2: System 2 Costs and Returns for Squash (per 0.1 acre planting)[a]

		System 2 (Intermediate Intensity)
Receipts		
Marketable yield (lb)		**703**
Price ($/lb)		**1.25**
Total receipts ($)		**879.19**
Costs		
Machinery Costs ($)		**158.65**
	Moldboard plow	3.58
	Rotary mow	8.56
	Disc	5.91
	Cultipacker	3.27
	Apply compost	2.89
	Mark rows	1.00
	Cultivate squash	5.42
	Cultivate squash 2	5.42
	Cultivate squash 3	2.71
	Irrigate	42.00
	Spray	0.93
	Trap crop charge	9.69
	Miscellaneous support time	52.50
	Harvest machinery time	14.77
Material Costs ($)		**70.28**
	Compost	12.00
	Transplants	32.27
	Spray	15.05
	Trap crop	10.97
Marketing Costs ($)		**175.84**
Total Costs ($)		**404.77**
Net return ($/season)		**474.42**
Net return ($/lb)		**0.67**
Total operator hours required		24.93
Acres managed given 1500 operator hours		6.02
Net return given 1500 hours available ($/season)		19,609
Net return per operator hour ($/hour)[b]		13.07

[a] In this analysis it is assume that the farm operator performs all labor.

[b] This represents the returns per operator hour (assuming 1500 hours were used) and accounts for all expenses including overhead costs.

Table 4.3: System 3 Costs and Returns for Squash (per 0.1 acre planting)[a]

		System 3 (Bio-extensive)
Receipts		
Marketable yield (lb)		**521**
Price ($/lb)		**1.25**
Total receipts ($)		**651.38**
Costs		
Machinery Costs ($)		**113.40**
	Flail mow	6.42
	Moldboard plow	1.79
	Disc	3.94
	Cultipacker	2.73
	Apply compost	1.44
	Mark rows	0.50
	Cultivate squash	2.71
	Cultivate squash 2	2.71
	Cultivate squash 3	2.71
	Irrigate	21.00
	Rotary tiller	7.49
	Springtooth harrow	4.37
	Spray	0.47
	Trap crop charge	4.85
	Miscellaneous support time	26.25
	Harvest machinery time	10.94
	Cover crop	13.09
	Re-ridge	
Material Costs ($)		**57.14**
	Compost	7.50
	Transplants	16.13
	Spray	7.53
	Trap crop	5.48
	Cover Crop	20.50
Marketing Costs ($)		**130.28**
Total Costs ($)		**300.82**
Net return ($/season)		**350.56**
Net return ($/lb)		**0.67**
Total operator hours required		19.16
Acres managed given 1500 operator hours		8.18
Net return given 1500 hours available ($/season)		18,508
Net return per operator hour ($/hour)[b]		12.34

[a] In our analysis it is assume that the farm operator performs all labor.

[b] This represents the returns per operator hour (assuming 1500 hours were used) and accounts for all expenses including overhead costs.

Table 4.4: System 4 Costs and Returns for Squash (per 0.1 acre planting)[a]

	System 4 (Ridge-till)
Receipts	
Marketable yield (lb)	**834**
Price ($/lb)	**1.25**
Total receipts ($)	**1042.31**
Costs	
Machinery Costs ($)	**154.49**
Rotary mow	8.56
Apply compost	2.89
Mark rows	1.00
Cultivate squash	2.71
Cultivate squash 2	2.71
Cultivate squash 3	2.71
Irrigate	42.00
Spray	0.93
Trap crop charge	9.69
Miscellaneous support time	52.50
Rotary mow	0.00
Scrape ridges	9.30
Harvest machinery time	17.51
Re-ridge	1.98
Material Costs ($)	**70.28**
Compost	12.00
Transplants	32.27
Spray	15.05
Trap crop	10.97
Marketing Costs ($)	**208.46**
Total Costs ($)	**433.23**
Net return ($/season)	**609.08**
Net return ($/lb)	**0.73**
Total operator hours required	26.28
Acres managed given 1500 operator hours	5.71
Net return given 1500 hours available ($/season)	25,828
Net return per operator hour ($/hour)[b]	17.22

[a] In this analysis it is assume that the farm operator performs all labor.

[b] This represents the returns per operator hour (assuming 1500 hours were used) and accounts for all expenses including overhead costs.

Table 4.5: System 1 Receipts, Costs, Returns, and Management Measures

	System 1 (High Intensity)			
	Cabbage and Peas	Lettuce and Spinach	Potato	Squash
Receipts				
Marketable yield for primary cash crop (lb)[a]	4,065	56	1,409	693
Marketable yield for secondary cash crop (lb)	483	550		
Price for primary cash crop ($/lb)[b]	0.75	48.00	0.89	1.25
Price for secondary cash crop ($/lb)	4.00	3.00		
Total receipts ($)	**4,980.38**	**4,349.97**	**1,260.00**	**865.69**
Costs				
Machinery Costs ($)	338.54	262.25	233.2	165.54
Material Costs ($)	206.78	371.59	155.07	131.78
Marketing Costs ($)	996.08	869.99	252	173.14
Total Costs ($)	**1,541.39**	**1,503.84**	**640.26**	**470.46**
Net return ($/season)	**3,438.98**	**2,846.13**	**619.74**	**395.23**
Total operator hours required	81.58	89.78	44.10	25.68
Acres managed given 1500 operator hours	1.84	1.67	3.40	5.84
Net return given 1500 hours available ($/season)	54,295	38,615	12,143	14,149
Net return per operator hour ($/hour)	36.20	25.74	8.10	9.43
Sum of net returns per 0.4 acres ($/season)				7,300

[a] Lettuce yields are measured as 24-head cases.

[b] Unit price of lettuce is $48 per 24-head case. The per pound potato price in the first entry point was $1.00 and was $0.75 in the second entry point; the prices shown for each system represent an average

Table 4.6: System 2 Receipts, Costs, Returns, and Management Measures

	System 2 (Intermediate Intensity)			
	Cabbage	Lettuce	Potato	Squash
Receipts				
Marketable yield for primary cash crop (lb)[a]	4,154	59	1,562	703
Marketable yield for secondary cash crop (lb)				
Price for primary cash crop ($/lb)[b]	0.75	48.00	0.85	1.25
Price for secondary cash crop ($/lb)				
Total receipts ($)	**3,115.46**	**2,814.48**	**1,333.13**	**879.19**
Costs				
Machinery Costs ($)	219.09	182.83	229.70	158.65
Material Costs ($)	187.83	303.15	140.63	70.28
Marketing Costs ($)	623.09	562.90	266.63	175.84
Total Costs ($)	**1,030.02**	**1,048.87**	**636.95**	**404.77**
Net return ($/season)	**2,085.45**	**1,765.61**	**696.17**	**474.42**
Total operator hours required	56.43	56.92	45.65	24.93
Acres managed given 1500 operator hours	2.66	2.64	3.29	6.02
Net return given 1500 hours available ($/season)	46,498	37,592	13,939	19,609
Net return per operator hour ($/hour)	31.00	25.06	9.29	13.07
Sum of net returns per 0.4 acres ($/season)				5,022

[a] Lettuce yields are measured as 24-head cases.

[b] Unit price of lettuce is $48 per 24-head case. The per pound potato price in the first entry point was $1.00 and was $0.75 in the second entry point; the prices shown for each system represent an average

Table 4.7: System 3 Receipts, Costs, Returns, and Management Measures

	System 3[a] (Bio-extensive)	
	Lettuce	Squash
Receipts		
Marketable yield for primary cash crop (lb)[b]	28	521
Marketable yield for secondary cash crop (lb)		
Price for primary cash crop ($/lb)[c]	48.00	1.25
Price for secondary cash crop ($/lb)		
Total receipts ($)	**1,353.24**	**651.38**
Costs		
Machinery Costs ($)	115.84	113.40
Material Costs ($)	171.62	57.14
Marketing Costs ($)	270.65	130.28
Total Costs ($)	**558.11**	**300.82**
Net return ($/season)	**795.13**	**350.56**
Total operator hours required	30.04	18.35
Acres managed given 1500 operator hours	4.99	8.17
Net return given 1500 hours available ($/season)	30,767	19,720
Net return per operator hour ($/hour)	20.51	13.15
Sum of net returns per 0.4 acres ($/season)		2,291

[a] System 3 was fallow for cabbage and potatoes.
[b] Lettuce yields are measured as 24-head cases.
[c] Unit price of lettuce is $48 per 24-head case. The per pound potato price in the first entry point was $1.00 and was $0.75 in the second entry point; the prices shown for each system represent an average weighted price across the two entry points.

Table 4.8: System 4 Receipts, Costs, Returns, and Management Measures

	System 4 (Ridge-till)			
	Cabbage	Lettuce	Potato	Squash
Receipts				
Marketable yield for primary cash crop (lb)[a]	4,169	54	1,013	834
Marketable yield for secondary cash crop (lb)				
Price for primary cash crop ($/lb)[b]	0.75	48.00	0.87	1.25
Price for secondary cash crop ($/lb)				
Total receipts ($)	**3,126.94**	**2,568.24**	**878.63**	**1,042.31**
Costs				
Machinery Costs ($)	225.13	184.22	219.47	154.49
Material Costs ($)	195.57	300.01	140.63	70.28
Marketing Costs ($)	625.39	513.65	175.73	208.46
Total Costs ($)	**1,046.09**	**997.89**	**535.82**	**433.23**
Net return ($/season)	**2,080.85**	**1,570.35**	**342.80**	**609.08**
Total operator hours required	55.55	54.11	36.22	26.28
Acres managed given 1500 operator hours	2.70	2.77	4.14	5.71
Net return given 1500 hours available ($/season)	47,252	34,596	5,260	25,828
Net return per operator hour ($/hour)	31.50	23.06	3.51	17.12
Sum of net returns per 0.4 acres ($/season)				4,603

[a] Lettuce yields are measured as 24-head cases.

[b] Unit price of lettuce is $48 per 24-head case. The per pound potato price in the first entry point was $1.00 and was $0.75 in the second entry point; the prices shown for each system represent an average

Table 4.9: Whole Farm Analysis by System[a]

	System 1 (High Intensity)	System 2 (Intermediate Intensity)	System 3 (Bio-extensive)	System 4 (Ridge-till)
Total receipts ($)	**11,456.04**	**8,142.26**	**4,009.24**	**7,616.12**
Costs				
Machinery costs ($)	999.53	790.27	458.49	783.32
Material costs ($)	865.22	701.88	457.53	706.49
Marketing costs ($)	2,291.21	1,628.45	801.85	1,523.22
Total costs	4,155.95	3,120.61	1,717.86	3,013.03
Net return ($/season)	**7,300.08**	**5,021.65**	**2,291.38**	**4,603.08**
Total operator hours required	241.01	183.93	96.78	172.17
Acres managed given 1500 operator hours	2.49	3.26	6.20	3.48
Whole farm net return given 1500 hours available ($/season)	36,498	32,016	26,578	31,167
Net return per operator hour ($/hour)	24.33	21.34	17.72	20.78

[a] Analysis based on a farm with 0.1 acres of each crop.

Table 4.10: An Analysis for a Mixed System Across Crops[a]

Crop	Cabbage	Lettuce	Potato	Squash	
Best System	System 2 (Intermediate Intensity)	System 2 (Intermediate Intensity)	System 2 (Intermediate Intensity)	System 4 (Ridge-till)	Total
Receipts					
Marketable yield (lb)[b]	4,153	59	1,562	834	
Price ($/lb)[c]	0.75	48.00	1.00	1.25	
Total receipts ($)	**3,115.46**	**2,814.48**	**1,333.13**	**1,042.31**	**8,305.38**
Costs					
Material Costs ($)	187.83	303.15	140.63	70.28	701.88
Marketing Costs ($)	623.09	562.90	266.63	208.46	1,661.08
Total Costs	1,030.02	1,048.87	636.95	433.23	3,149.07
Net return ($/season)	**2,085.45**	**1,765.61**	**696.17**	**609.08**	**5,156.31**
Total operator hours required	56.43	56.92	45.65	26.28	185.28
Acres managed given 1500 operator hours	2.66	2.64	3.29	5.71	3.24
Net return given 1500 hours available ($/season)	46.498	37,592	13,939	25,828	32,808
Net return per operator hour ($/hour)	31.00	25.06	9.29	17.22	21.87

[a] The first four columns of results are based on an operation that produces 0.1 acres; the final column provides results based on an operation that produces 0.4 acres.

[b] Lettuce yields are measured as 24-head cases.

[c] Unit price of lettuce is $48 per 24-head case.

