Profitability and Environmental Stewardship for Row Crop Production: Are There Trade-offs?

Christina B. Jolejole
Department of Agricultural, Food and Resource Economics
Michigan State University
East Lansing, MI 48824-1039

Scott M. Swinton
Department of Agricultural, Food and Resource Economics
Michigan State University
East Lansing, MI 48824-1039

G. Philip Robertson
W. K. Kellogg Biological Station and
Department of Crop and Soil Sciences
Michigan State University
Hickory Corners, MI 49060

Sara P. Syswerda
Department of Crop and Soil Sciences
Michigan State University
East Lansing, MI 48824

Contributed Paper prepared for presentation at International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009

The authors gratefully acknowledge support from the National Science Foundation under Human and Social Dynamics Grant No. 0527587 and Long-term Ecological Research Grant No. 0423627. Thanks are also due to the Michigan Agricultural Experiment Station and the Michigan State University Environmental Science and Policy Program. For valuable discussions, they thank Natalie Rector, Rob Shupp, and Lenisa Vangjel. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation or other research sponsors.

**Profitability and Environmental Stewardship for Row Crop Production:
Are There Trade-offs?**

1. Introduction

Farmers play an important role acting as ecosystem managers that help maintain the natural supporting ecosystem services that make agriculture productive (Swinton, et al., 2006). Moreover, they make choices that can change the type, magnitude and relative mix of services provided by the ecosystems (Rodriguez et al, 2006). By their choice of inputs and management practices, they face important trade-offs such as those between agricultural production and ecosystem services such as biodiversity, water and soil quality.

Careful selection of crop systems involves examining trade-offs between profitability and environmental impact. Gebremedhin and Schwab (1998) provided an extensive literature review on the effects of crop rotations on profitability and the environment. For example, they pointed out that less dependence on external inputs, i.e. less dependence on fertilizer and chemicals, can reduce the costs for the farmers and at the same time using less chemicals is beneficial for environment. Cover crops incur planting costs for the farm but can also improve soil structure, increase soil organic matter, water percolation, beneficial insect population, suppress weeds, reduce soil erosion and fix residual N after the grain is harvested (Gebremedhin and Schwab, 1998; Jones and Ritchie, 1996). Dhuyvetter et al (1996), points out how conservation tillage reduces operation costs as it reduces expenses for labor, fuel, oil, and machinery use costs and at the same time increases water infiltration and water loss from evaporation.

Invariably, the environmental objectives conflict with one another and farmers' choices involve significant tradeoffs.

But what lies behind the farmers' decisions are the incentives they have for doing a particular practice. Empirical studies in the soil conservation literature have shown that the most important motive for adoption is the "selfish", financial-economic concern, or profits including financial attributes in some sense (Chouinard et al, 2008). Cary and Wikinson (1997) and Honlonkou (2004) found that adoption of conservation practices depends on financial economic indicators such as profitability. Graafland (2002) modeled the trade off between profit and stewardship centering upon the profit maximization principle. In a farmer focus group[1] conducted in south-central and central Michigan, several farmers expressed their commitment to environmental stewardship, but felt that profitability and business viability had to come first. One of the farmers said, "I always try to choose practices that have environmental benefits but if it's going to cause me to lose money then I can't take that choice."

On the other hand, a category of literature focuses on social and attitudinal issues in agricultural production, including stewardship motives. Wunderlich (1991) examined the evolution of the concept of stewardship among agricultural producers and stressed that farmers view themselves as stewards and that their farming is a way of life rather than a business to maximize profit. Ryan, Erickson and De Young (2003) examined the motives for protecting biodiversity and water quality in the Midwest. They discovered that an important factor in motivating conservation is attachment to the land, and that

---

[1] S.M. Swinton, N. Rector, G.P. Robertson, C.B. Jolejole and F. Lupi. July, 2007. "Ecosystem Services from Farmland: What do farmers think?". Unpublished manuscript.

producers are more likely to engage in a practice that makes their farm appear well managed.

Clearly, the literature shows that there are economic and non-economic conservation incentives. An integrated analysis of economic and environmental indicators of alternative cropping systems can be done using a multi-objective approach grounded in multi-attribute utility theory. Antle et al. (2004) discussed trade off frontier analysis as a modeling system for agricultural and environmental policy analysis. Trade off analysis quantifies the relationship between key economic and environmental indicators at the level of a farm field. For policy analysis, results may be aggregated on a bigger scale.

New crop production technologies have been studied in light of this growing concern for environmental stewardship practices. In particular, Kellogg Biological Station's Long-term Ecological Research (KBS-LTER) project evaluated the environmental benefits from low input crop rotations. The LTER program is a fundamental ecological research network funded by the National Science Foundation. It started in 1980 and now supports more than two dozen field sites in North America, Antarctica and Polynesia. The KBS-LTER founded in 1988 is the site focused on agricultural ecology. It has developed a cropping system that offers comparable yields with less pesticides and fertilizers applied than conventional systems in the northern Cornbelt. Despite the environmental benefits, few farmers have adopted this crop system.

This paper looks at the profitability of the different cropping systems including the low-input crop rotation that KBS developed. Moreover, the paper develops trade off frontiers between profitability and environmental performance using enterprise budgets from Michigan research trials and selected environmental indicators from the KBS. It contributes to the growing body of knowledge about the economic and environmental impact of alternative cropping systems while trade off analysis allows stakeholders to make informed decisions concerning the dual goals of agricultural production and safeguarding the environment.

