Sustainable Agriculture Research; Vol. 5, No. 4; 2016
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

# Profitability of Organic Vegetable Production via Sod Based Rotation and Conventional Versus Strip Tillage in the Southern Coastal Plain

Mona Ahmadiani[1], Chun (Cathy) Li[1], Yaqin Liu[1], Esendugue Greg Fonsah[2], Christine M. Bliss[3], Brent V. Brodbeck[3] & Peter C. Andersen[3]

[1]Department of Agriculture and Applied Economics, University of Georgia, Corner Hall, Athens, GA 30206, USA

[2]Department of Agriculture and Applied Economics, University of Georgia, Tifton, GA, 31793, USA

[3]University of Florida, Institute of Food & Agricultural North Research and Education Center 155 Research Road, Quincy, FL 32315, USA

Correspondence: Mona Ahmadiani, Department of Agriculture and Applied Economics, University of Georgia, Corner Hall, Athens, GA 30206, USA. E-mail: monaah@uga.edu

Received: June 27, 2016 Accepted: July 13, 2016 Online Published: September 15, 2016
doi:10.5539/sar.v5n4p46 URL: http://dx.doi.org/10.5539/sar.v5n4p46

**Abstract**

There are little economic data concerning the profitability of organic vegetable crops in the Southern Coastal Plain, especially in reference to sod-based rotation and tillage alternatives. A three-year experiment was conducted at the North Florida Research and Education Center-Quincy involving a crop rotation sequence of oats and rye (winter), bush beans (spring), soybean (summer) and broccoli (fall). Bush beans and broccoli were the cash crops. This paper presents analyses of the riskiness of organic production utilizing years in bahiagrass prior to initiating the crop rotation sequence and conventional tillage (CT) versus strip tillage (ST). Methods of “Risk-rated enterprise budget” and “Analyses of Variance-Covariance Matrix (ANOVA)” were utilized for determining relative profitability, and coefficient of variation was applied for measuring riskiness of each treatment. Three years of bahiagrass prior to initiating the crop rotation sequence, in combination with conventional tillage, had the highest profitability and ranked as the least risky scenario. The second most profitable treatment was conventional tillage with four years of bahiagrass. Focusing on strip tillage, four years of bahiagrass with strip-tillage ranked third in term of profitability.

**Keywords:** economic returns, broccoli, bush bean, sod-based rotation, tillage treatment

## 1. Introduction

The demand for organically-grown products in the United States has increased substantially such that the previously supply-driven organic sector is now market-driven. As a result, the marketing boom has increased retail sales of organic foods from $3.6 billion in 1997 to $21.1 billion in 2008 (Dimitri & Oberholtzer, 2009). Consequently, the organic sector is now the fastest growing sector of the U.S. agricultural economy. As of 2007, the 48-state total certified organic farms was over 4 million acres (USDA Census; 2009). However, transition to organic production has great regional variation. California has the most organically-certified acreage in production, with Washington, Wisconsin, Minnesota, Iowa, Pennsylvania, Ohio, New York, Vermont and Maine rounding out the top 10 (Greene & Kreman, 2003).

In contrast, the Southern Coastal Plain (defined in this paper as Florida, Georgia and Alabama) have less than 15,000 acres of organic production (USDA Census, 2009), or less than 0.3% of the national total acreage. Moreover, there has been a great reduction in the number of commercial farms in the southeastern U.S. based on agronomic crops due to higher costs of inputs, climatic conditions and low commodity prices. Until recently, there has been little incentive for the industry to develop and utilize sustainable farming systems such as sod-based crop rotation or by utilizing organic agro-ecosystems (Drost et al., 1996; Katsvairo et al., 2007). Individual organic producers in the Southern Coastal Plain have taken the initiative, and are already organically producing a variety of crops. Winter vegetables are the most prominent due to lower pest pressures and marketing windows. However, the acreage of organic vegetables remains small, off-farm inputs are high and marketing is primarily local. Current local markets for organic vegetables and other products are not meeting consumer demand. Thus, development of more efficient production systems that increase the profitability and assist in transition to organic systems is critical in the Southern Coastal Plain.

Economic sustainability increasingly depends on selecting profitable enterprises, sound financial planning, proactive marketing, risk management, and good overall management (Sullivan, 2003). Previous studies have focused on crop rotation and tillage methods individually. For instance, Gebremedhin and Schwab (1998) reviewed the economic literature on crop rotation systems, and reported that rotation-based cropping systems usually perform as well or better than continuous monocultures under most environmental and economic conditions. Zwingli et al. (1989) analyzed the economic potential of vegetable production using simple crop rotations and report that rotations are generally more stable with respect to markets. Martin and Hanks (2009) evaluated the combination of crop rotations and tillage, and calculated net return of each treatment from the enterprise budget. Minimum tillage and a corn rotation was illustrated to have the largest net return and lowest risk in the every other year rotation.

Crop rotation and minimum tillage practices can be economically profitable and environmentally sustainable. Other studies applied expected value-variance analysis to three years data of center-pivot irrigated corn production and tested three tillage methods (conventional, conservation and minimum tillage practices). They found that the conservation tillage methods consistently produced the highest profitability (Tew et al., 1986; Archer et al., 2008).