Table 4.11: Examination of the Impact of 10% Changes in Key Revenue and Cost Items on Net Return ($/0.4 acres)

Scenario	System 1 (High Intensity)		System 2 (Intermediate Intensity)		System 3 (Bio-extensive)		System 4 (Ridge-till)	
	$/season	%	$/season	%	$/season	%	$/season	%
Baseline net return	7,300.08		5,021.65		2,291.38		4,603.08	
Marketable yield								
High +10%	8,185.16	12.1	5,657.08	12.7	2,579.42	12.6	5,197.52	12.9
Low -10%	6,411.85	-12.2	4,386.27	-12.7	2,003.32	-12.6	4,009.69	-12.9
Price ($/lb)								
High +10%	8,216.97	12.6	5,674.48	13.0	2,588.91	13.0	5,215.20	13.3
Low -10%	6,384.01	-12.5	4,371.72	-12.9	1,997.87	-12.8	3,996.62	-13.2
Fuel cost ($ per gallon)								
High +10%	7,275.33	-0.3	5,002.89	-0.4	2,284.29	-0.3	4,585.26	-0.4
Low -10%	7,321.69	0.3	5,040.46	0.4	2,298.47	0.3	4,621.95	0.4
Marketing costs ($)								
High +10%	7,069.39	-3.2	4,858.83	-3.2	2,217.50	-3.2	4,451.28	-3.3
Low -10%	7,527.63	3.1	5,184.52	3.2	2,365.26	3.2	4,755.93	3.3
Overall total change[a] ($)								
High +10%	9,500.36	30.1	6,597.17	31.4	3,005.54	31.2	6,077.01	32.0
Low -10%	5,387.99	-26.2	3,655.47	-27.2	1,674.00	-26.9	3,324.85	-27.8

[a] Here the term "High" is used to represent a 10% increase in yields, prices, and costs. Similarly, the term "Low" represents a 10% decrease in yields, prices, and costs. Note, however, that an increase in yield or price increases net return whereas an increase in costs decreases net return, and conversely for a decrease in yield, price and costs.

Table 4.12: Probability of Yields Ranges on Net Return with ($1000/0.4 acres)

Distribution	System 1 (High Intensity)			System 2 (Intermediate Intensity)			System 3 (Bio-extensive)			System 4 (Ridge-till)		
Baseline	7.30			5.02			2.29			4.60		
	Low	High	Prob. (%)	Low	High	Prob. (%)	Low	High	Prob. (%)	Low	High	Prob. (%)
Normal	6.41	8.19	30.9	4.39	5.66	38.4	2.00	2.58	44.7	4.01	5.20	81.9
	3.63	10.97	90	2.93	7.11	90	1.49	3.09	90	3.87	5.33	90
Gamma	6.41	8.19	38.1	4.39	5.66	46.9	2.00	2.58	49.6	4.01	5.20	90.6
	4.58	10.42	90	3.45	6.78	90	1.68	2.96	90	4.03	5.20	90
Beta	6.41	8.19	35.3	4.39	5.66	45.6	2.00	2.58	53.4	4.01	5.20	90.5
	4.15	10.01	90	3.26	6.59	90	1.62	2.90	90	4.01	5.18	90

[a] Here the term “High” is used to represent an upper bound on yields. Similarly, the term “Low” represents a lower bound in yields.

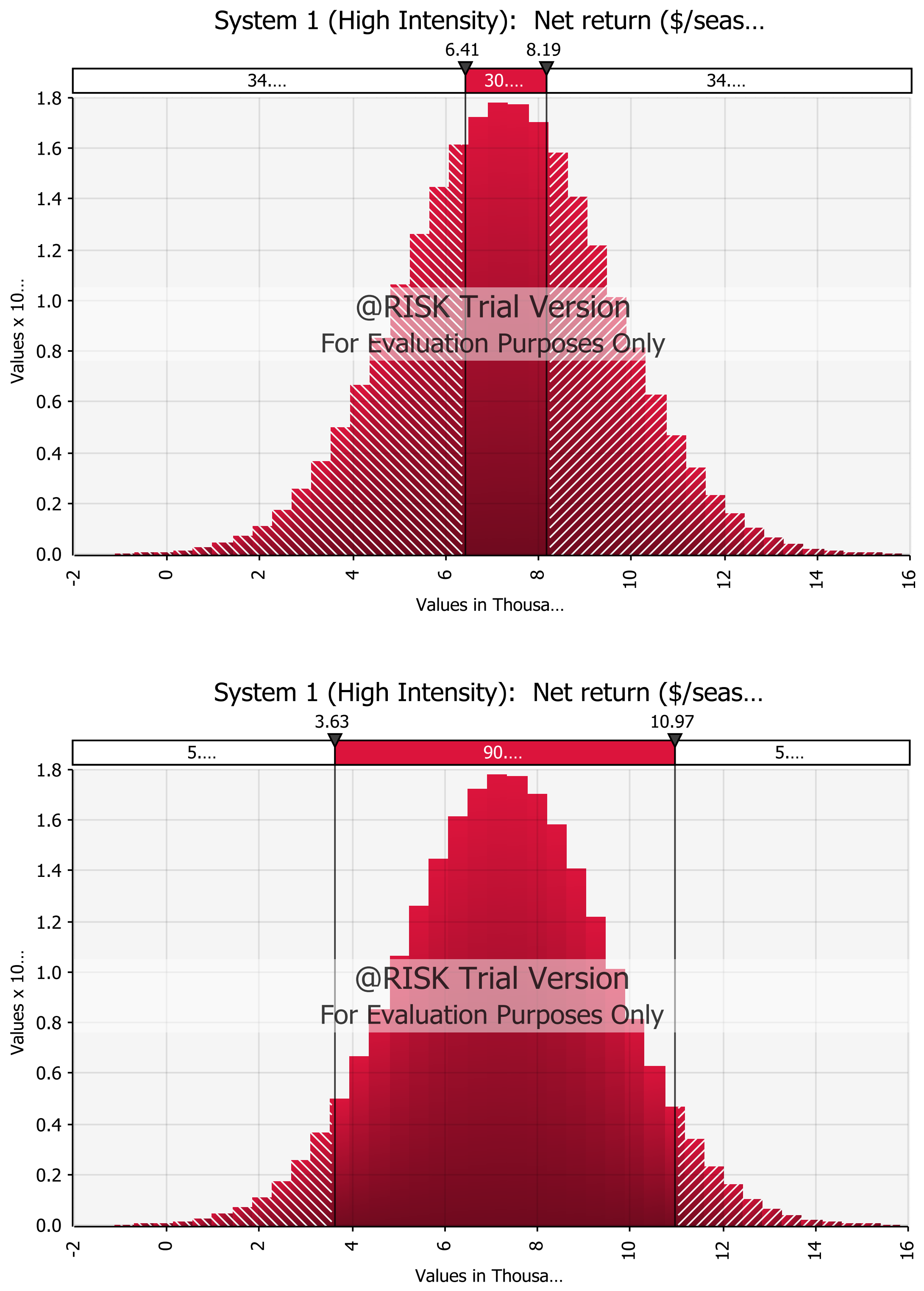


Figure 4.1: System 1 Net Revenue: Yield with normal distribution

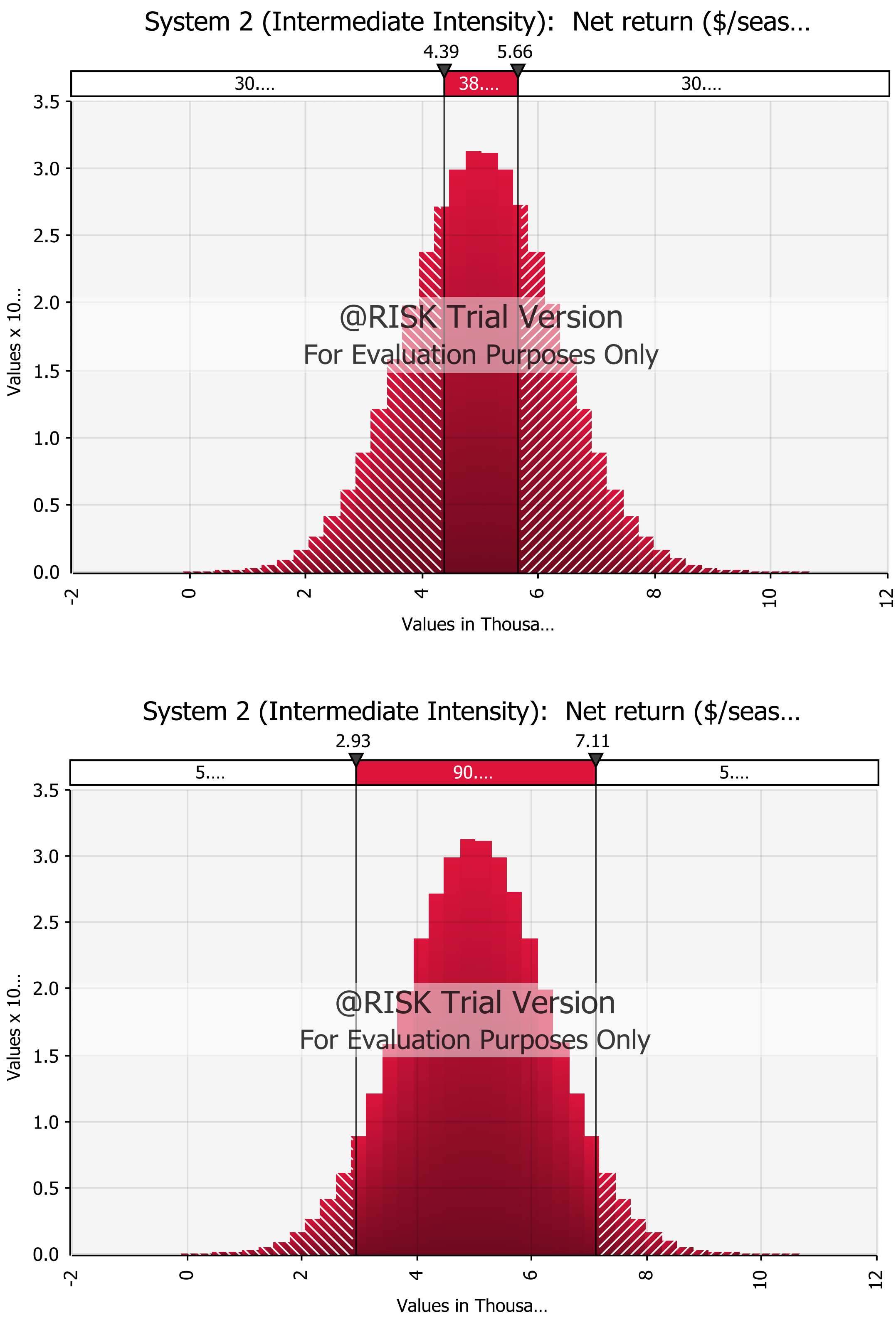
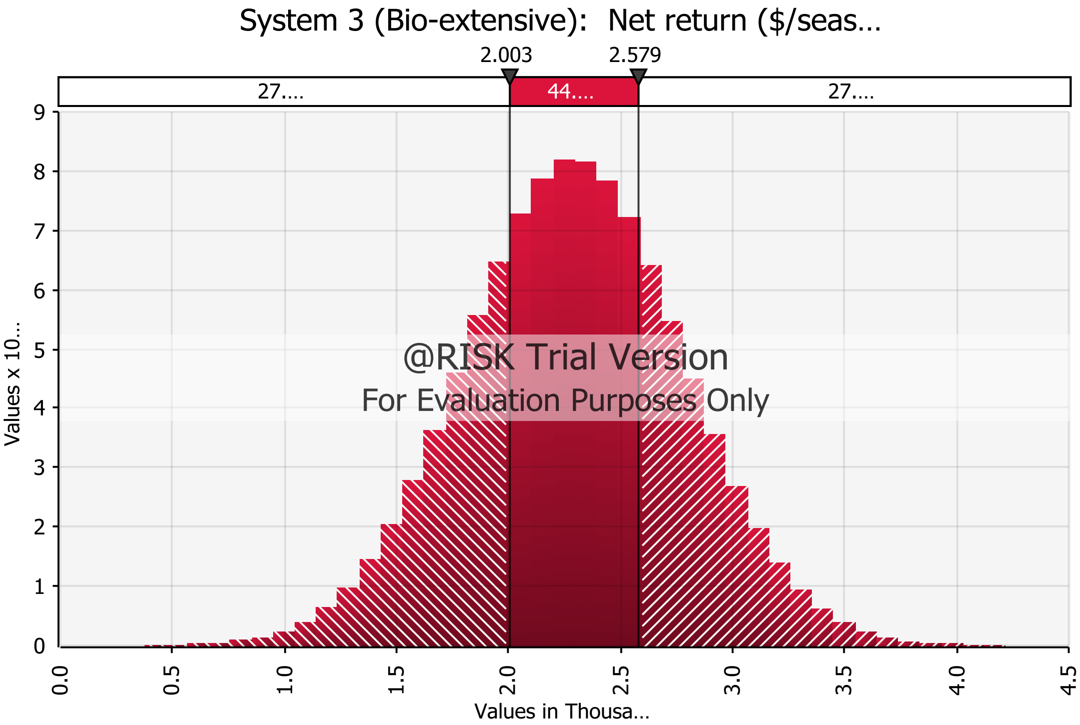