2. Objectives of the Study

The objectives of this study are: (1) to compare the profitability of the cropping systems by constructing enterprise budgets for all the cropping systems, (2) to construct trade-off frontiers between profitability and selected environmental indicators for all the cropping systems and (3) to identify preferred cropping systems from the trade-off frontiers.

3. Conceptual Framework: Environment-Profit Trade Offs

The concept of trade off is fundamental to economics and derives from the idea that resources are scarce. Consequently, to obtain more of one scarce good, an individual or society collectively must give up some amount of another good. Trade off analysis applies these principles to derive information about sustainability of agricultural production systems, by quantifying the inter-relationships among environmental indicators implied by the underlying processes and the economic behavior of profit maximization.

The integrated economic and environmental systems have multiple objectives. Thus the idea of a multi-attribute utility function is fitting in assessing these trade offs where a general efficiency rule is used that applies to all decision makers who generally care about the different attributes (King and Robison, 1984).

Following the framework by Chouinard et al (2006), we build on the model of a farmer behavior by integrating environmental attributes from a multi-attribute utility function to determine dominance and production possibilities function (PPF) to determine technical efficiency. It is worth noting that in reality, farmers do not think in terms of production functions rather they think of production technologies and farm practices. Farmers identify a specific combination of inputs and outputs, i.e. practices, as a farm technology.

We start with a multi-attribute utility function. We assume that the farmers would want to maximize a utility function that is increasing in profits π and environmental quality E.

$$MaxU = U(\pi, E)\,; \quad \frac{\partial U}{\partial \pi} > 0; \frac{\partial U}{\partial E} > 0 \tag{1}$$

Where,

$$E = e(x_E, x_P)\,; \quad \frac{\partial E}{\partial x_E} > 0; \frac{\partial E}{\partial x_P} < 0 \tag{2}$$

$$\pi = p_Q Q - p_x x - c_0\,; \quad \frac{\partial \pi}{\partial Q} > 0; \frac{\partial Q}{\partial x_P} > 0; \frac{\partial Q}{\partial x_E} > 0 \tag{3}$$

Environmental quality, E, is an increasing function of environmental enhancing inputs, x_E, and decreasing with polluting inputs, x_P. Also profit, π, is a function of output Q, input x, fixed costs c_0, output prices p_Q and input prices p_x.

Figure 1.1 shows a generically shaped PPF. The PPF shows how a fixed resource such as land can be allocated most efficiently between two different outputs. Although traditionally outputs are marketed, they can also include non-marketed services like environmental quality, E. Anything lying inside the frontier is considered a technically inefficient choice. PPF therefore determines technical efficiency.

The slope of the PPF is the marginal rate of substitution between the two outputs. So that the slope, $\frac{\partial \pi}{\partial E}$, shows the marginal rate of technical substitution or the change in profit, π, per unit change in environmental quality, E. This is the implied cost of to the farmer of increasing environmental services provision to improve environmental quality.

A particular farmer, i, maximizes utility where indifference curve, U_i^0 is tangent to the PPF (in particular point A) and produces corresponding profit and environmental quality. For farmer i any point above the indifference curve U_i^0 would be preferred.

Even among individuals whose utility fits the assumptions in Equation (1), the shape of indifference curves for different individuals may differ, meaning that they have different relative preferences between profit, π, and environmental quality, E. This makes this type of analysis appealing because it covers wider type of individuals including policy makers so long as their utility fits this common assumption (King and Robison, 1984).

The shaded area represents points that would be preferred over point A by any farmer whose utility function meets the general assumptions in Equation (1), because it allows one to increase profit and/or decrease environmental damage at the same time. The area could be called the *area of profitability-environmental quality dominance* relative to point A.

This study makes use of two environmental indicators data on global warming potential (GWP) and nitrate leaching which both exhibit negative environmental effect. From this point forward to the end of the section, we will denote to this as environmental damage (ED). Figure 1.2 presents a diagram with measures of environmental damage and profit on the axes.

King and Robison, (1984) noted that an *efficiency criterion* divides the decision alternatives into two mutually exclusive sets: efficient set and inefficient set. The efficient set contains the choice of every individual whose preferences conform to the assumptions associated with the criterion. No element in the inefficient set is preferred by decision makers with the preferences assumed. Thus, inefficient alternative choices are no longer considered in the decision.

More formally, *profit-environmental quality efficiency criterion* is stated in terms of these two conditions, 1 and 2: Outcome distribution1 ith profit π_1 and environmental damage ED_1, dominates outcome distribution 2 with profit π_2 and environmental damage ED_2, if $\pi_1 \geq \pi_2$ and $ED_1 \leq ED_2$ and if one of these two inequalities is strict. *Efficiency criteria* are useful in cases where preferences are not known directly but we do observe technology characteristics (King and Robison, 1984).

In Figure 1.2, point A' is where farmer i maximizes utility. The shaded region represents points that are profit-environmental quality dominant over initial point A' because it allows one to increase profit and/or decrease environmental damage at the same time. Points B and D on the other hand represents tradeoffs relative to point A. Point B is a dominated choice relative to point A because even though it allows the individual to increase profit, environmental damage increases at the same time. The same goes for point D because even though environmental damage is decreased, profit is also decreased. Point C is simply an inefficient choice because it gives lower utility to anyone whose preferences fit equation 1.