Klonsky (2012) found expected yields of several crops (alfalfa, tomato, field corn, broccoli/lettuce, raisins, walnuts) in California were comparable for organic and conventional production, with an exception of lower expected output for organic strawberries and almonds; profitability of these crops depended on price premiums. Crop yield and economic performance of organic, low-input and conventional farming system were compared over an eight-year period on research from the "Sustainable Agriculture Farming System Project" in California (Clark et al. 1999). They applied four farming-system treatments including 2 and 4 years rotation (Note 1) and compared conventional, low input and organic systems. The organic treatments had the highest return and were the most profitable among four year rotations. Also, bean yields and profit over the eight years indicate good short-term and long-term potential for low-input and organic systems and make it a good candidate as a transition crop even without a premium price. Marois and Wright (2003) used a working business model to predict the potential income of continuous cropping of cotton and peanuts compared to a 4-year rotation consisting of 2 years of grazing cattle on bahiagrass followed by peanuts and cotton. The model predicted that a 200-acre farm would yield $5,000 per year growing continuous cotton compared to $22,000 per year under the 4-year rotation that included two years of bahiagrass rotation. Marois et al. (2002) showed the average peanut yield in the Southeast U.S. was about 2,500 lbs. per acre, but yields after bahiagrass were often 3,500–4,500 lbs. per acre. Economic modeling showed that profits for cotton and peanuts in a sod-based rotation were about two times greater than those for a peanut-cotton-cotton rotation.

The benefits of bahiagrass include increased soil porosity, soil organic matter, soil moisture retention, and reduced plant disease and soil nematode populations (Gallaher et al., 2003; Johnson et al., 1999; Marois et al., 2003; Marois & Wright, 2003; Sumner et al., 1999). It is inexpensive to establish and maintain compared to similar perennial grasses such as hybrid bermudagrass (Hancock et al., 2013). For example, bahiagrass establishment costs and annual expenses were approximately $30 to $200 per acre, and $50 to $150 less than bermudagrass respectively. Balkcom et al. (2007) compared crop yields, production costs, revenue and net economic returns in the conventional peanut-cotton-peanut vs. bahiagrass-bahiagrass-peanut-cotton rotations, and conventional tillage (CT) versus strip tillage (ST). Net returns for the two crop rotations and tillage systems were determined using enterprise production budget for each year. Rotation system did not affect yield, revenue or return. Tillage was the most important factor in the study, and CT was superior to ST both in terms of yield, revenue and net return.

This study evaluates an organic vegetable production system utilizing variable years of sod-based rotation and bahiagrass, and CT versus ST in the Southern Coastal Plain. The main production limitations in the Southern Coastal Plain are infertile, compacted, droughty soils, limited water retention, loss of valuable top soils and pest suppression. Sod-based crop rotation and organic crop production greatly improve the physical properties of soils (Drinkwater et al., 1995; Waldon et al., 1998). Furthermore, the benefits of crop rotation systems in organic production may be enhanced if used in combination with ST. Strip tillage may decrease production expenses for labor, fuel, and machinery, reduce water loss from soil due to evaporation, and positively affect yields by minimizing soil loss and soil compaction (Gebremedhin & Schwab, 1998). Although utilization of ST in organic systems may require intensive management to alleviate weed control problems, severe erosion and depleted soils in the Southern Coastal Plain dictates that reduced or no systems tillage should be utilized whenever possible.

The objective of this paper is to analyze profitability and economic viability of different combination in sod-based rotation coupled with tillage treatments in organic vegetable production (Note 2). Yields and input costs data during the long term field experimental period was collected and analyzed using enterprise budget approach. A comparison of variable years of sod-based rotation coupled with different tillage techniques (CT and ST) were carried out to determine which system provides optimal solution in terms of financial lucrativeness to growers. There are many attendant economic, environmental and ecological components of these agricultural systems; however, it is clear that the adoption of agricultural technologies by farmers are closely related to economic profitability (Hoorman et al., 2009; Garcia-Préchac et al., 2004; Siri-Prieto & Ernst, 2009; Ikemura and Shukla, 2009; Johnson et al., 1999; Sumner et al., 1999)

## 2. Material and Methods

The primary goal of this project was to integrate advances made on sod-based rotation and strip tillage into organic systems for vegetable production in the Southern Coastal Plain. In this study we combined; 1) two tillage treatments of conventional tillage (CT) and strip tillage (ST), and 2) five rotation treatments including 0, 1, 2, 3 and 4 years of bahiagrass preceding annual vegetable cropping rotations. All treatment combinations were utilized in similar annual crop rotation with oats/rye (winter), bush beans (spring), soybean (summer) and broccoli (fall). Experiments were conducted for 3 years of field trials (from 2010-2013) at the University of Florida, North Florida Research and Education Center, Quincy, Florida. The experiment had four replications for all ten treatments (Note 3). For the purpose of simplicity, the above-mentioned treatments will be denoted by conventional tillage with zero year of bahiagrass (CT0), conventional tillage with one year of bahiagrass (CT1), conventional tillage with two years of bahiagrass (CT2), conventional tillage with three years of bahiagrass (CT3), conventional tillage with four years of bahia grass (CT4), strip tillage with zero year of bahiagrass (ST0), strip tillage with one year of bahiagrass

(ST1), strip tillage with two years of bahiagrass (ST2), strip tillage with three years of bahiagrass (ST3) and strip tillage with four years of bahiagrass (ST4) in the rest of the paper (Table 1; Note 3).