Figure 4.2: System 2 Net Revenue: Yield with normal distribution



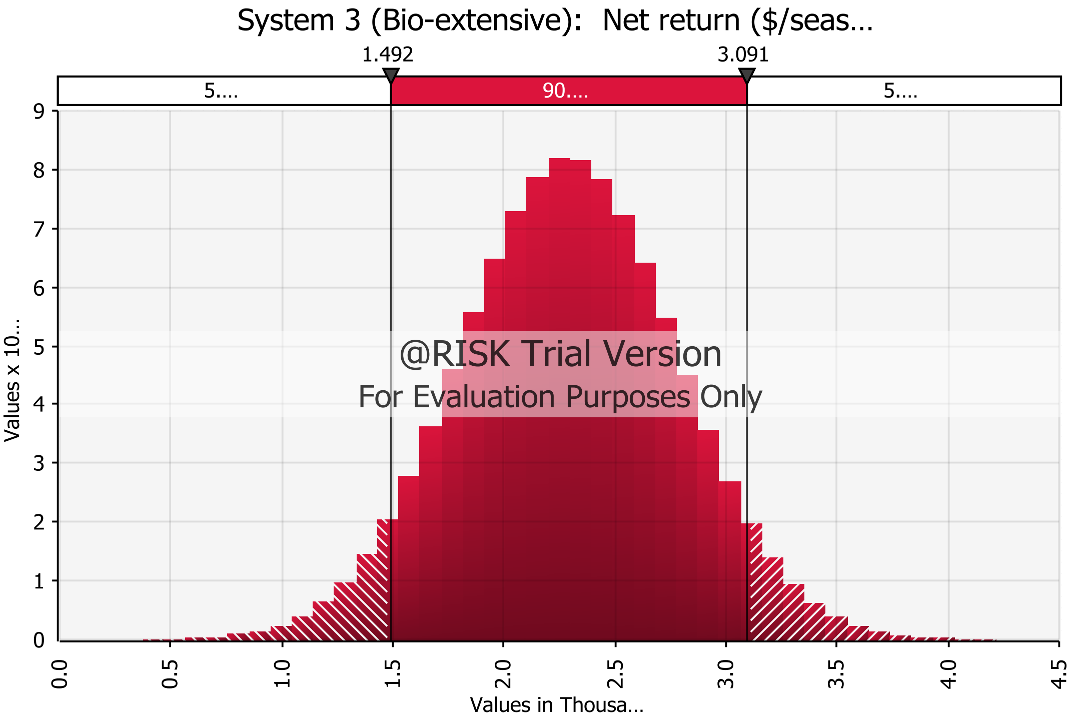


Figure 4.3: System 3 Net Revenue: Yield with normal distribution

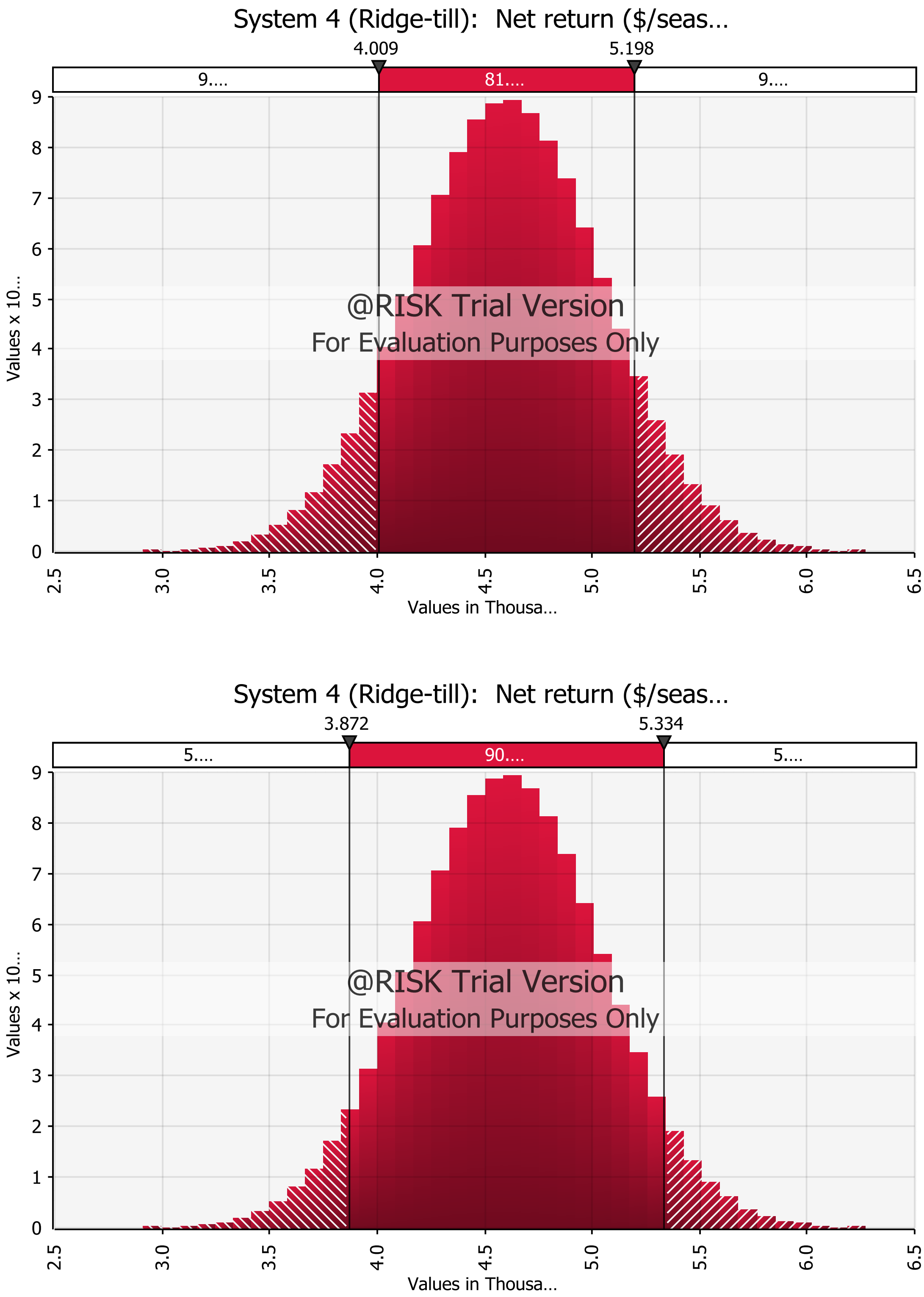


Figure 4.4: System 4 Net Revenue: Yield with normal distribution