The procedure for building trade off frontiers is analogous to risk efficiency with two variables, such as mean-variance efficiency (King and Robison, 1984). The basic idea is to increase the good and decrease the bad (i.e. increase the mean and decrease the variance). Likewise, the farmer tries to increase profit and decrease environmental damage. Efficiency determination involves mapping alternative practices or policies and evaluating their efficiency in the sense of giving the best profitability for a given level of environmental performance, or the best environmental outcome at a given profitability level. Efficient choices will lie on a frontier, where there is a trade-off between improving profitability and environmental performance. The slope of the trade off frontier represents the opportunity cost of environmental choices in terms of reduced farm income (Antle, Capalbo and Crissman, 1998). The steeper the slope, the greater is the opportunity cost for improving the environmental stewardship measured by the foregone profit. Thus, the slope, $\frac{\partial \pi}{\partial ED}$, represents the implicit cost of foregone income from changing the systems to decrease environmental damage.

Moreover, the influence of the exogenous factors can be seen on the shape of the frontier curves and can also be considered as drivers of the production system that could result in a shift of the frontier. This can be referred to as change in system's exogenous drivers as policy, technology or resource change scenarios (Weersink et al, 2002). There are several studies that constructed trade off frontiers. Kelly, Lu and Teasdale (1996) did a simulated analysis of long-term impacts of different cropping systems including trade off analysis of net return and different components of environmental quality. Van der Veeren and Lorenz (2002), looked at the cost effectiveness, spatial equity and sustainability and constructed trade off curves to show relationships among the three.

4. Background of the Study: Site and Experimental Treatments

In this study, the trade offs between profitability and some environmental indicators for several cropping systems were constructed and analyzed. The KBS-LTER main experimental site was the source of data for this study. It is a 60 hectare site divided into six different treatments, each one replicated into six one-hectare plots. Four of these seven systems are annual crop rotations and two are perennial crops, namely, alfalfa and poplar.

The annual crops are corn-soybean-wheat rotations (CSW) with four treatments. The conventional cropping system uses university extension recommended chemical inputs and chisel plowing. The no-till system uses conventional chemical inputs and uses no-tillage management. The low-input system uses 2/3 of the chemical inputs as the conventional, banded herbicide and tillage to control weeds, and a winter cover crop in 2 of 3 years. In the organic system, no chemical inputs or manure are used. Mechanical cultivation is used for weed control, and cover crops are used.

Perennial systems include alfalfa and poplar. The poplar treatment is a fast growing *Populus* clone that is fertilized only once when established. It is harvested every 9-10 years and allowed to coppice or regrow from stems. On the other hand, the alfalfa stands are fertilized with phosphorus, potassium, boron and lime according to soil tests and university recommended rates. The alfalfa is harvested 3-4 times per year and replanted every five to six years. Table 1.1 summarizes the differences among the treatments.

The experimental plots for the study are located at W.K. Kellogg Biological Station (KBS) in Hickory Corners, Michigan. The site is located at the northern end of the U.S. Cornbelt, 50 km east of Lake Michigan (42° 24'N, 85° 24'W) on soils developed from glacial outwash deposited 12000 years ago. Annual rainfall averages 890 mm y^{-1} with about half falling as snow and potential evapotranspiration (PET) exceeds precipitation for about 4 months of the year. Mean annual temperature is 9.7 °C. (More information is at http://lter.kbs.msu.edu).

5. Types and Sources of Data

The data include agronomic farm data (site specific production and input data), external price data and environmental data (site-specific experimental data for calibration of biophysical models). Agronomic farm data and prices were used in constructing the enterprise budgets to measure profitability. Environmental data were used together with the computed profits to construct trade off analysis.

5.1 Agronomic Data

Agronomic data include yields, fertilizer and herbicide application rates, seeding rates, and tillage activities from the KBS-LTER agronomic log. For the cropping systems,15 years of data from 1993 to 2007, equivalent to five complete crop rotations of corn, soybean and wheat was used.[2] While for the perennial systems, the poplar data covered a complete ten-year cycle from 1989 to 1998 and the alfalfa data covered a three complete five-year cycles from 1989 to 2003.

5.2 Price and Cost Data

Cost data for this study were collected from a variety of secondary sources in an effort to represent actual prices observed in Michigan. The input and output price sources are presented in tables 1.2 and 1.3, respectively. The price data includes the 1978-2008 National Agricultural Statistics Service (NASS) agricultural prices[3], average organic prices for 2008 from the Economic Research Service of the United States Department of Agriculture (ERS-USDA) website[4], price of fertilizer and herbicides from an agricultural input vendor in Michigan as of April 2008[5], average organic certification

[2] http://lter.kbs.msu.edu/datasets
[3] http://www.nass.usda.gov/QuickStats/index2.jsp
[4] http://www.ers.usda.gov/Data/OrganicPrices/
[5] Jorgensen Farms Elevator, Pers. Comm., April 24, 2008, Fax request for Input Prices

costs from Institute of Food and Agricultural Sciences of University of Florida, and the cost of tillage operations from the custom machine work rates in the Saginaw Valley and on Iowa State University custom rate survey.