Table 1. Summary Codes for the different treatments in the sod-based rotation studies in Florida, 2011-2013.

| Treatment | Explanation |
|---|---|
| CT0 | Conventional tillage with zero year of bahiagrass |
| CT1 | Conventional tillage with one years of bahiagrass |
| CT2 | Conventional tillage with two years of bahiagrass |
| CT3 | Conventional tillage with three years of bahiagrass |
| CT4 | Conventional tillage with four years of bahiagrass |
| ST0 | Strip tillage with zero year of bahiagrass |
| ST1 | Strip tillage with one years of bahiagrass |
| ST2 | Strip tillage with two years of bahiagrass |
| ST3 | Strip tillage with three years of bahiagrass |
| ST4 | Strip tillage with four years of bahiagrass |

The climatological and environmental conditions, detailed experimental design, soil characteristics and treatments are described in Bliss et al., (2016). Economics and statistical analysis were adopted using a risk-rated enterprise budget approach and the classic two-way factorial ANOVA. Fundamental economic measures for conducting the economic analysis of alternative production scenarios are net revenue of each cropping system and approach of risk-rated budget enterprise were utilized for comparing net revenue and riskiness of above treatment.

### 3. Risk-Rated Enterprise Budget Approach

Preparation of an enterprise budget and analyzing the preferable measure of return requires identification of cultural operations and their associated costs, identification and valuation of production inputs, and the proper valuation of output (Gebremedhin and Schwab, 1998; Fonsah & Maltag Group, 2009a; 2009b; Fonsah & Chidelebu, 2012). A risk-rated enterprise budget is the broadest assessment of profitability compared to a deterministic enterprise budget; the expected returns of each treatment will be computed by taking different scenarios of price and yield into account. Considering broccoli and bush bean as two cash crops in this experiment, 5 scenarios of "pessimistic", "worst", "median", "best" and "optimistic", are assigned for constructing risk-rated budget enterprise. A 15% and 35% percentage decrease and increase in broccoli yield and 21% and 28% decrease and increase in its price were adopted for these scenarios, respectively, based on historic yield information and USDA data (Fonsah et al., 2008; Ferrer et al., 2011).

A 25% and 50% increase and decrease in bush bean yield and 25% and 46% increase and decrease in its price were also adopted for afore-mentioned scenarios. Variable costs of each production systems were broken down into pre-harvest, harvesting and marketing costs and the revenue was calculated by multiplication of median value of each cash crop (broccoli and bush bean) by its median price (Fonsah et al., 2008; Fonsah et al., 2007; Fonsah & Hudgins, 2007; Byrd et al., 2006 & 2007).

### 4. Results

Table 2 presents the average yield of two cash crops in this experiment for the ten treatments. More years of treatment with bahiagrass resulted in higher average yield of bush bean for both tillage treatments (Appendix A). Although CT produced higher average yield than ST for the same years of bahiagrass treatment for both crops, average yield of broccoli did not show significant increase in subsequent years of using bahiagrass. Comprehensive yield data for each year for bush bean and broccoli are illustrated in Bliss et al. (2016).

Table 2. Average yield of bush bean and broccoli in the different sod-based rotation study in Florida, 2011-2013 (lbs./acre)

| Crops | CT0 | CT1 | CT2 | CT3 | CT4 | ST0 | ST1 | ST2 | ST3 | ST4 |
|---|---|---|---|---|---|---|---|---|---|---|
| Bush beans Avg Yields | 7,012 | 6,774 | 6,141 | 12,222 | 12,104 | 5,971 | 5,566 | 6,323 | 9,154 | 9,640 |
| Broccoli Avg Yields | 5,004 | 4,833 | 6,230 | 7,505 | 6,638 | 4,568 | 3,100 | 5,314 | 4,563 | 4,780 |

Enterprise budgets were developed by The UGA Fruits and Vegetable Extension Ag-Economics Specialist, and value of net revenue for broccoli and bush bean for different treatments were calculated. Net return measure that was considered as the main variable for decision-making process that revealed profitability, were calculated under five possible risk-rated pricing and yield outcome (best, optimistic, median, pessimistic, and worst). The expected net return of each treatment in each year with its probability of occurrence is presented in appendix B (Fonsah & Hudgins, 2007; Fonsah et al., 2008; Ferrer et al., 2011).

Table 3 illustrates that, for bush bean, three years of bahiagrass was the most profitable among the CT treatments ($4,843/Ac), and net revenue increased substantially in second year of cultivation ($7,199/Ac) for this treatment. The second best scenario after CT3 in term of profitability was CT4 with value of $5,610/Ac. Second year of vegetable production for three year of bahiagrass (ST3) had the highest profit ($5,105/Ac) among strip-tillage treatments. The third year of vegetable cultivation for ST0 treatment yield net revenue of $4,150/Ac that was induced by its high yield equivalent to 8,524 pounds per acre. Total variable cost as a component of total cost is a function of yield, therefore, substantial variation in yield that might be induced by exogenous agricultural shocks like climate condition, lead to variation in variable cost. Total variable cost shows larger variation than total fixed cost (standard deviation is 864 vs 35).