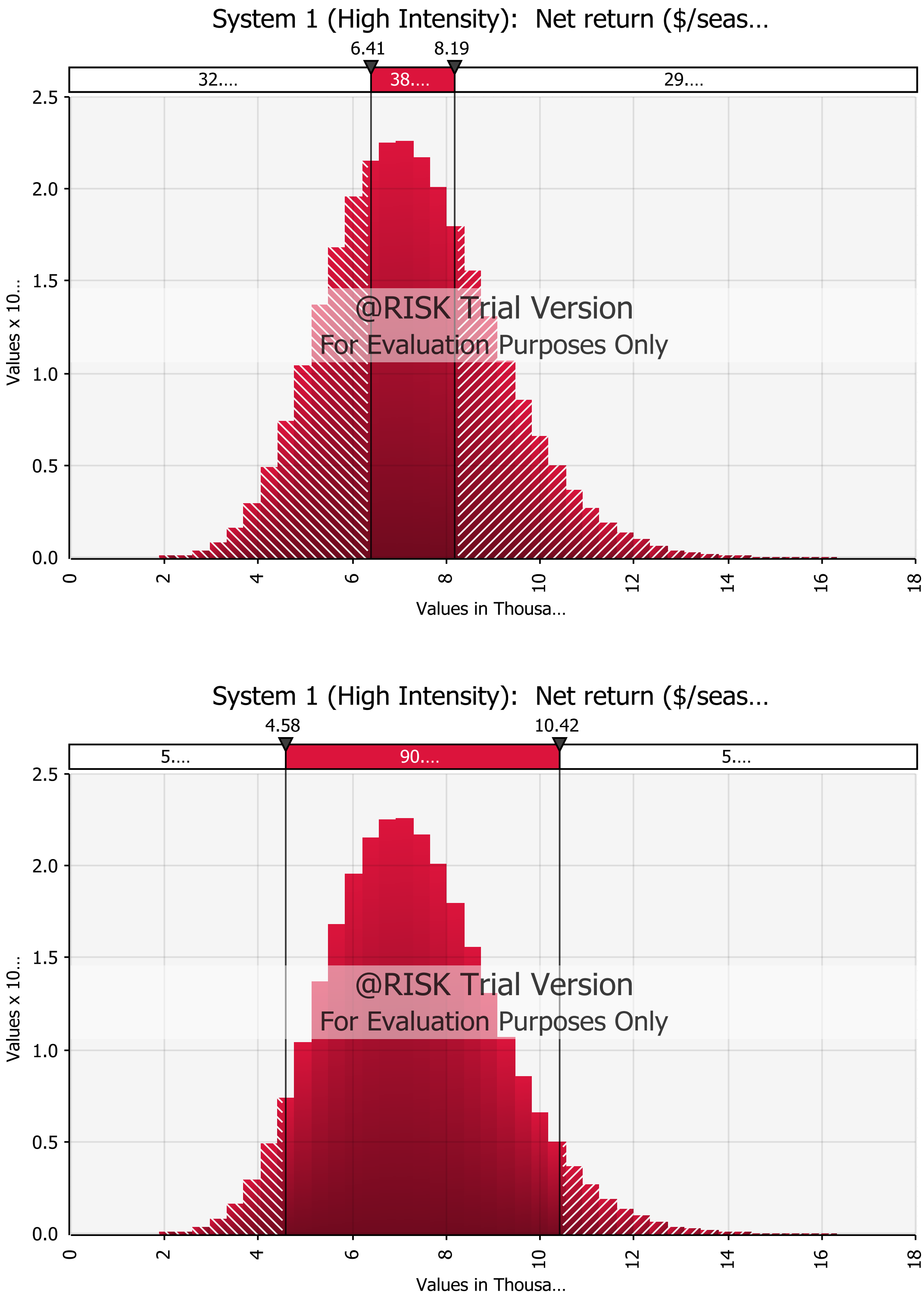


Figure 4.5: System 1 Net Revenue: Yield with gamma distribution

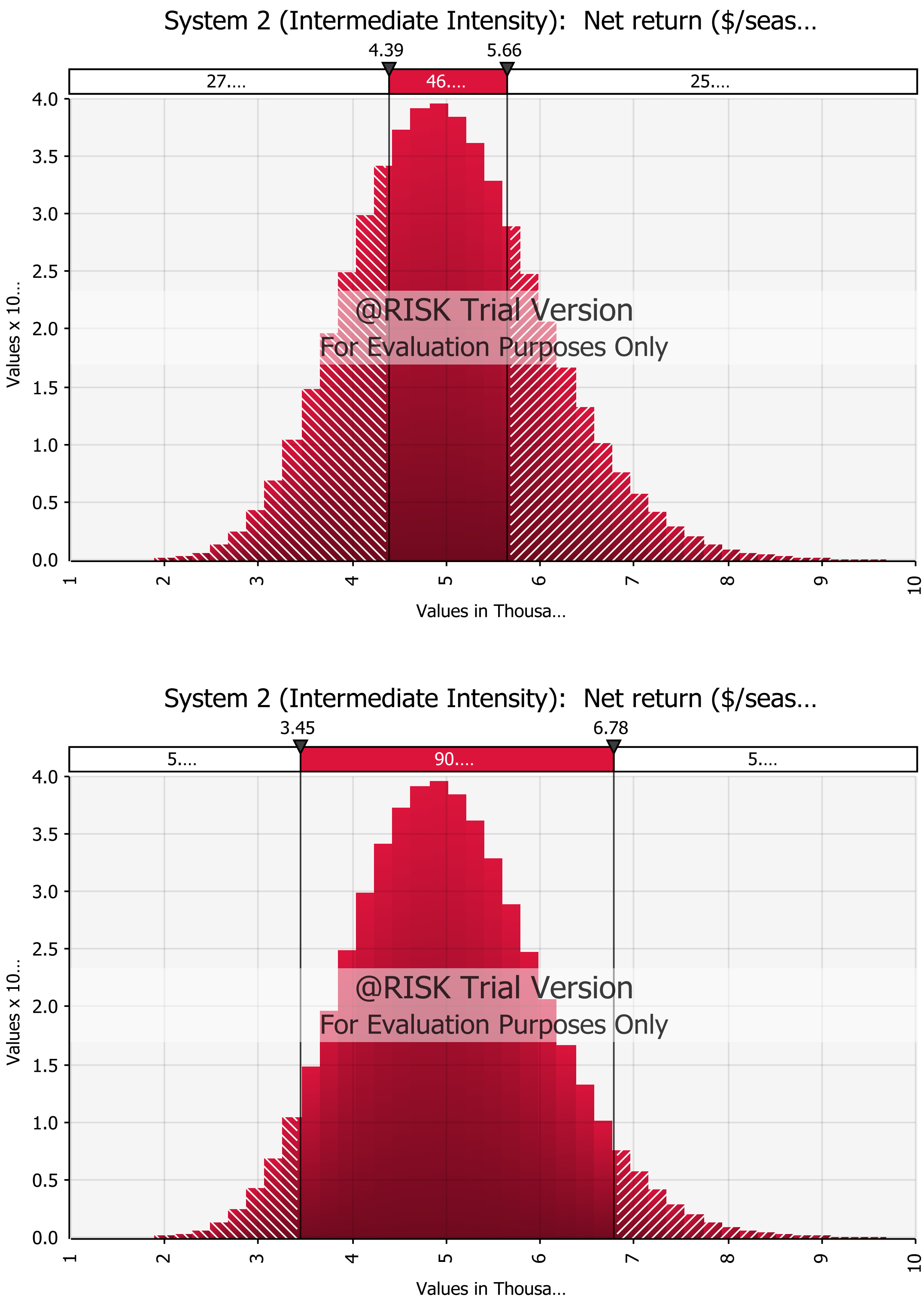


Figure 4.6: System 2 Net Revenue: Yield with gamma distribution

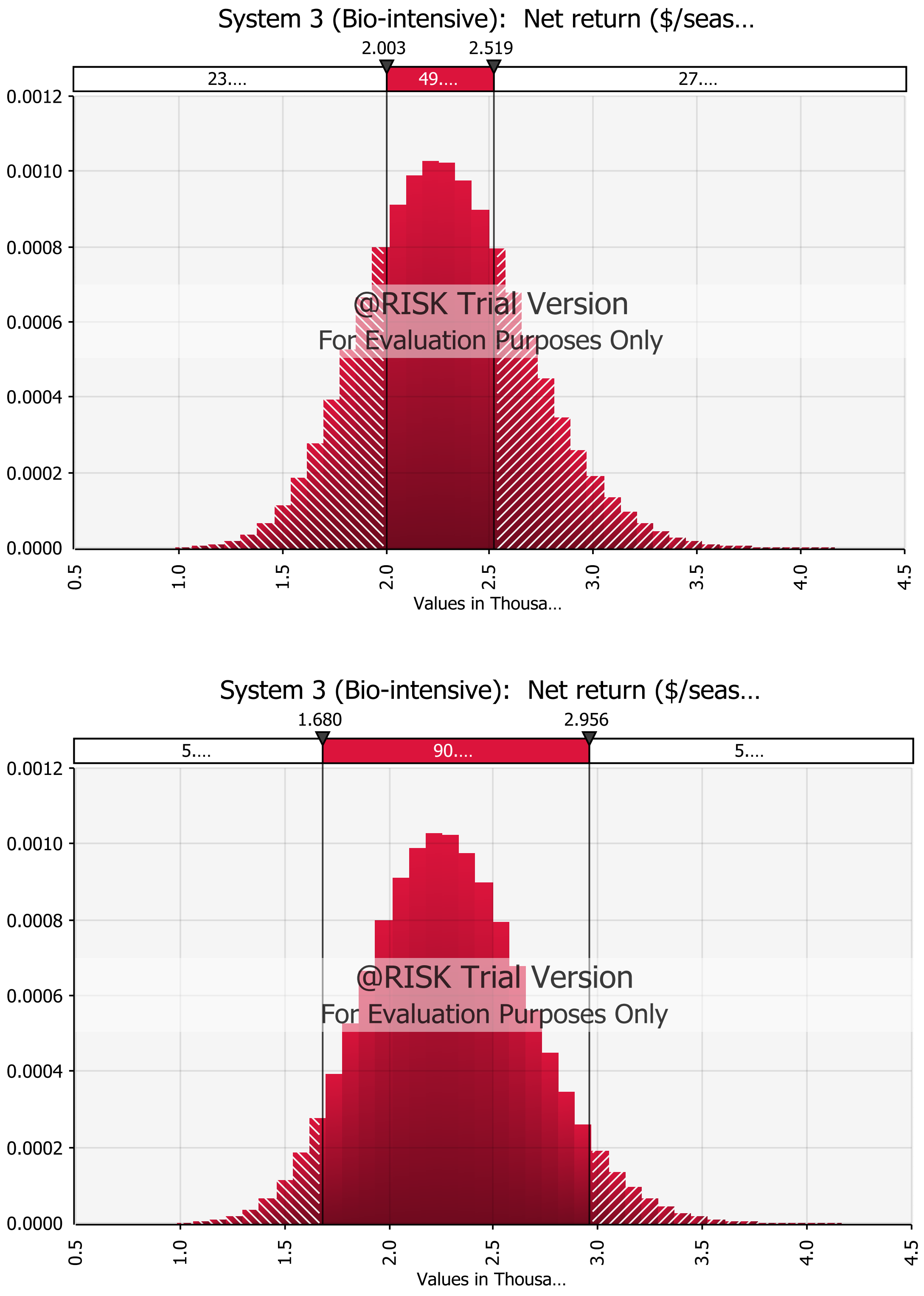
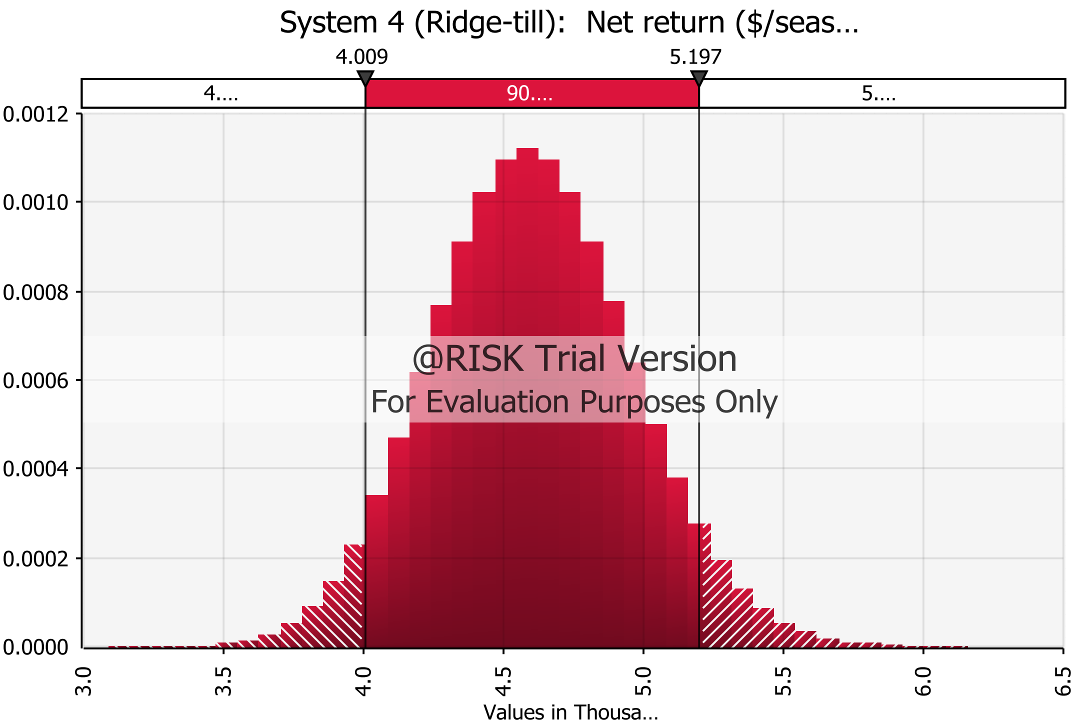