5.3 Environmental Data

Crop management practices directly affect the mix of ecosystem services generated. Some environmental indicators, namely global warming potential and nitrate leaching data collected at the Kellogg Biological Station, were used in the trade off analysis.

5.3.1 Global Warming Potential

The data used in the study was taken from the Robertson et al (2000) paper measuring the global warming potential of different treatments. Robertson et al (2000) reported that, globally, agriculture is responsible for 20% of the terrestrial greenhouse gas emissions. In particular, the major greenhouse gases coming from agriculture are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2).

A complete understanding of agriculture’s impact on global warming was performed by field-level analysis of all greenhouse gas emission rate fluctuations to derive the net global warming potential (GWP) for the different cropping systems (Robertson et al, 2000). Robertson et al (2000) performed greenhouse gas accounting in which the different gases that come from agriculture were given weighted values according to their "potency as a greenhouse gas". This potency of a gas is referred to by the Intergovernmental Panel on Climate Change (IPCC) as GWP.

5.3.2 Nitrate Leaching and Runoff

The data used came from Syswerda (2009) which looked at long-term nitrate loss for different treatments. They sampled soil at different depths, and nitrogen content was measured and recorded to measure leaching. Agricultural nitrogen comes from a wide variety of sources but primarily from inorganic fertilizer, animal waste, and nitrogen fixing plants. The KBS-LTER site includes no animal wastes.

Most crops only take up 50% of nitrogen applied (Syswerda, 2009; Robertson, 1997). The other 50% is subject to loss to the environment including leaching into groundwater (Syswerda, 2009; Fenn et al., 1998; Sanchez et al, 2004). This can impact human health when ingested. Leached nitrates can reach surface water leading to eutrophication and algal blooms, which harm or kill fish and other wildlife (Garrett and Buck, 1997). Ribaudo (2003) estimated the cost of mitigating U.S. water quality impairment due to nitrate in the tens of billions of dollars.

6. Methods

The first part of this section presents analysis of enterprise budgets to look at profitability and the second part explains the trade off frontier analysis using environmental data from the KBS-LTER experiments.

6.1 Profitability Using Enterprise Budgets

At the farm level, optimizing farmers choose the best cropping system among the technically feasible alternatives. As mentioned earlier, the conservation literature has shown that the most important motive for adoption is the financial-economic concern, or profits.

Profitability is a function of yield, output prices and operation costs which include seed costs, fertilizer, herbicides, insecticides and custom operations costs. Different cropping systems can have different operation costs and yields, thus it is important to use a common index for their comparison – a measure of net financial return to the farm.

This study compares the profitability of different production systems by calculating an annualized net return (annual payment stream with cumulative value equal to the net present value) for each system. The annual systems included the 4 cropping systems and the annualized present value was calculated assuming a balanced rotation where a third of available land is planted to each crop in each year. For the perennial systems, alfalfa and poplar, the analysis assumes three five-year and one ten-year complete cycles respectively. An annualized value was computed by dividing the present values by a present value interest factor for an annuity (Weston and Copeland, 1986, Appendix A.4). The discount rate chosen for this study was 5%, to reflect a real, risk free rate of return.

Enterprise budgeting is one of the most basic production economic tools available (Roberts and Swinton, 1996). It is relatively simple compared to other methods but can still provide a detailed, in-depth analysis. Enterprise budgets represent the estimates of receipts (income or gross returns), costs (fixed and variable costs), and profits associated with the production of agricultural products for an enterprise. They can be used to evaluate how one crop or activity can contribute to the profitability of a certain cropping system and to compare the contributions to profitability of the same crop or practice under different rotations (Gebremehedhin and Schwab, 1998; Christenson et al., 1995; Jones and Ritchie, 1996). Enterprise budgets can be used to rank the profitability of the different systems.

In order to conduct a profitability analysis of different cropping systems, a clear description of each system and its associated practices becomes essential (Table 1.1). If the differences are limited to only part of the farm operation, gross margin analysis of revenues minus costs that vary among treatments suffices for comparison across treatments (CIMMYT, 1988). In this case, the differences among the cropping systems are on the use of cover crops, amount of chemical use and tillage.

This study constructed enterprise budgets as shown in Appendix Tables 1 to 7 for the different treatments in Table 1.1. Gross margins cover selected cash expenses such as seed costs, fertilizer costs, herbicides costs, tillage costs and custom costs. The budgets omit costs that are unchanging across treatments such as land. Hence, although they do not fully measure profitability, they offer a complete measure of profitability differences across treatments. For Treatment 4, the no chemical treatment, two enterprise budgets were constructed, one assuming non-organic prices and the other assuming certified organic farm prices.

6.1.1 Relative Profitability

Among the cropping systems, the comparatively more profitable would always be preferred by a profit maximizing producer. Thus, selecting the optimal technology involves two stages: computing the profit for each treatment, t, then comparing across the T number of treatments.

Mathematically, profitability across is given by:

$$\pi_t = p_Q.Q(t|x_E, x_P) - c(t|p_x) - c_0 \qquad (4)$$

Where π is the profit or the revenue above selected costs. Q is the output which is a function of treatment, t, conditional on factors that contribute to output such as input used which includes both the polluting and environmental enhancing inputs, x_P and x_E. c is the variable which accounts for the costs that vary, which is a function of production technology or treatment, t, conditional on input prices, p_x. While c_0 accounts for the fixed costs which are the same for the treatments.