Table 3. A breakdown of all the key economic parameters and net revenue for the different sod-based rotation of bush bean, 2011-2013 (Dollar/acre)

| Treatment | Year | Pre-harvest variable costs | Total Harvest and marketing | Total Variable costs | Total Fixed costs | Total costs | Total Revenue | Net revenue |
|---|---|---|---|---|---|---|---|---|
| CT0 | 2011 | 1,851 | 1,976 | 3,827 | 804 | 4,631 | 7,480 | 2,849 |
| | 2012 | 2,066 | 1,587 | 3,652 | 836 | 4,488 | 5,656 | 1,168 |
| | 2013 | 2,364 | 1,769 | 4,134 | 881 | 5,014 | 7,187 | 2,172 |
| CT1 | 2012 | 2,066 | 1,820 | 3,885 | 836 | 4,721 | 6,487 | 1,766 |
| | 2013 | 2,364 | 1,593 | 3,957 | 881 | 4,838 | 6,470 | 1,633 |
| CT2 | 2011 | 1,851 | 867 | 2,719 | 804 | 3,522 | 3,284 | (239) |
| | 2012 | 2,066 | 1,863 | 3,928 | 836 | 4,764 | 6,639 | 1,875 |
| | 2013 | 2,364 | 1,903 | 4,267 | 881 | 5,148 | 7,730 | 2,582 |
| CT3 | 2012 | 2,066 | 3,020 | 5,085 | 836 | 5,921 | 10,764 | 4,843 |
| | 2013 | 2,364 | 3,411 | 5,775 | 881 | 6,656 | 13,854 | 7,199 |
| CT4 | 2013 | 2,364 | 2,892 | 5,256 | 881 | 6,137 | 11,747 | 5,610 |
| ST0 | 2011 | 1,851 | 884 | 2,735 | 769 | 3,503 | 3,345 | (158) |
| | 2012 | 2,066 | 1,392 | 3,458 | 801 | 4,259 | 4,963 | 704 |
| | 2013 | 2,364 | 2,404 | 4,768 | 845 | 5,613 | 9,763 | 4,150 |
| ST1 | 2012 | 2,066 | 989 | 3,055 | 801 | 3,855 | 3,525 | (330) |
| | 2013 | 2,364 | 1,753 | 4,117 | 845 | 4,963 | 7,121 | 2,158 |
| ST2 | 2011 | 1,851 | 752 | 2,603 | 769 | 3,372 | 2,846 | (525) |
| | 2012 | 2,066 | 2,055 | 4,121 | 801 | 4,921 | 7,325 | 2,404 |
| | 2013 | 2,364 | 1,737 | 4,101 | 845 | 4,947 | 7,055 | 2,108 |
| ST3 | 2012 | 2,066 | 2,282 | 4,348 | 801 | 5,148 | 8,134 | 2,986 |
| | 2013 | 2,364 | 2,716 | 5,080 | 845 | 5,925 | 11,031 | 5,105 |
| ST4 | 2013 | 2,364 | 2,294 | 4,658 | 845 | 5,504 | 9,319 | 3,815 |

Applying the classic two-way factorial ANOVA (Afifi & Azen, 1973) for assessing the treatment effect on bush bean net revenue illustrates that more years of bahiagrass with ST lead to statistically significant increase in net-revenue of bush bean. The corresponding p-value of F statistic for testing hypothesis of effectiveness of both treatments was $P<0.0001$ (Table 4). ANOVA table shows that separate main effect of more years of bahiagrass and using ST treatment have statistically significant power in explaining change in net revenue ($P < 0.0001$ and $P < 0.038$, respectively). Interaction term in two-way ANOVA matrix captures the change in effect of treatment 1 over different values of treatment 2. The interaction term for two treatments was not significant ($P< 0.23$) and this means that effects of treatment 1 and treatment 2 are independent.

Table 4. Statistical analysis of treatment effect on net revenue of bush bean.

| Source | Partial sum of square | Degree of freedom | Mean sum of square | F - stat | Prob < F |
|---|---|---|---|---|---|
| Model | 229 834 126 | 9 | 25 537 125.1 | 7.11 | 0.0001 |
| Years of bahiagrass | 201 877 686 | 4 | 50 469 421.4 | 14.06 | 0.0000 |
| Tillage* | 15 975 386.4 | 1 | 15 975 386.4 | 4.45 | 0.0378 |
| Bahiagrass*tillage | 20 380 679.9 | 4 | 5 095 169.98 | 1.42 | 0.2345 |
| Residual | 308 799 202 | 86 | 3 590 688.39 | | |
| Total | 538 633 328 | 95 | 5 669 824.5 | | |

***** For designing the ANOVA analysis, code 1 and 2 are assigned for conventional tillage and strip tillage respectively and same codes as years of bahiagrass are assigned for bahiagrass treatments.