Figure 4.7: System 3 Net Revenue: Yield with gamma distribution



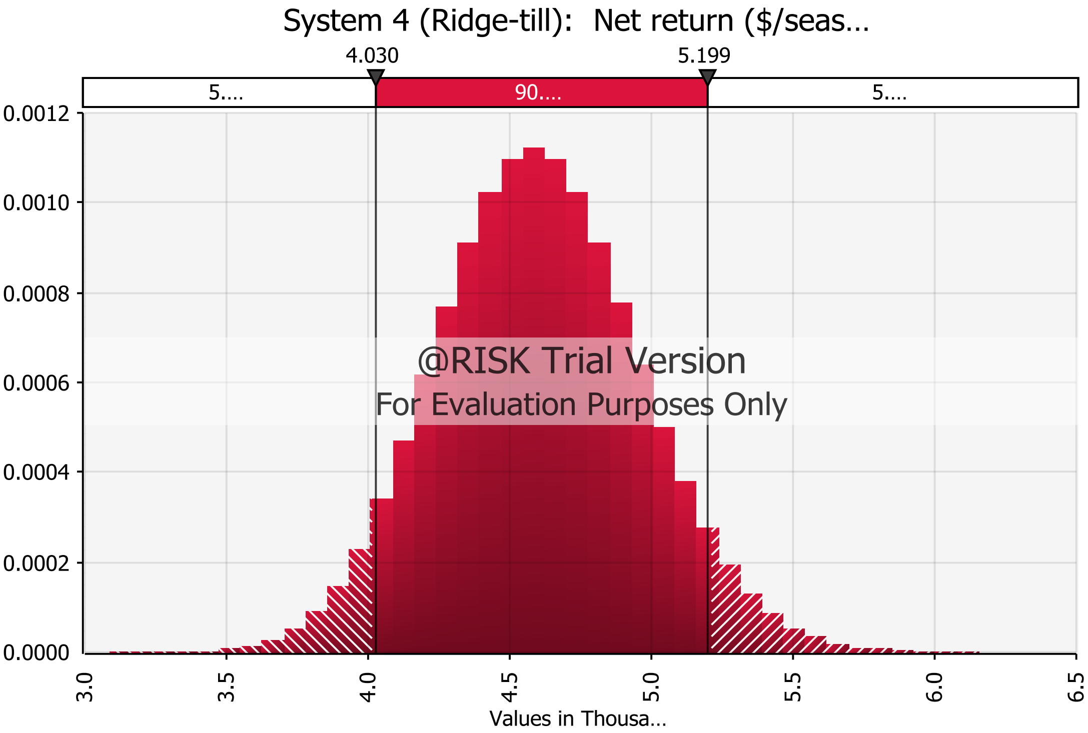


Figure 4.8: System 4 Net Revenue: Yield with gamma distribution

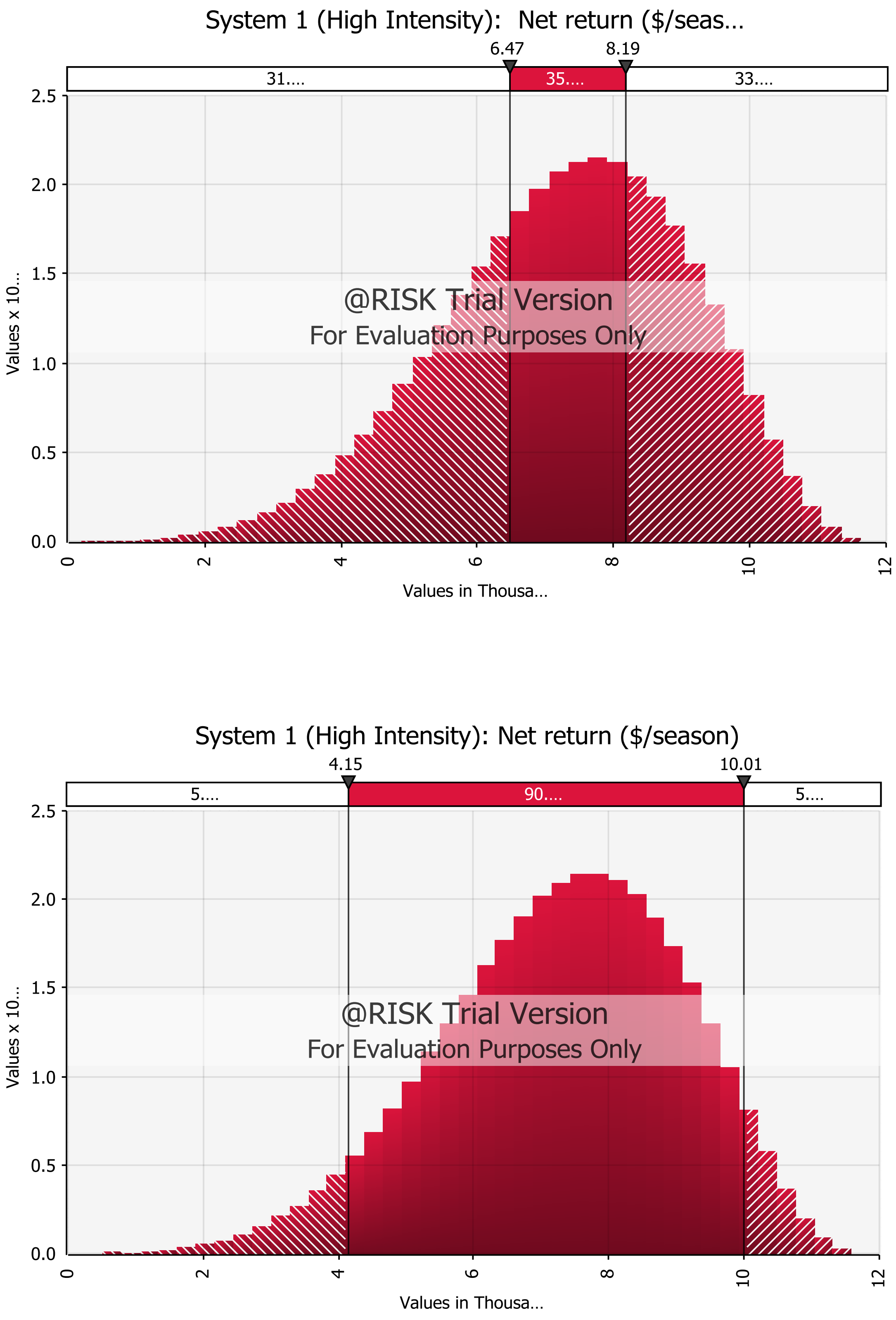


Figure 4.9: System 1 Net Revenue: Yield with beta distribution

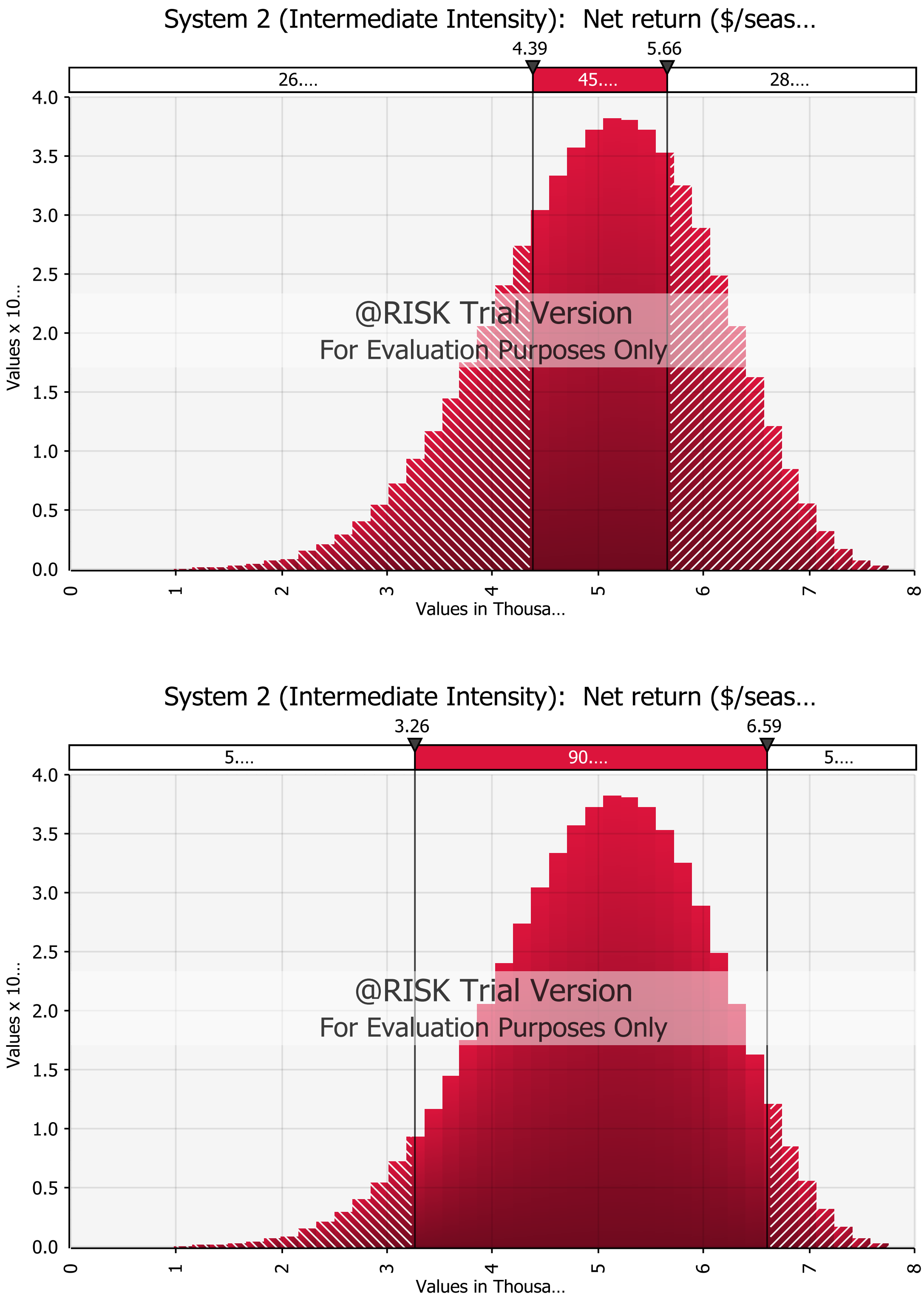


Figure 4.10: System 2 Net Revenue: Yield with beta distribution

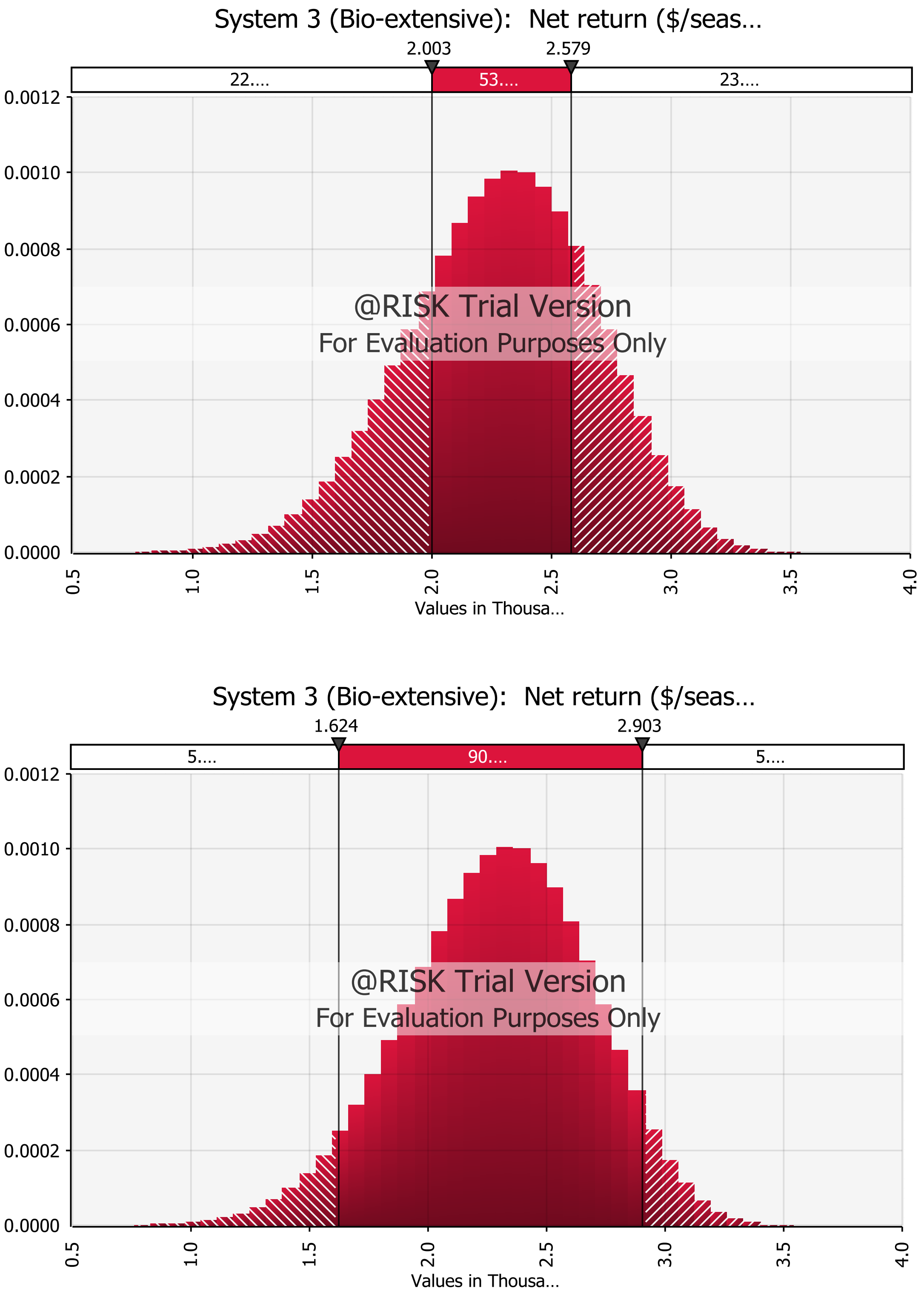


Figure 4.11: System 3 Net Revenue: Yield with beta distribution

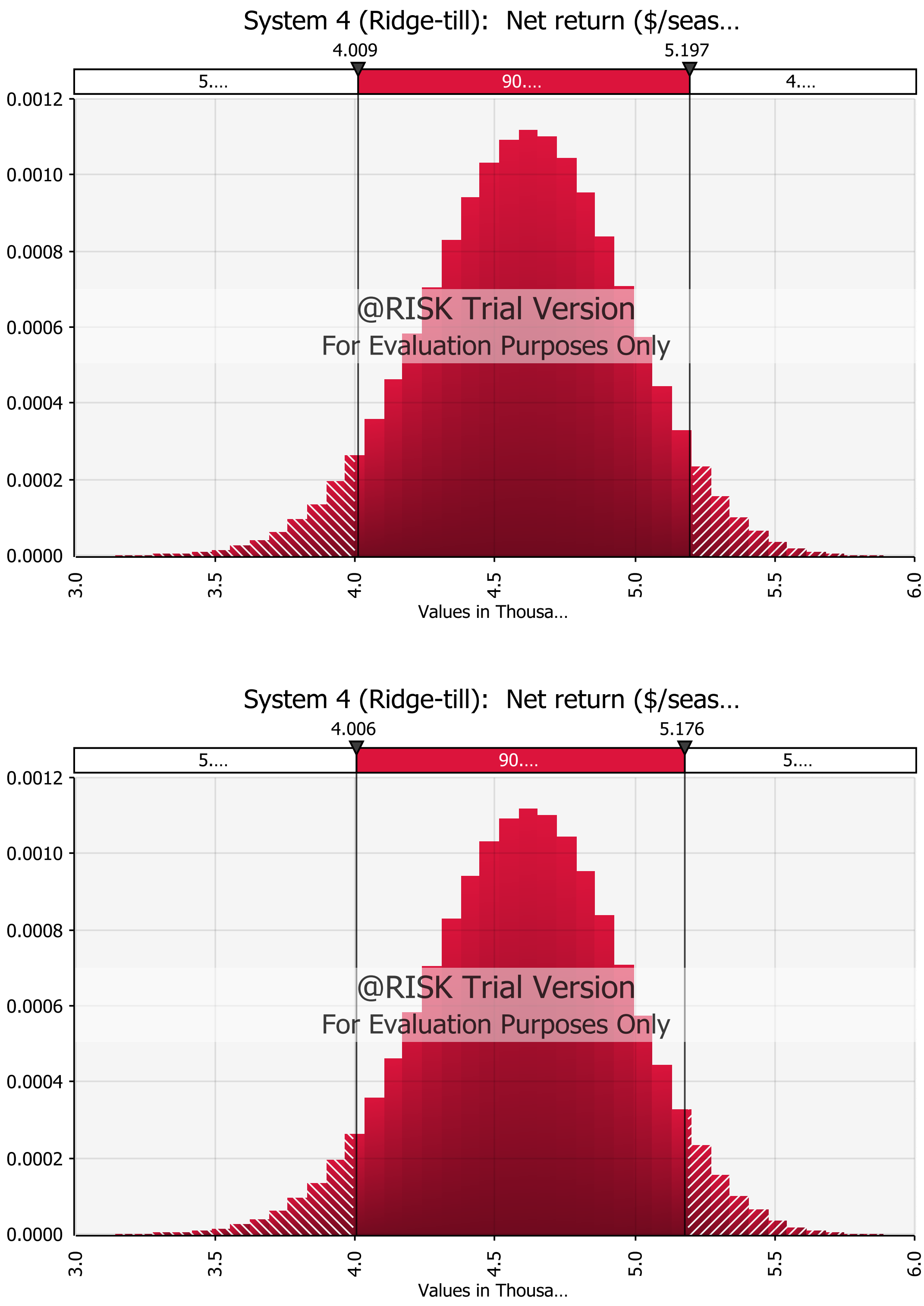


Figure 4.12: System 4 Net Revenue: Yield with beta distribution

CHAPTER 5

COMMERCIAL ADOPTION AND MARKETING CHANNEL OPTIONS FOR VEGETABLES PRODUCED IN THE ORGANIC CROPPING SYSTEMS

As the demand for organic food has increased, we have also seen a rise in the quantity of food sold through direct marketing channels such as farmers' markets, community-supported agriculture (CSA), community gardens, and green roofs. The analysis in Chapter 4 assumed that crops from the OCS would be sold at farmer's markets. Data from university experimental trials offers useful information concerning new technologies; however, there is naturally a gap between economic findings from an experimental trial and a commercial setting. Next I discuss alternative marketing channels and provide some preliminary economic implications for a farm that sells OCS products directly to restaurants. Because the OCS uses strategic on-farm experiments, we can build on and extend organic management practices of successful, innovative organic growers to other farm and market scenarios. Changing some of the assumptions made in earlier chapters can provide insight to the application of the OCS to wholesale markets, and direct-to-consumer markets including community supported agriculture and urban farming.

5.1 Commercial Wholesale

The majority of organic food sales (93%) take place through conventional and natural food supermarkets (OTA, 2010). Consumer demand for variety, convenience and quality are just some of the demand-side forces that have led to market expansion and new accessibility. Historically, fresh fruits and vegetables has been the most popular organic category. Fresh produce are important in the organic sector because they are often "gateway" products, or the first organic products purchased by consumers (Dettman and Dimitri, 2010). In response to the growing popularity of organic products, conventional supermarkets as well as other mass market merchandisers have increased their stock of organic fruits and vegetables.

The OCS model can be extrapolated to a commercial wholesale model by changing assumptions about machinery costs and price received for crops. The model used in the analysis so far has assumed that products are sold at retail prices at a farmer's market. Compared to direct markets, retail outlets will purchase produce from the farmer at a lower price, but in larger volume. However, produce from a farm following the OCS is better suited for small commercial businesses that are vertically integrated. Total input costs would be much higher for a large company. A commercial wholesale farm would utilize more machinery requiring more fuel. The machinery would probably be more efficient; for example we assume a tractor with 25 horsepower, while a larger farm may use a tractor with 65 horsepower, which would reduce the labor hours. A large operation would probably have more land and require more labor. In addition, a larger farm can have a larger more geographically spread out consumer base therefore increasing marketing costs, which would include transportation and distribution. Groceries stores may require special packing with store logos and nutritional labeling, which would increase the materials costs and product preparation time. Product specification and volume commitments along with distributor's demands such as dictated prices, deadlines and delivery logistics are cited as reasons small farmers in Central New York tend to avoid the wholesale marketing channel (LeRoux et al., 2010).

5.2 Direct-to-Consumer Market Channels

The majority of farms that sell directly to consumers are small farms with less than $50,000 in total farm sales located near urban centers in the Northeast and West Coast (U.S. Census of Agriculture, 2007). The OCS would be best suited for direct-to-consumer enterprises including CSA, farmer’s market, farm stands, and U-pick operations. The experimental design is modeled after farms that sell at retail in direct markets. According to the 2007 Census of Agriculture, the value of sales in the direct-to-consumer marketing channel increased from $551 million in 1997 to $1.2 billion in 2007. LeRoux et al. (2010) found that the CSA market channel offers the highest direct-to-market sales volume and higher prices than wholesale channels. In addition, the authors identified the CSA channel to have the highest profitability margin.

In a CSA model, the consumer pays for a share before harvest, which assists with cash flow. Regardless of yields, the farm operator is guaranteed the agreed amount for the season. System 1 (High Intensity) would likely be most desirable because it produces two additional crops. The marketing costs may decrease depending on how pick-ups are arranged, i.e. farmer’s market, farm pick up, drop off, or mailed to home. Sometimes delivery costs are transferred to the consumer as a delivery fee. Labor costs can also vary depending on the type of direct-to-consumer marketing channel. For example, a U-pick enterprise would shift the harvest time from the farm operator to the consumer. The U-pick channel is the second highest volume direct-to-consumer marketing channel in New York State, but the farmer receives a lower price compared with other direct market channels (LeRoux et al., 2010).

5.3 Marketing Channels Linked to Urban Farming

Another possible application of the OCS is to the burgeoning field of urban farming. Urban agriculture takes the form of backyard, roof-top and balcony gardening, community gardening in vacant lots and parks, roadside urban fringe agriculture and livestock grazing in open space. Urban agriculture increases both the amount of food available to people living in cities and access to fresh vegetables. Urban farming present another set of possibly marketing channels including mobile retailers, street food, cooperatives, and direct-to restaurant sales.

For many organic producers, New York City provides a veritable local market with potential. New York City is the largest city in the United States and accounts for approximately 40% of New York State's population. New York City only had two farmers' markets in 1979 and has over 45 in 2008. The inability of upstate farmers to transport their produce into New York City is often noted as a barrier to market entry.

City residents can still obtain fresh organic vegetables via urban agriculture. The demand for fresh produce has led to initiatives that support public green spaces and community gardens. This new trend could lead to either for profit and nonprofit models. Community gardens can promote healthy communities and provide food security for low income families. Some urban gardeners have used empty lots to start community or urban garden as the pH is kept neutral. The lots are either public space or abandoned, reducing the land costs. Machinery costs would decrease since it would be difficult to utilize tractors and other large farm equipment in small areas. On the other hand, labor costs would increase since there may be more than one farm operator and the work previously performed by machines would be substituted for hand labor. Community gardening contributes to the preservation of open space, provide access to it, and create sustainable uses of the space. Similarly, micro-gardening or the intensive cultivation of vegetables in small spaces such as balconies, roof tops and patios allows the urban farmer to grow produce in containers such as wooden crates, custom built beds, or even car tires.