6.1.2 Crop Prices and Sensitivity Analysis

Choi and Helberger (1993) looked at how sensitive are crop yields to price changes and farm programs. Moreover, Houck and Gallagher (1976) using time series for 1951-1972 estimated the corn yield changes with respect to changes in corn price.

In this paper, we also look at the sensitivity of profitability changes in response to changes in crop prices. A reasonable time series price data from National Agricultural Statistics Service (NASS) was used (1978-2008). Crop prices were deflated to year 2008 using the 2008 Economic Report of the President for the producer price index for farm products.

Standard deviations were computed to determine a low price scenario, and a high price scenario relative to the baseline. The low price scenario is computed by subtracting the computed standard deviation from the baseline price while the high price scenario is computed by adding the computed standard deviation to the baseline price.

Thus, expected profit can be written in terms of both price scenario, j , and technology treatment, t ,

$$\pi_{tj} = p_{Qj}.Q_t(t|x_E, x_P) - c_t(t|p_x)] \qquad (5)$$

where subscript j represents the price scenario (low, mean, or high price scenario).

6.2 Trade-Off frontiers and Efficiency Determination

This study illustrates the tradeoffs between the economic and environmental sustainability of different agricultural systems. The joint distribution of outcomes is presented in a graphical form with environmental measures on the y-axis and revenue over selected costs or gross margin on the x-axis. A given point on the graph represents the joint environmental-economic outcome for a given type of technology or cropping system adopted. Each different KBS-LTER treatment (conventional, no-till, low-input, organic, alfalfa, poplar and successional plots) generates a new point. Connecting the points via ideal point method (IPM) forms a frontier.

Using IPM idea, we look for at least one point that dominates the other points. Generally, along the frontier, the idea is that gains in one area cause losses in the other one. If there is a win-win situation, then one of the points must have been inefficient. As we can recall in previous section, the tradeoff curve represents the joint distribution of economic-environmental outcomes that are efficient.

7. Results and Discussion

Appendix Tables 1 through 7 present the enterprise budgets for the different treatments presented in Table 1.1. The information is summarized in bar charts in Figures 1.3 and 1.4 where revenue above selected costs and gross revenue vis-a-vis costs across treatments are presented. The no chemical or "organic" treatment under certified organic selling prices generated the highest revenue followed by the no-till treatment, the low input treatment and the conventional treatment. Organic prices have been high, thus generating highest profits. When the same treatment was evaluated using non-organic prices, the profit was lowest among the four cropping systems. This could be explained by the low yield performance of this treatment. The mean yields in Figure 1.5 show that the organic treatment did not perform well for corn, soybean or wheat. No-till performed best in yields followed by low input and conventional treatment. Thus, at non-organic selling prices, the no-till treatment generated the highest profit. An interesting issue is given the profitability of organic treatment with large premium, Michigan Department of Agriculture reports that only 140 farms out of 53,000 farms across the state are currently certified as organic farms under USDA's National Organic Program, which is less than 1% of all Michigan farms.[6] One possible reason why more farmers are not adopting organic practices is the transaction and time cost of procuring a certification. During the three-year adjustment, farmers suffer lower yields without higher prices. Moreover, if most farmers switch to organic farming, the large price premiums might cease to persist.

---

[6] Sattleberg, J. 2008. "Getting to Organic." http://74.125.95.132/search?q=cache:zh8DUGkYZdUJ:www.moffa.org/f/Getting_to_Organic_2008.pdf+organic+farmers+in+michigan&cd=11&hl=en&ct=clnk&gl=us

Figure 1.6 shows a stacked bar graph of proportion of inputs by treatment. Tillage cost was high for the organic treatment and low input treatments. While chemical cost was highest for the no till treatment, the low input treatment had low cost on agrichemicals but had the highest cost for tillage due to reliance on tillage for weed control. The no-till treatment had zero tillage cost but the highest agrichemical cost for weed control. Figure 1.6 shows that there are increased herbicide costs with the no-till treatment. Thus, a no-till budget may appear less expensive in terms of tillage costs, but agrichemical costs are increased.

The annualized revenue and costs for the perennial systems, alfalfa and poplar, are also included in the analysis. Looking at the stacked bar graph on proportion of input costs, alfalfa generated the highest custom costs, like hay baling, but all in all annualized total costs for other things are low for alfalfa and poplar. Annualized revenue for poplar and alfalfa were also low.

The effects of changes in crop prices are also subjected to crop price sensitivity analysis, as shown in Figure 1.7. This shows how changes in crop prices could impact profitability. With this fact in mind the study calculated the net return for three different price scenarios (high, mean and low) by taking the average of the deflated prices from 1978-2008 and computing standard deviations from the actual prices observed presented in Appendix Table 8. Ranking of systems by relative profitability does not seem to change regardless of crop price scenario. This shows that ranking is robust to output prices making the information meaningful for managerial decisions.

Table 1.4 summarizes the revenue above selected costs together with environmental indicators namely, global warming and nitrate leaching. Figures 1.8 and

1.9 show the plotted points and estimated tradeoff frontiers between nitrate leaching and revenue above selected cost and between GWP and revenue above selected costs, respectively.