Table 5 shows average economic parameters for bush bean over three years of experiment. Three and four years of bahiagrass lead to maximum value of net revenue for bush bean respectively. Also, for a given year of bahiagrass, CT treatment leads to higher net revenue compared to ST treatments. Comparing “Total fixed cost” and “Total variable cost” across treatments shows that CT is more costly than ST for the same number of years of bahiagrass. Considering CT3 and ST3 as the most profitable treatments for the bush bean for two alternative tillage treatments, opportunity cost of 3 years of growing bahiagrass for a farmer that forgoes vegetable production, would be $6,189 for conventional tillage (three years net revenue from CT0) and $4,696 for strip-tillage (three years net revenue from ST0)[1]. This estimation suggests that a farmer would have profit even after accounting for opportunity cost of forgoing vegetable production, such that for CT3, the two years net revenue after subtracting opportunity cost is $5,853, and for ST3 the two years net revenue after subtracting opportunity cost is $3,395.

Higher variation in profit translates into higher risk. Therefore, in this study, we present “Coefficient of Variation (CV)” to illustrate riskiness of each alternative compare to other alternatives. CT1 was the least risky production alternative of all treatments and ST3 is the least risky production alternative among ST treatments (Table 5). Also, CT3 has the highest profitability among all treatments, and ranks third in term of least riskiness of profitability.

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[1] For this estimation, we assume that any three sequential years of growing bush bean provide approximately the same net revenue for the farmers as in our experiment in CT0 and ST0.

Table 5. A breakdown of all the key economic parameters including net revenue and coefficient of variations for the different sod-based rotation of bush bean, 2011-2013 (Dollar/acre)

| Treatment | Pre-harvest variable costs | Total Harvest and marketing | Total Variable costs | Total Fixed costs | Total costs | Total Revenue | Net Revenue | Coefficient of variation |
|---|---|---|---|---|---|---|---|---|
| CT0 | 2,094 | 1,777 | 3,871 | 840 | 4,711 | 6,774 | 2,063 | 0.41 |
| CT1 | 2,215 | 1,706 | 3,921 | 858 | 4,780 | 6,479 | 1,699 | 0.06 |
| CT2 | 2,094 | 1,544 | 3,638 | 840 | 4,478 | 5,884 | 1,406 | 1.04 |
| CT3 | 2,215 | 3,215 | 5,430 | 858 | 6,288 | 12,309 | 6,021 | 0.28 |
| CT4 | 2,364 | 2,892 | 5,256 | 881 | 6,137 | 11,747 | 5,610 | - * |
| ST0 | 2,094 | 1,560 | 3,654 | 805 | 4,458 | 6,024 | 1,565 | 1.46 |
| ST1 | 2,215 | 1,371 | 3,586 | 823 | 4,409 | 5,323 | 914 | 1.92 |
| ST2 | 2,094 | 1,515 | 3,608 | 805 | 4,413 | 5,742 | 1,329 | 1.21 |
| ST3 | 2,215 | 2,499 | 4,714 | 823 | 5,537 | 9,583 | 4,046 | 0.37 |
| ST4 | 2,364 | 2,294 | 4,658 | 845 | 5,504 | 9,319 | 3,815 | - * |

* Since there is only one year of net revenue of bush bean available for CT4 and ST4, measure of Coefficient of variation is not computable for these two treatments.

Estimated economic parameters for broccoli showed that first year of cultivation for zero and two years of bahiagrass and CT treatment have the two highest net revenue among the ten treatments (Table 6). The first year of cultivation in zero and two years of bahiagrass with ST treatments ranks 3rd and 4th in term of profitability. Variation in total variable cost was higher than total fixed cost, which was induced by variation in yield.

Table 6. A breakdown of all the key economic parameters and net revenue for the different sod-based rotation of broccoli, 2011-2013 (Dollar/acre)

| Treatment | Year | Pre-harvest variable costs | Total Harvest and marketing | Total Variable costs | Total Fixed costs | Total costs | Total Revenue | Net Revenue |
|---|---|---|---|---|---|---|---|---|
| CT0 | 2011 | 2,134 | 2,554 | 4,688 | 851 | 5,539 | 11,293 | 5,754 |
| | 2012 | 2,853 | 385 | 3,238 | 958 | 4,196 | 1,697 | (2,500) |
| | 2013 | 3,030 | 1,034 | 4,065 | 1,006 | 5,071 | 4,608 | (463) |
| CT1 | 2012 | 2,903 | 1,375 | 4,278 | 966 | 5,244 | 6,057 | 813 |
| | 2013 | 3,080 | 1,194 | 4,274 | 1,013 | 5,287 | 5,320 | 32 |
| CT2 | 2011 | 2,184 | 2,487 | 4,671 | 1,398 | 6,069 | 10,996 | 4,928 |
| | 2012 | 2,903 | 1,160 | 4,064 | 966 | 5,029 | 5,111 | 82 |
| | 2013 | 3,080 | 1,284 | 4,364 | 1,013 | 5,377 | 5,719 | 342 |
| CT3 | 2012 | 2,903 | 2,293 | 5,197 | 966 | 6,162 | 10,103 | 3,940 |
| | 2013 | 3,080 | 1,692 | 4,772 | 1,013 | 5,786 | 7,539 | 1,754 |
| CT4 | 2013 | 3,080 | 1,720 | 4,800 | 1,013 | 5,813 | 7,662 | 1,848 |
| ST0 | 2011 | 2,184 | 2,187 | 4,371 | 823 | 5,194 | 9,672 | 4,478 |
| | 2012 | 2,903 | 387 | 3,291 | 931 | 4,221 | 1,707 | (2,515) |
| | 2013 | 3,080 | 994 | 4,074 | 978 | 5,052 | 4,428 | (624) |
| ST1 | 2012 | 2,903 | 306 | 3,210 | 931 | 4,140 | 1,349 | (2,791) |
| | 2013 | 3,080 | 1,422 | 4,502 | 978 | 5,480 | 6,335 | 855 |
| ST2 | 2011 | 2,184 | 2,264 | 4,447 | 823 | 5,270 | 10,009 | 4,739 |
| | 2012 | 2,903 | 868 | 3,771 | 931 | 4,702 | 3,824 | (878) |
| | 2013 | 3,080 | 1,254 | 4,334 | 978 | 5,312 | 5,586 | 274 |
| ST3 | 2012 | 2,903 | 1,018 | 3,921 | 931 | 4,852 | 4,485 | (367) |
| | 2013 | 3,030 | 1,557 | 4,586 | 971 | 5,557 | 6,935 | 1,378 |
| ST4 | 2013 | 3,080 | 1,452 | 4,532 | 978 | 5,510 | 6,469 | 959 |