This type of urban agriculture integrates horticulture production techniques with environmentally friendly technologies suited to cities, such as rainwater harvesting and household waste management. Micro-gardening is best for a self-sufficient food supply, but may also generate income from small surpluses. Marketing costs would be highly dependent on the crop yield and the target market for the crops. Developing agricultural capacity within or close to urban areas like New York City has the potential to reduce food transportation costs and environmental impacts, provide economic development opportunities, and reduce disparities in healthful food access to underserved communities. Despite these potential advantages, there are challenges to building a viable urban agricultural enterprise including scalability, site availability and labor costs.

5.4 Extending the Baseline Analysis to Examine Farm- to-Restaurant Sales

The use of seasonal, local, and organic produce is growing in popularity among chefs and high-end restaurants. Restaurants buy directly from farmers for several reasons including perceived quality and freshness, customer requests for local products, and the availability of specialty varieties and unique produce. Farmers can benefit from additional income and relationships with local businesses gained through the farm-to-restaurant marketing channel. However, direct-to-restaurant sales are not without challenges. The challenges of meeting the restaurant's availability, variety, and timeliness needs are similar to those found in the commercial wholesale marketing channel. In addition, prices received are about 20% less than retail and chefs may expect further discounts for higher volume purchases (Roos, 2010). LeRoux et al. (2010) also note that direct-to-restaurant channels have a fewer number of associated costs, but higher costs overall. For example, costs for delivery, training and certification for food safety, and packaging may be some anticipated costs for farms selling to larger foodservice companies.

Table 5.1 provides a modified enterprise budget for direct-to-restaurant sales using the OCS data with changes to time and cost assumptions. As an illustrative example, the adjustments provide a rough estimate of how marketing costs might change for this sales outlet. The price is adjusted to 80% of the baseline retail price and this is reflected in the total receipts.

Machinery and materials costs remain the same. The marketing cost assumption of 20% of total receipts is broken down by communication, delivery, advertisement, and bookkeeping. A key difference between costs for the farm-to-restaurant channel and the farmer's markets is the increase in communication time and costs. An additional 50 hours are added to account for time processing orders, developing relationships with chefs, and local delivery for System 2 (Intermediate Intensity) and System 4 (Ridge-till). Proportional adjustments were made to total operator hours for System 1 (High Intensity) and System 3 (Bio-extensive) based on the number of cash crops. The majority of enterprise budgets are calculated at the farmgate level and do not include transportation. Levinson, Corbett and Hashimi (2005) estimated the operating cost for commercial trucks transporting based on fuel, repair, maintenance, tires and depreciation costs to be $0.31 per kilometer. Here it is assumed that 2000 miles (3219 kilometers) are driven per season to transport the produce to local restaurants. Again, the mileage is adjusted for System 1 (High Intensity) which may have a larger market due to higher yields from the secondary crops and for adjusted downwards for System 3 (Bio-extensive). Advertisement costs (based on local printing costs) include business cards, price lists, product information sheets, preparation tips/recipes and websites. A farmer utilizing the farm-to-restaurant marketing channel will require bookkeeping software and machinery to record transactions and invoice the restaurant.

In this example, marketing costs account for 23% to 52% of total receipts, which represent a larger percentage than the 20% calculated in the previous tables. As with the baseline analysis for the farmer's market scenario, net returns are highest in System 1 (High Intensity) and lowest in System 3 (Bio-extensive). Interestingly, when land and labor are taken into account, the whole farm net return is negative. This can be attributed to the additional marketing time needed in the direct-to-restaurant marketing channel and lower total receipts. In this example, a farm operator would maximize profits by selling at a farmer market instead of direct-to-restaurant, which is consistent with the findings by LeRoux et al. (2010). In reality, most farm operators have the option to utilize multiple marketing channels, which can have both a positive and negative impact on profitability. However, business relationships and farm reputation can improve with increased exposure to different marketing channels, but these traits are more difficult to measure quantitatively.

5.5 Summary of Marketing Channel Opportunities for Organic Vegetable Crops

In order to ensure income for small organic farms, it is essential to connect farmers to markets. Currently, organic farmers in New York State utilize a variety of marketing channels which include farmer's markets, farm stands, U-pick operations, wholesale distributors, CSA, restaurants, specialty shops and supermarkets, food processors as well as international markets. Traditional direct markets are often the main sales outlet for smaller farms that are exempt from organic certification (farms selling less than $5,000 of organic products each year), while organically certified farms favor retail and wholesale marketing channels. The majority of organic farmers (58.4%) sold their agricultural products locally within a 100 mile radius. Approximately 35% of certified organic farm sales were conducted regionally or more than 100 miles but less than 500 miles (USDA-NASS, 2008). With some changes, the OCS can be applied to farms selling products to these traditional and nontraditional markets.

Table 5.1: Modifying the Baseline Results to Consider the Direct-to-Restaurant Channel[a]

		System 1 (High Intensity)	System 2 (Intermediate Intensity)	System 3 (Bio-extensive)	System 4 (Ridge-till)
Total receipts ($)		**9164.83**	**6513.81**	**3207.39**	**6092.90**
Costs					
Machinery costs ($)		999.53	790.27	458.49	783.32
Material costs ($)		865.22	701.88	457.53	706.49
Marketing costs ($)		2,146.69	1,647.79	823.90	1,647.79
	Communications	600	600	300	600
	Transportation	1,496.69	997.79	498.90	997.79
	Advertisement	50.00	50.00	25.00	50.00
	Bookkeeping	200.00	200.00	100.00	200.00
Total costs		4,011.44	3,139.94	1,739.92	3,137.60
Baseline net return ($/season)		7,300.08	5,021.65	2,291.38	4,603.08
Modified net return ($/season)		**5,153.39**	**3,373.86**	**1,467.48**	**2,955.29**
Total operator hours required		316.01	233.93	121.78	222.17
Acres managed given 1500 operator hours		1.90	2.56	4.93	2.70
Whole farm net return given 1500 hours available ($/season)		(12,927)	(17,074)	(19,473)	(20,314)
Net return per operator hour ($/hour)		(8.62)	(11.38)	(12.98)	(13.54)

[a] Analysis based on a farm with 0.1 acres of each crop.