By using the efficiency criteria discussed earlier, we know that the ideal direction for both environmental indicators would be moving toward southeast direction in both XY space as indicated by the arrow on the lower right of the diagram. That is because moving towards that direction would mean improved profits and less negative environmental effect.

By selecting efficient points we see that in Figure 1.8 for global warming potential as environmental indicator, alfalfa and certified organic treatments dominate the rest. Anything lying to the left or above that solid line is dominated in the sense that there is a chance to increase the profit or decrease negative environmental effects or both by moving towards the frontier. Excluding the certified organic prices from the analysis yields a different frontier which includes no till and alfalfa, as shown by the dashed line. The slope for the dashed tradeoff frontier is steeper than the tradeoff frontier with a solid line which implies that the farmer can improve GWP at a lower unit cost in reduced profitability.

Regarding the nitrate leaching, the certified organic and no-till treatments dominate the rest as shown by the solid line in Figure 1.9. Excluding certified organic yields a tradeoff frontier that only includes only the no-till treatment. In this case, no-till treatment is a corner solution meaning one technology exists in the efficient set.

8. Summary and Conclusion

In both the trade off frontiers, the conventional treatment is dominated. Also, the organic treatment is dominated unless certified organic prices are used. This shows that the conventional treatment is a dominated choice, which leads to the question of why farmers are still using this technology. Based on the trade off frontiers, the no-till cropping system shows a potential as an efficient choice for the farmer. With the method presented in this study, it was shown that tradeoffs exist as farmers make choices between environmental and economic goals. Trade-off curves represent a convenient means of summarizing the information for policy makers and form the basis for conceptualizing sustainability policies.

Table 1.1 Description for the Different Treatments at KBS-LTER

Treatment	Description
Conventional	Standard chemical input CSW rotation, chisel plowed
No-Till	Standard chemical input CSW rotation no-tilled
Low Input	Low chemical Input CSW rotation conventionally tilled (ridge till for 1993), with Cover Crops, banded herbicide, starter N at planting, additional post plant cultivation
Organic	Zero chemical input CSW rotation conventionally tilled (ridge till for 1993), With Cover Crops, additional post planting cultivation (rotary hoe)
Poplar	Populous clones on Short Rotation (9-10 years) harvest cycle
Alfalfa	Continuous Alfalfa, replanted every 6-7 years

Source: KBS-LTER Website, http://lter.kbs.msu.edu/about/experimental_design.php

Table 1.2. Input Prices and Sources

Input	Price	Unit	Source
Corn Seed	$ 111.00	per 80000 kernels	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Soybean Seed	$ 27.60	bu	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Wheat Seed	$ 7.30	bu	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Red Clover Seed	$ 174.00	cwt	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Organic Corn Seed	$ 2.95	per 200 seeds	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Organic Soybean Seed	$ 32.00	bu	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Organic Wheat Seed	$ 0.30	lb	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Poplar Cuttings	$ 0.22	cutting	Average price cited by nurseries in Great Lakes Region; University of Minnesota recommendations, April 2008; http://www.cinram.umn.edu/newsletter/Poplar-Profits.htm
Alfalfa Seeds	$ 4.50	lb	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Nitrogen	$ 0.71	lb	Average price cited by agricultural input supply company in Michigan, i.e. Jorgensens; March 2008
Phosphorus	$ 0.89	lb	Average price cited by agricultural input supply company in Michigan, i.e. Jorgensens; March 2008
Potassium	$ 0.55	lb	Average price cited by agricultural input supply company in Michigan, i.e. Jorgensens; March 2008
Pesticides	varies	varies	Average price cited by agricultural input supply company in Michigan, i.e. Jorgensens; March 2008
Cost of Certification of an Average Size Farm	$ 9.43	per acre	Ferguson, 2004; Organic Certification Procedures and Costs
Machinery - Custom Costs	varies	varies	Stein, 2008 Machine Work Rates for Saginaw MI and Iowa State , 2008, Iowa Custom Rate Survey

Table 1.3. Output Prices and Sources

Output	Price	Unit	Source
Corn	$ 2.66	bu	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Soybean	$ 6.09	bu	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Wheat	$ 3.29	bu	NASS 2008 Agricultural Statistics Report, http://www.nass.usda.gov/QuickStats/index2.jsp
Organic Corn	$ 3.01	bu	ERS-USDA Average Organic Prices 2008, http://www.ers.usda.gov/Data/OrganicPrices/
Organic Soybean	$ 12.29	bu	ERS-USDA Average Organic Prices 2008, http://www.ers.usda.gov/Data/OrganicPrices/
Organic Wheat	$ 5.49	bu	ERS-USDA Average Organic Prices 2008, http://www.ers.usda.gov/Data/OrganicPrices/
Price Deflator	-	-	Price was deflated to 2008; Whitehouse Economic Report; http://www.gpoaccess.gov/eop/tables08.html
Alfalfa Hay	$ 39.00	ton	Center for Dairy Profitability, 2008, Crop Enterprise Budgets, http:www.cdp/wisc.edu
Poplar Wood	$ 45.00	ton	Average price cited by nurseries in Great Lakes Region; University of Minnesota recommendations, April 2008; http://www.cinram.umn.edu/newsletter/Poplar-Profits.htm