The results of ANOVA matrix for assessing treatment effect of tillage method and bahiagrass rotation on net revenue of broccoli is presented in Table 7. Model specification of effect of both treatments on the net revenue of broccoli has no statistically significant explanatory power. The corresponding P-value of F statistic for treatments' interaction in ANOVA matrix was $P<0.18$ which illustrated that net revenue of broccoli was not sensitive to years in bahiagrass or tillage treatments. Although difficult to explain why the lack of net revenue sensitivity thereof, we are tempted to partially blame the insensitive broccoli yield/revenue results for both treatments (bahiagrass and tillage treatments) to any of the several unfavorable good agricultural practices (GAP) such as changes in soil quality, insufficient weed, disease and insect control etc., adopted for the crop that could have an impact on the yield during the growing season of the study. The most noticeable feature for broccoli was sever cutworm damage to very young broccoli that occurred at high rates in some blocks but not in others. However, converting to ST had significant main effect on the increase in net revenue of broccoli.

Table 7. Statistical analysis of treatment effect on net revenue of broccoli

| Source | Partial sum of square | Degree of freedom | Mean sum of square | F - stat | Prob <F |
|---|---|---|---|---|---|
| Model | 98 016 122.1 | 9 | 10 890 680.2 | 1.45 | 0.1785 |
| Years of bahiagrass | 34 672 614.2 | 4 | 8 668 153.56 | 1.16 | 0.3355 |
| Tillage | 57 882 739.1 | 1 | 57 882 739.1 | 7.73 | 0.0067 |
| Bahiagrass*tillage | 21 585 286.8 | 4 | 5 396 321.7 | 0.72 | 0.5804 |
| Residual | 644 325 213 | 86 | 7 492 153.64 | | |
| Total | 742 341 335 | 95 | 7 814 119.32 | | |

The analysis of riskiness of profitability of broccoli, CT3 is the least risky production alternative among conventional tillage treatments (CT0, CT1, CT2, CT3, CT4) and ST2 and ST3 are the least risky production alternatives among strip tillage treatments (ST0, ST1, ST2, ST3, ST4) (Table 8). ST0, CT0 and ST1 are the riskiest treatments for broccoli.

Table 8. A breakdown of all the key economic parameters including net revenue and coefficient of variations for the different sod-based rotation of broccoli, 2011-2013 (Dollar/acre)

| Treatment | Pre-harvest variable costs | Total Harvest and marketing | Total Variable costs | Total Fixed costs | Total costs | Total Revenue | Net Revenue | Coefficient of variation |
|---|---|---|---|---|---|---|---|---|
| CT0 | 2,673 | 1,324 | 3,997 | 938 | 4,935 | 5,866 | 930 | 4.6 |
| CT1 | 2,992 | 1,284 | 4,276 | 990 | 5,266 | 5,688 | 422 | 1.3 |
| CT2 | 2,722 | 1,644 | 4,366 | 1,126 | 5,492 | 7,275 | 1,784 | 1.5 |
| CT3 | 2,992 | 1,993 | 4,985 | 990 | 5,974 | 8,821 | 2,847 | 0.5 |
| CT4 | 3,080 | 1,720 | 4,800 | 1,013 | 5,813 | 7,662 | 1,848 | -* |
| ST0 | 2,722 | 1,190 | 3,912 | 911 | 4,823 | 5,269 | 447 | 8.1 |
| ST1 | 2,992 | 864 | 3,856 | 954 | 4,810 | 3,842 | (968) | 2.7 |
| ST2 | 2,722 | 1,462 | 4,184 | 911 | 5,095 | 6,473 | 1,378 | 2.2 |
| ST3 | 2,966 | 1,287 | 4,254 | 951 | 5,205 | 5,710 | 506 | 2.4 |
| ST4 | 3,080 | 1,452 | 4,532 | 978 | 5,510 | 6,469 | 959 | -* |

* Since there is only one year of net revenue of broccoli and bush bean available for C4 and S4, measure of Coefficient of variation is not computable for these two treatments.

Considering CT3 as the most profitable treatment for the broccoli, net revenue after subtracting opportunity cost is $2,904 ($5694 – $2790).