CHAPTER 6

CONCLUSION AND FUTURE RESEARCH

6.1 Summary

Fresh fruits and vegetables have been the top selling category of organically grown food since the organic food industry introduced retail products over three decades ago; today they still continue to outsell other food categories in terms of value (OTA, 2010). However, certified organic cropland only accounts about 0.5% of agricultural land in the United States (USDA-ERS, 2008).

The OCS seeks to provide farmers with a holistic evaluation of distinct organic cropping systems by analyzing synergies and trade-offs among rotations, cover crops, soil fertility, weeds, pests and economics with the goal of helping farm operations to become more prosperous, sustainable and environmentally friendly. As a long-term systems experiment, the OCS project investigates the consequences of organic crop production systems with contrasting tillage regimes, cover crops and applied amendments on yields and profitability.

The majority of economic research that examines organic markets focuses on consumer issues. Of the research examining production economics issues in organic markets, few studies emphasize whole systems properties such as yields and economics for vegetables. With five years of data and two completed crop rotations, the results from this research provide preliminary guidance on the economic considerations for organic vegetable systems in temperate climates. While different cropping systems are best suited for different crops, overall, System 1 (High Intensity) is the most profitable system for the farm operator as a whole. Sensitivity analyses performed on whole systems baseline results indicated that yield and price had the largest impact on net operator return. While experimental data is valuable, the data collected were augmented with simulation work since the project is ongoing and only a small sample is available.   Since yield is highly variable, various Monte Carlo simulations were run to analyze different possible yield distributions from poor yields to bumper crops. Additional data is necessary to test the goodness-of-fit for yield under these three distributions. The baseline results assume that OCS products were sold at a farmer's market; however, other commercial settings were considered here including wholesale, direct, and urban agricultural markets.

6.2 Conclusion

The use of systems thinking and integrated management strategies is fundamental to organic agriculture. USDA regulations concerning organic production practices are now well defined, but are flexible and allow a wide range of systems that comply with the standards. Agricultural producers need to carefully assess the trade-offs between the numerous management options and strategies to maximize profitability while also considering biological and social sustainability. The research reported here examines the economic implications of such flexibility by assessing the profitability of alternative organic cropping systems. The OCS experiment compares four different cropping systems that comply with USDA organic standards on an experiment station farm. Data from the experiment enable us to perform an economic analysis that examines profitability and land management capability across the systems. The results will help small-scale farmers develop management plans that meet USDA organic certification requirements and generate profits.

This thesis examines the economic implications in the several systems in a multiple-year crop rotation of cabbage, lettuce, potatoes and squash. The results indicate that net returns to both land and labor range widely across the alternative systems for each crop, and that different systems generate the highest net returns for different crops. System 1 (High Intensity) generated the highest net returns per acre and per labor hour for an operation producing all four crops; it would generate more than an operation that adopted a mixed approach using System 2 (Intermediate Intensity) and System 4 (Ridge-till). Overall, the most striking result of our analysis is that whole farm net returns per hour were similar across the four systems, even when yields and returns per acre differed widely. This result indicates that in the absence of constraints on land availability, organic cropping systems that use cover crops and fallow periods to reduce weeds and improve soil quality may result in little loss of net return to labor for small-scale producers.

This study also performed a sensitivity analysis to examine how small percentage changes in the prices, yields, fuel costs, and marketing expenses influence net returns at the farm level. This sensitivity analysis suggests that net returns are more responsive to changes in yields and prices received, and less responsive to changes in input costs. This supports the need for continuing research that focuses on improving yields for organic vegetables. Changes in prices can be achieved through various mechanisms, yet for a niche market such as organic produce they are primarily driven by an increase in demand via new information and promotional efforts that introduce the product to more consumers. Agricultural producers and policy-makers interested in expanding markets and generating revenue for organic produce should look to policies or industry-led initiatives that increase demand for organic vegetable products.

6.3 Future Research

While this study offers valuable insight on the profitability of organic cropping systems, there are areas that require further research. Additional data will provide more precise results and there are plans to continue collecting new data from ongoing trials of the OCS. The parametric approach of modeling yields usually involves selection of distributions, parameter estimation and assessment of goodness-of-fit. With the addition of long-term time series experimental data, the distribution of historical yields can be compared to the normal, gamma and beta simulations by utilizing a goodness-of-fit test such as the Shapiro-Wilkes, Chi-squared, Anderson-Darling or Kolmogorov-Smirnov tests. Extensions of the sensitivity analysis introduced here can provide implications for crop insurance and risk.

The analysis provided in this thesis maximizes profitability for a risk neutral farm operation. However, a risk adverse farmer may also choose to implement System 1 (High Intensity) because they will grow more cash crops and mitigate risk with diversification of crops. Future studies can use math programming to study risk with formal optimization models to better understand decisions of risk adverse farmers.

There is a strong consensus in the organic research community that systems experiments are necessary and informative. The OCS is one of the few long-term organic studies in the United States and the only one to apply a ridge till system for growing vegetables. Although this study utilizes a carefully constructed crop rotation by expert farmers, there are endless other variations in cash crops that maybe more suitable for different climates, regions, markets and cultural preferences.

Lastly, this project was designed to emulate real farms and the majority of farms are small. Applications of this study to large commercial farms would also provide interesting results, which could then provide the basis for comparative studies between economics of scale. In addition, the large commercial farm model could also provide insight into other markets such as retailing with national supermarkets, international retailers and food service.

6.4 An Argument for Increased Public Expenditures for Organic Production Research

Organic farmers have made a clear request for information on how management changes affect the soil, yields and economic returns in their farming systems. Organic farming is knowledge intensive, and organic farmers regularly experiment with new crops and practices on small areas of their farms. These efforts may produce ambiguous or even misleading results due to confounding information between treatments and spatial variation. Lack of repetition in years with varying weather conditions can also serve to muddle results. As such, long-term systems experiments designed to investigate biological, physical and economic consequences of organic crop productions systems are best poised to examine the impacts of these interactions. Investment in sustainable farming research and collaboration between farmers, educators and researchers could also drive advances in organic technology.

The government has focused primarily on developing national certification standards to assure consumers that certified organic products meet a set of nationally consistent standards. The scope of organic policy has expanded, and we now have a series of programs and pilot projects to help organic producers with production problems and risks as well as promote organic agricultural products overseas. The USDA is undertaking national organic agriculture research efforts. For example, the National Institute of Food and Agriculture (NIFA) is an agency within the USDA which manages the Organic Agriculture Research and Extension Initiative. The OREI provides funds for projects that will enhance the ability of producers and processors who have already adopted organic standards to grow and market high quality organic agricultural products. The OCS supports the OREI goals of facilitating development of organic agriculture, evaluating the potential benefits of producers who use organic methods, and conducting advanced on farm research. To maximize farmer learning from the OCS, outreach and engagement efforts include:

- Field days, workshops, webinars
- Creating on-farm research networks
- Publications for farmers (online, newsletters, and magazines)

These objectives provide opportunities for experimental learning about economic conditions in organic systems while increasing the capacity of organic farmers for effective experimentation. These networking and educational efforts will deliver information and key finds from this project to organic farmers and ultimately help them develop sound organic farm plans to meet NOP organic requirements.

Additional funding for research and development activities related to organic research, are expected to yield improved soil quality; more efficient cycling of nutrients with consequently lower costs and few off-farm impacts; reduced weed, insect and disease problems in vegetable crops; improved crop yields and crop quality; higher economic returns and increased understanding by farmers of the natural processes occurring on their farms.

REFERENCES

Altieri, M., and P. Rosset. (1999). "Ten reasons why biotechnology will not ensure food security, protect the environment and reduce poverty in the developing world." *AgBioForum* 2(3), 155–162.

Anderson, J.R. (1974). "Simulation methodology and application in agricultural economics." *Review of Marketing and Agricultural Economics* 42(1), 3–55.

Asami, D., Y. Hong, D. Barret, and A. Mitchell. (2003). "Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn grown using conventional, organic, and sustainable agricultural practices." *Journal of Agricultural and Food Chemistry* 2003(51), 1237–1241.

Badgley, C., J. Moghtader, E. Quintero, E. Zakem, M. Chappell. K. Aviles-Vazquez, A. Samulon, and I. Perfecto. (2007). "Organic Agriculture and the Global Food Supply." *Renewable Agriculture and Food Systems* 22(2), 86–108.

Bengtsson, J., J. Anstrom. A.C. Weibull. (2005). "The effects of organic agriculture on biodiversity and abundance: a meta-analysis." *Journal of Applied Ecology* 42(2), 261–269.

Beyl, C.A. (1991). "History of the Organic Movement." Online. Available at http://www.hort.purdue.edu/newcrop/history/lecture31/r_31-3.html. [Retrieved December 5, 2011].

Burket, J. Z., D.D. Hemphill, and R.P. Dick. (1997). "Winter cover crops and nitrogen management in sweet corn and broccoli rotations." *HortScience* 32, 664–668.

Cavigelli, M.A., B.L. Hima, J.C. Hanson, J.R. Teasdale, A.E. Conklin, and Y. Lu. (2009). "Long-term economic performance of organic and conventional field crops in the Mid-Atlantic region." *Renewable Agriculture and Food Systems* 24(2), 102–119.

Conner, D. and A. Rangarajan. (2009). "Production costs of organic vegetable farms: Two case studies from Pennsylvania." *HortTechnology* 19, 2193–199.

Dalgaard, T., N. Halberg, and J.R. Porter. (2001). "A model for fossil energy use in Danish agriculture used to compare organic and conventional farming." *Agriculture, Ecosystems & Environment* 87(1), 51–56.

Day, R. H. (1965). “Probability distributions of field crop yields.” *Journal of Farm Economics* 47, 713–741.

Delate, K., C. Cambardella, and A. McKern. (2008). “Effects of organic fertilization and cover crops on an organic pepper system.” *HortTechnology* 18, 215–226.

Delate, K., M. Duffy, C. Chase, A. Holste, H. Friedrich and N. Wantate. (2003). “An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa.” *American Journal of Alternative Agriculture* 18, 59–69.

Dettman, R.L. and C. Dimitri. 2010. “Who’s buying organic vegetables? Demographic characteristics of U.S. consumers.” *Journal of Food Products Marketing* 16(1), 79–91.

Dimitri, C., E. C. Jaenicke and L. Oberholtzer. (2008). “Local marketing of organic food by certified organic processors, manufacturers, and distributors.” *Journal of Agribusiness* 26(2), 157–174.

European Commission Research. (2009). “Organic Food: Higher Quality, Lower Costs.” European Research Area, Agriculture and Food. Online. Available at http://ec.europa.eu/research/research-for-europe/agriculture-quality-low-input-food_en.html. [Retrieved June 5, 2011].

Ferreira, V. A., G. A. Weesies, D. C. Yoder, G. R. Foster, and K. G. Renard. (1995). “The site and condition specific nature of sensitivity analysis.” *Journal of Soil & Water Conservation*. 50(5), 493–549.

Flessa, H., R. Ruser, P. Dörsch.,T. Kam , M.A. Jimenez, J.C. Munch, and F. Beese. (2002). “Integrated evaluation of greenhouse gas emissions (CO_2,CH_4, N_2O) from two farming systems in southern Germany.” *Agriculture, Ecosystems and Environment* 91, 175–189.

Fuller R.J., L.R. Norton, R.E. Feber, P.J. Johnson, D.E. Chamberlain, A.C. Joys, F. Matthews R.C. Stuart, M.C. Townsend, W.J. Manley, M.S. Wolfe, D.W. Macdonald and L.G. Firbank. (2005). “Benefits of organic farming to biodiversity vary among taxa.” *Biology Letters* 1(4), 431–434.

Franzlubbers, A. and R. Haney. (2006). “Assessing Soil Quality in Organic Agriculture.” The Organic Center. Online. Available at www.organic-center.org. [Retrieved June 5, 2011].

Giraud, K.L., C.A. Bond, and J.K. Bond. (2005). "Consumer preferences for locally made specialty food products across northern New England." *Agricultural and Resource Economics Review* 34(2), 204–216.

Green, R.E., S.J. Cornell, J.P.W. Scharlemann, and A. Balmford. (2005). "Farming and the Fate of Wild Nature." *Science* 307(5709), 550–555.

Hansen, B., H.F. Alroe and K.E. Steen. (2001). "Approaches to assess the environmental impact of organic farming with particular regard to Denmark." *Agriculture, Ecosystems and Environment* 83(1-2), 11–26.