Table 1.4 Mean Values forRevenue Above Selected Costs and Different Environmental Indicators

Treatment	Revenue Above Selected Costs ($/acre)	Nitrate Leaching (Mean kg No3-N/acre)	Global Warming Potential (g of carbon dioxide equivalents/m-2)
Conventional	122	6.07	114
No-Till	140	-1.54	14
Low-Input	134	0.12	63
Organic in Non-organic Prices	83	0.12	41
Organic in Organic Prices	182	0.12	41
Poplar	18	0.07	-20
Alfalfa	36	1.09	-105

Sources: Revenues and costs from enterprise budgets; environmental indicators from G.P. Robertson et al (2000), Syswerda (2009)

Figure 1.1 Production possibilities frontiers with profits and environmental quality and indifference curve for Farmer i

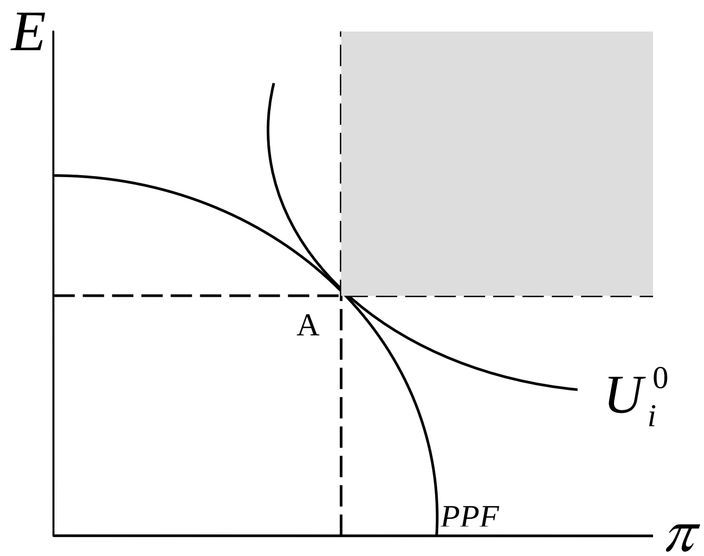


Figure 1.2 Production possibilities frontiers with profits and environmental damage and indifference curve for Farmer i