The average net revenue of sod-based rotation and tillage treatment was calculated for both crops (Table 9). Two main sources of variability in the enterprise budget were yield and the variable cost associated with yield. From the table, we can conclude that CT treatments with four and three years of previous bahiagrass rotation (CT3 and CT4) are ranked 1$^{st}$ (two treatments) in term of economic profitability which is induced by highest yield in both cash crops (CT3 provide the highest profitability). The ST3 and ST4 treatments are considered 2$^{nd}$ best in term of profitability.

Analyzing the coefficient of variation for each sod-based rotation and tillage treatments shows that less years of bahiagrass (CT0, ST0, ST1) lead to higher variation in profit, which is stated to be more risky from the perspective of risk-averse farmers. This result is consistent for each of the cash crop separately, while production of bush bean is less risky than broccoli for each treatment.

Table 9. A breakdown of all the key economic parameters including net revenue and coefficient of variations for the different sod-based rotations, 2011-2013 (Dollar/acre)

| Treatment | Pre-harvest variable costs | Total Harvest and marketing | Total Variable costs | Total Fixed costs | Total costs | Total Return | Net Rev. | Rank of Net Rev. | Coefficient of variation | Rank of Coeff. of variation |
|---|---|---|---|---|---|---|---|---|---|---|
| CT0 | 4,766 | 3,102 | 7,868 | 1,778 | 9,646 | 12,640 | 2,994 | 6 | 5.0 | 7 |
| CT1 | 5,207 | 2,991 | 8,197 | 1,848 | 10,045 | 12,167 | 2,122 | 8 | 1.4 | 2 |
| CT2 | 4,816 | 3,188 | 8,004 | 1,966 | 9,970 | 13,159 | 3,190 | 5 | 2.6 | 3 |
| CT3 | 5,207 | 5,208 | 10,415 | 1,848 | 12,263 | 21,130 | 8,868 | 1 | 0.8 | 1 |
| CT4 | 5,444 | 4,612 | 10,056 | 1,894 | 11,950 | 19,409 | 7,459 | 2 | -* | -* |
| ST0 | 4,816 | 2,749 | 7,566 | 1,715 | 9,281 | 11,293 | 2,012 | 9 | 9.6 | 8 |
| ST1 | 5,207 | 2,235 | 7,442 | 1,777 | 9,219 | 9,165 | (54) | 10 | 4.6 | 6 |
| ST2 | 4,816 | 2,976 | 7,793 | 1,715 | 9,508 | 12,215 | 2,707 | 7 | 3.4 | 5 |
| ST3 | 5,181 | 3,786 | 8,968 | 1,774 | 10,741 | 15,293 | 4,551 | 4 | 2.8 | 4 |
| ST4 | 5,444 | 3,746 | 9,191 | 1,824 | 11,014 | 15,788 | 4,774 | 3 | -* | -* |

* Since there is only one year of net revenue of broccoli and bush bean available for C4 and S4, measure of Coefficient of variation is not computable for these two treatments.

The statistical analysis for assessing the effectiveness of CT versus ST and sod-based rotation treatment on farm aggregate net revenue (summation of net revenue of both cash crops) was accomplished by applying two-way ANOVA and utilizing appropriate testing tools (Table 10). Model specification, separate main effectiveness of more years of bahiagrass and tillage treatments and their interaction effect are all proved to be significant in explaining the increase in net revenue ($P < 0.05$ level).

Table 10. Statistical analysis of treatment effect on total net revenue of both bush bean and broccoli

| Source | Partial sum of square | Degree of freedom | Mean sum of square | F - stat | Prob > F |
|---|---|---|---|---|---|
| Model | 481 850 879 | 9 | 53 538 986.6 | 6.83 | 0.0000 |
| Years of bahiagrass | 315 773 097 | 4 | 78 943 274.4 | 10.07 | 0.0000 |
| Tillage | 134 675 857 | 1 | 134 675 857 | 17.18 | 0.0001 |
| Bahiagrass*tillage | 81 171 322.7 | 4 | 20 292 830.7 | 2.59 | 0.0423 |
| Residual | 673 974 150 | 86 | 7 836 908.72 | | |
| Total | 1.1558e+09 | 95 | 12 166 579.3 | | |

## 5. Discussion

The objective of this study was to evaluate sod-based rotation and CT versus ST on profitability of farming with bush bean and broccoli as cash crops. Our economic analyses of data from an experimental crop rotation project conducted over three years, indicated that 3 and 4 years bahiagrass were the most profitable treatments for both bush bean and broccoli, and consequently for whole system containing both cash crops. These results parallel results from Marois and Wright (2003) and Marois et al. (2002) documenting the economic benefits of utilizing sod-based rotations in conventional production.

Economic benefits of tillage treatments are less clear cut. Close investigation on cost components of CT and ST illustrates that ST was better agricultural practice due to reducing cost of production and providing larger net revenue for the growers of bush bean. Broader benefits of minimum-till treatments were illustrated in the studies of Ascough et al. (2009) who utilized "Stochastic Dominance" methodology to examine which of three different tillage systems (chisel plow, no-till, and ridge-till) were the most risk-efficient in terms of maximizing economic profitability (net return) across a range of risk aversion preferences. Results showed that net return of corn crop using no-till tillage system was preferred across the entire range of risk aversion regardless of whether the objective of the decision maker was minimizing risk or maximizing net return.