Hanson, J.C., E. Lichtenberg, A.M. Decker, and A.J. Clark. (1993). "Profitability of no-tillage corn following a hairy vetch cover crop." *Agricultural Economics* 6(3),432–43.

Heckman, J. (2006). "A History of Organic Farming: Transitions from Sir Albert Howard's War in the Soil to the USDA National Organic Program." *Renewable Agriculture and Food Systems* 21(3), 143–150.

Henehan, B.M., and J. Li. (2010). "Organic agriculture in New York State." *AEM Extension Bulletin 2010-13,* Charles H. Dyson School of Applied Economics and Management, Cornell University.

Hu, W., T. Woods, and S. Bastin. (2009). "Consumer acceptance and willingness to pay for blueberry products with nonconventional attributes." *Journal of Agricultural and Applied Economics* 41(1), 47–60.

Jacobsen, K.L., C.L. Escalante and C.F. Jordan. (2010). "Economic analysis of experimental organic agricultural systems on a highly eroded soil of the Georgia Piedmont, USDA." *Renewable Agriculture and Food Systems* 25(2), 296–308.

James, J., B. Rickard and W. Rossman. (2009). "Product differentiation and market segmentation in applesauce: Using a choice experiment to assess the value of organic, local, and nutrition attributes." *Agricultural and Resource Economics Review* 38(3), 357–370.

Johnson, S. E. and E.Toensmeier. (2009). "How expert organic farmers manage crop rotations" In *Crop Rotation on Organic Farms: A Planning Manual*, C. L. Mohler and S. E. Johnson, eds., pp. 3–20. Ithaca, New York: Natural Resource, Agriculture, and Engineering Service.

Johnston, A.E., P.R. Poulton, and K. Coleman. (2009). "Chapter 1 Soil Organic Matter: Its Importance in Sustainable Agriculture and Carbon Dioxide Fluxes" In *Advances in Agronomy*, D. L. Sparks, eds., pp1–57. Newark, Delaware: Academic Press.

Just, R.E. and Q. Weninger. (1999). "Are crop yields normally distributed?" *American Journal of Agricultural Economics* 81(2), 287–304.

Korschens, M., A. Weigel, and E. Schulz. (1998). "Turnover of soil organic matter and long-term balances – tools for evaluating sustainable productivity of soils." *Zeitschrift fuer Pflanzenernaehrung und Bodenkunde* 161(4), 409–424.

Krebs, J.R., J.D. Wilson, , R.B. Bradbury, and G.M. Siriwardena. (1999). "The second silent spring?" *Nature* 400, 611–661.

Kremen, C., N.M. Williams, and R.W. Thorp. (2002). "Crop pollination from native bees sat risk from agricultural intensification*."* *Proceedings of the National Academy of Sciences of the United States of America* 99(26), 16812–16816.

Levinson, D., M. Corbett, and M. Hashimi. "Operating Costs for Trucks." Online. Available at: http://nexus.umn.edu/papers/truckoperatingcosts.pdf. [Retrieved December 15, 2011].

LeRoux, M.N., T.M. Schmit, M. Roth, and D.H. Streeter. (2010). "Evaluating marketing channel options for small-scale fruit and vegetable producers." *Renewable Agriculture and Food Systems* 25(1), 16–23.

Loureiro, M.L., J.J. McCluskey, and R.C. Mittelhammer. (2001). "Assessing consumer preferences for organic, eco-labeled, and regular apples." *Journal of Agricultural and Resource Economics* 26(2), 404–416.

Lowenfels, J. and W. Lewis. (2006). *Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web*. Portland, Oregon: Timber Press

Maeder, P., A. Fliessbach, D. Dubois, L. Gunst, P. Fried and U. Niggli. (2002). "Soil fertility and biodiversity in organic farming." *Science*, 296 (5573), 1694–1697.

McBride, W.D. and C. Greene. (2008). "The profitability of organic soybean production." *Renewable Agriculture and Food Systems* 24(4), 276–284.

Molinar, R., M. Yang, K. Klonsky and R. De Moura. (2005). “Sample Costs to Produce Summer Squash.” University of California Cooperative Extension. Online. Available at http://coststudies.ucdavis.edu/files/squashvs2005.pdf. [Retrieved June 5, 2011].

Musser, W.N., J. Ohannesian, and F.J. Benson. (1981). "A safety-first model of risk management for use in extension programs.” *North Central Journal of Agricultural Economics* 3(1), 41–46.

New York State Department of Agriculture & Markets. (2011). “Organic Farming Information Center.” Online. Available at http://www.agriculture.ny.gov/AP/ organic/. [Retrieved December 5, 2011].

Niggli, U., A. Fliessbach, P. Hepperly, and N. Scialabba, N. (2009) . “Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems.” *FAO*, April 2009, Rev. 2 – 2009.

Nordell, A, and E. Nordell. (2007). *Weed the Soil, Not the Crop: A Whole Farm Approach to Weed Management*. 42 pp. Available from the authors.

Northeast Organic Farming Association of New York. “About NOFA-NY.” Online. Available at http://www.nofany.org/about. [Retrieved December 5, 2011].

O’Riordan, T., and D. Cobb. (2001). “Assessing the consequences of converting to organic agriculture.” *Journal of Agricultural Economics* 52(1), 22–35.

Ogbuchiekwe, E.J., M.E. McGiffen Jr., and M. Ngouajio. (2004). “Economic return in production of lettuce and cantaloupe is affected by cropping system and management practice.” *HortScience* 39, 1319–1323.

Olesen, J.E., I.A. Rasmussen, M. Askegaard, and K. Kristensen. (2002). “Whole-rotation dry matter and nitrogen grain yields from the first course of an organic farming crop rotation experiment.” *Journal of Agricultural Science* 139, 361–370.

Organic Trade Association. “U.S. Organic Industry Overview.” Online. Available at http://www.ota.com/pics/documents/2010OrganicIndustrySurveySummary.pdf. [Retrieved June 5, 2011].

Pacini, C., A. Wossink, G. Giesen, C. Vazzana, and R. Huirne. (2002). Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. *Agriculture, Ecosystems and Environment* 95(2003), 273–288.

Peck, G.M., I.A. Merwin, and M.G. Brown. (2010). “Integrated and organic fruit production systems for ‘Liberty’ apple in the Northeast United States: A systems-based evaluation.” *HortScience* 45,1038–1048.

Perfecto, I. and C. Badgley. (2007). “Can organic agriculture feed the world?” *Pesticide News* 78, 17–19.

Petersen, S.O., K. Regina, A. Pöllinger, E. Rigler, L. Valli, S. Yamulki, M. Esala, C. Fabbri, E. Syväsalo, and F.P. Vinther. (2005). “Nitrous oxide emissions from organic and conventional crop rotations in five European countries.” *Agriculture, Ecosystems & Environment* 112, 200–206.

Pimentel, D. (2005). “Environmental and economic costs of the application of pesticides primarily in the United States.” *Environment, Development, and Sustainability* **7**, 229–252.

Pollan, M. (2007). *The Omnivore’s Dilemma: A Natural History of Four Meals*. New York: Penguin Books.

Ramirez, O.A., S. Misra and J. Field. (2001, August 5-8). “Are Crop Yields Normally Distributed?” Paper presented at the annual meeting of the American Agricultural Economics Association, Chicago, Illinois.

Rodale Institute. “The History of the Rodale Institute.” Online. Available at http://www.rodaleinstitute.org/about_us. [Retrieved December 5, 2011].

Rodale Institute. “The Farming Systems Trial: Celebrating 30 years.” Online. Available at http://www.rodaleinstitute.org/files/FSTbookletFINAL.pdf. [Retrieved December 1, 2011].

Roos, D. (2010). “ Marketing to Restaurants.” North Carolina Cooperative Extensive. Online. Available at http://www.ces.ncsu.edu/chatham/ag/SustAg/marketingrestaurants.html. [Retrieved December 5, 2011].

Schoofs, A., M.H. Entz, R.C. Van Acker, J.R. Thiessen Martens, and D.A. Derksen. (2005). “Agronomic performance of pesticide free production under two crop rotations.” *Renewable Agriculture and Food Systems* 20(2), 91–100.

Sellen, D., J.H. Tolman, D.G.R. McLeod, A. Weersink, and E.K. Yiridoe. (1996). “A comparison of financial returns during early transition from conventional to organic vegetable production.” *Journal of Vegetable Crop Production* 1, 11–39.

Shepherd, M.A., R. Harrison, J. Webb. (2002). "Managing soil organic matter – implications for soil structure on organic farms." *Soil Use and Management* 18, 284–292.

Studdert, G. and H. Echeverria. (2000). "Crop rotations and nitrogen fertilization to manage soil organic carbon dynamics." *Soil Science Society America Journal*, 64(July-August): 1496–1503.

Stolze, M., A. Piorr, A. Haring, and S. Dabbert. (2000). *The Environmental Impacts of Organic Farming in Europe*. Stuttgart-Hohenhiem: University of Hohenheim.

Swinton, S.M. and R.P. King. (1991). "Evaluation robust regression techniques for detrending crop yield data with non-normal errors." *American Journal of Agricultural Economics* 73(2), 446–451.

Tourte, L., R.F. Smith, K.M. Klonsky, and R.L. De Moura. (2009). "Sample costs to produce organic leaf lettuce." University of California Cooperative Extension. Online. Available at http://coststudies.ucdavis.edu/files/lettuceleaforganiccc09.pdf. [Retrieved September 6, 2011].

United Nations. (2009). "Agriculture at a Crossroads." Online. Available at http://www.agassessment.org/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Global%20Report%20(English).pdf. [Retrieved December 5, 2011].

United Nations. (2007). "Organic Agriculture and Food Security In Africa." Online. Available at http://www.unctad.org/en/docs/ditcted200715_en.pdf. [Retrieved December 5, 2011].

United Nations. (2010). "Promotion and protection of all human rights, civil, political, economic, social and cultural rights, including the right to development." Online. Available at http://www.srfood.org/images/stories/pdf/officialreports/20110308_a-hrc-16-49_agroecology_en.pdf. [Retrieved December 5, 2011].

U.S. Department of Agriculture Census of Agriculture. (2010). "Farms, Land Use and Sales of Organically Produced Commodities on Certified and Exempt Organic Farms: 2008." Online. Available at http://www.agcensus.usda.gov/Publications /2007/Online_Highlights/Organics/ organics_1_01.pdf. [Retrieved June 2011].

U.S. Department of Agriculture Economic Research Service. (2008). "Organic product introductions in U.S. retail markets, by year and category." Online. Available at www.ers.usda.gov/Briefing/organic/Data/OrgProdIntro19862008.xls. [Retrieved June 5, 2011].

U.S. Department of Agriculture Economic Research Service. (2008). "Certified organic and total U.S. acreage, selected crops and livestock, 1995-2005." Online. Available at http://www.ers.usda.gov/Data/organic/Data/certified%20and%20total %20us%20acreage%20selected%20crops%20livestock%2095-05.xls. [Retrieved June 5, 2011].

U.S. Department of Agriculture Marketing Services. (2011). "National Organic Program." Online. Available at http://www.ams.usda.gov/AMSv1.0/nop. [Retrieved June 5, 2011].

U.S. Department of Agriculture National Agricultural Statistics Services. (2007). "New York is an Agricultural State." Online. Available at http://www.nass.usda.gov/Statistics_by_State /New_York/Publications/ Statistical_Reports/NYisanAgState07.pdf. [Retrieved June 5, 2011].

U.S. Department of Agriculture National Agricultural Statistics Services. (2011). "Vegetable Report." Online. Available at http://www.nass.usda.gov/Statistics_by _State /New_York/ Publications/Statistical_ Reports/01jan/veg0111.pdf. [Retrieved June 5, 2011].

U.S. Department of Agriculture National Organic Program. (2005). "Organic Foods Production Act of 1990 [As Amended Through Public Law 109-97, Nov. 10, 2005]." Online. Available at http://www.ams.usda.gov/AMSv1.0/getfile?dDocName =STELPRD C5060370&acct=nopgeninfo. [Retrieved June 5, 2011].

Umberger, W. J., D. D. Thilmany McFadden, and A. R. Smith. (2009). "Does altruism play a role in determining U.S. consumer preferences and willingness to pay for natural and regionally produced beef?" *Agribusiness* 25(2), 268–285.

Wang, X., K. Curtis, and K. Moeltner. (2011, February 8-11). "Modeling the impact of new information on consumer preferences for specialty meat products." Paper presented at the 55th annual Australian Agricultural and Resource Economics Society, Melbourne Australia.

Wiswall, R. (2009). *The Organic Farmer's Business Handbook: A Complete Guide to Managing Finances, Crops, and Staff – and Making a Profit*. White River Junction, Vermont: Chelsea Green Publishing.