In our studies, however, CT3 had the highest profitability for both bush beans and broccoli induced by large yield for these treatments. Conventional tillage with four years of bahiagrass (CT4), strip tillage with three years of bahiagrass (ST3) and strip tillage with four years of bahiagrass (ST4) were the second, third and fourth most profitable treatments respectively. This study also investigated riskiness of each treatment by examining coefficient of variation. It should be noted that risk analysis based on CV cannot be generalized especially that our result was strictly based on the limited observation years' research data. The least risky treatments for bush bean, broccoli and whole system were conventional tillage with one year of bahiagrass (CT1), conventional tillage with three years of bahiagrass (CT3) and conventional tillage with four years of bahiagrass (CT4) as they performed much better than all ST treatments. These advantages of CT parallel results of Chan et al. (2010) comparing the profitability of four different organic cropping systems for winter squash and cabbage in New York which found and a combination of compost for nitrogen, occasional cover crops and CT had the highest revenues for cabbage.

Statistical analyses based on ANOVA matrix provide growers a prediction of profitability of sod-based rotation and tillage alternatives. Although the model for testing impact of treatments on net revenue of broccoli did not show any significant effect, net revenue of bush bean and system total revenue were sensitive to both treatments. This suggests that a move toward organic vegetable production by incorporating sod-based rotation and CT can lead to higher profit for farmers.

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**Note**

Note 1: 1) four-year rotation: processing tomato, safflower, corn and bean and a winter grain and/or legume double-cropped with bean. 2) two-year rotation: tomato and wheat rotation 3) conventional input, low-input and organic input.

Note 2: Based on the same experiment, Bliss et al. (2016) have studied the influence of bahia grass, tillage, and cover crop on organic production and soil quality in the southern coastal plain. This study focuses on the economic profitability of bahia grass and tillage treatments as information presented before plus the economic analyses would be two unwieldy to present in one paper.

Note 3: Two years of bahia grass has more replication. In the complementary study by Bliss et al., (2016) (Note 1), treatments of "years of bahia grass" are distinguished based on **the number of years in the vegetable** preceding the bahia grass treatment. In this paper, the economic profitability of two treatments of bahiagrass rotation and tillage, plots with two years of bahiagrass but different years of vegetation are assumed as the replication of the same treatment.

**Appendix A**

**U.S. Units Conversion to International System Units**

Table A1. U.S. Units Conversion to International System Units

| To convert from (U.S. Units) | To (IS Units) | Multiply By |
|---|---|---|
| Acre | Hectare (ha) | 0.404 |
| Pound (lbs) | Kilogram (kg) | 0.453 |
| Pound (Ibs) | Ton | 0.0005 |
| Ibs/acre | Kg/ha | 1.1209 |
| $/acre | $/ha | 2.471 |

**Appendix B:**

**Expected Return from Total Acreage**

Table B1. Expected Return from Total Acreage (Dollar)

| Crop | Treatment | Year | Net Revenue | Chance for profit |
|---|---|---|---|---|
| Bush bean | CT0 | 2011 | 5,754 | 99% |
| | | 2012 | (2,500) | 1% |
| | | 2013 | (463) | 32% |
| | CT1 | 2012 | 813 | 73% |
| | | 2013 | 32 | 51% |
| | CT2 | 2011 | 4,928 | 98% |
| | | 2012 | 82 | 53% |
| | | 2013 | 342 | 61% |
| | CT3 | 2012 | 3,940 | 96% |
| | | 2013 | 1,754 | 86% |
| | CT4 | 2013 | 1,848 | 87% |
| | ST0 | 2011 | 4,478 | 98% |
| | | 2012 | (2,515) | 1% |
| | | 2013 | (624) | 26% |
| | ST1 | 2012 | (2,791) | 1% |
| | | 2013 | 855 | 73% |
| | ST2 | 2011 | 4,739 | 99% |
| | | 2012 | (878) | 14% |
| | | 2013 | 274 | 59% |
| | ST3 | 2012 | (367) | 35% |
| | | 2013 | 1,378 | 82% |
| | ST4 | 2013 | 959 | 75% |
| Broccoli | CT0 | 2011 | 2,849 | 90% |
| | | 2012 | 1,168 | 75% |
| | | 2013 | 2,172 | 84% |
| | CT1 | 2012 | 1,766 | 82% |
| | | 2013 | 1,633 | 80% |
| | CT2 | 2011 | (239) | 40% |
| | | 2012 | 1,875 | 83% |
| | | 2013 | 2,582 | 86% |
| | CT3 | 2012 | 4,843 | 93% |
| | | 2013 | 7,199 | 96% |
| | CT4 | 2013 | 5,610 | 94% |
| | ST0 | 2011 | (158) | 44% |
| | | 2012 | 704 | 68% |
| | | 2013 | 4,150 | 92% |
| | ST1 | 2012 | (330) | 38% |
| | | 2013 | 2,158 | 84% |
| | ST2 | 2011 | (525) | 27% |
| | | 2012 | 2,404 | 86% |
| | | 2013 | 2,108 | 84% |
| | ST3 | 2012 | 2,986 | 89% |
| | | 2013 | 5,105 | 94% |
| | ST4 | 2013 | 3,815 | 91% |