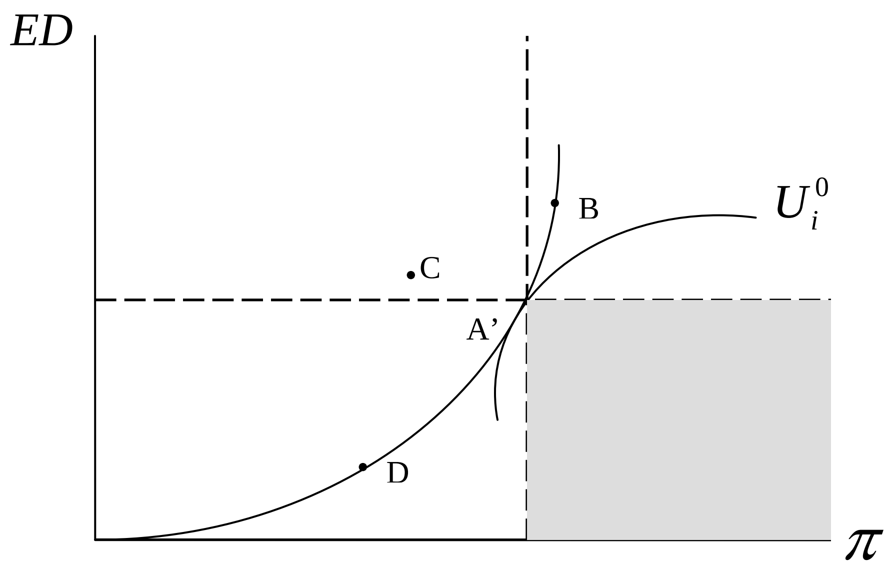
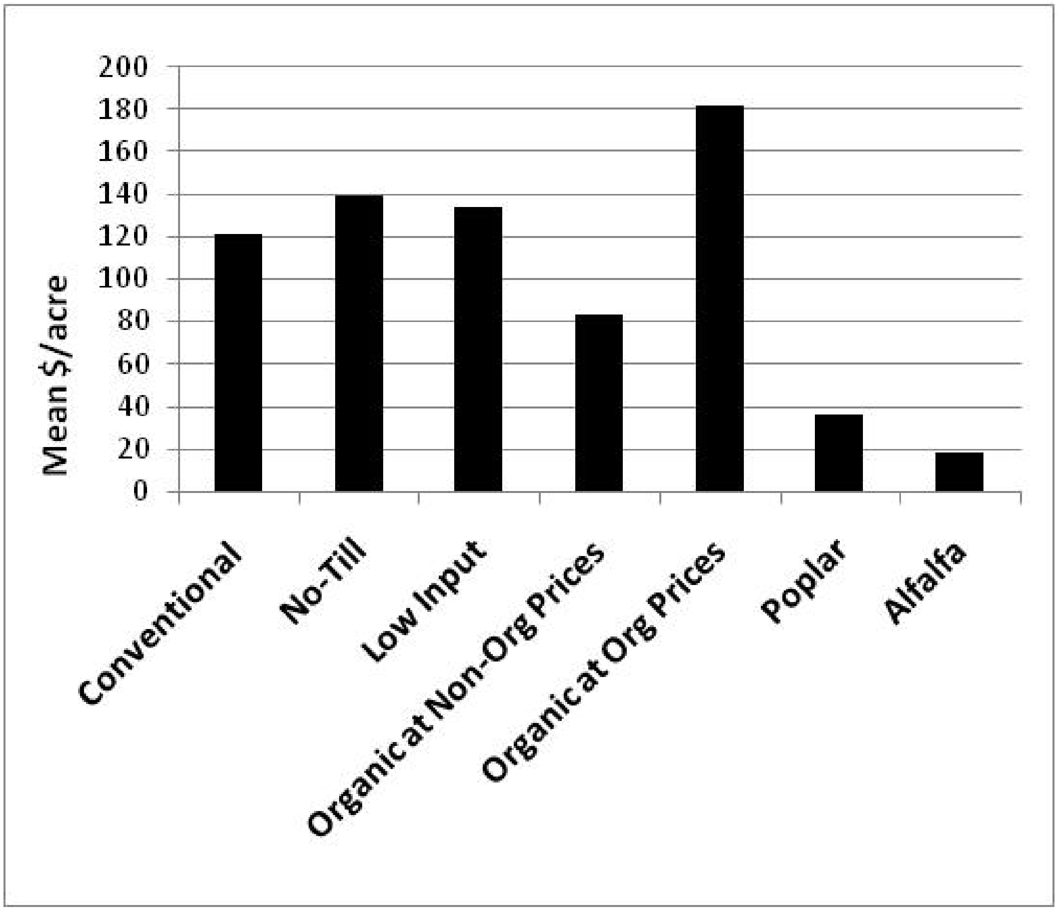
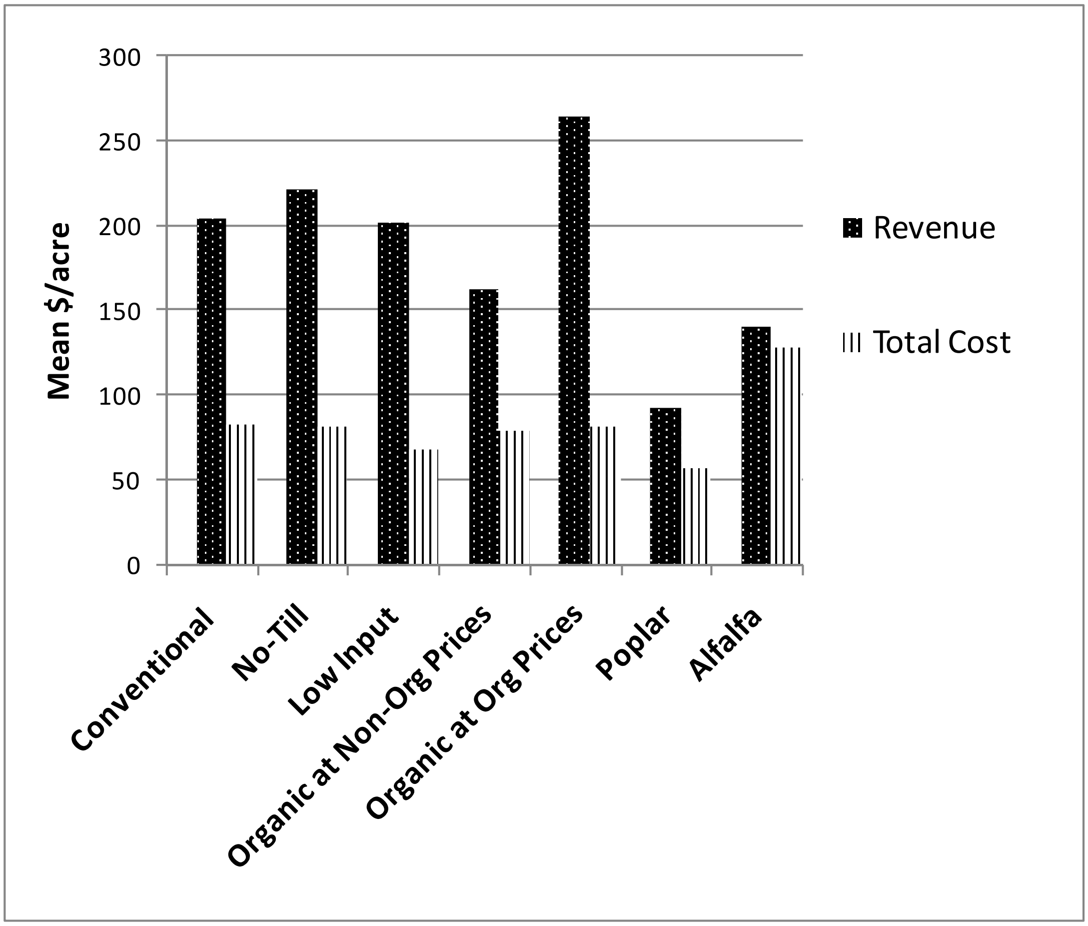


Figure 1.3 Mean revenue above selected costs across treatments, KBS-LTER, Hickory Corners, Michigan, 1993-2007*



* Except for alfalfa:1989-2004; poplar:1989-1998.

Figure 1.4 Mean revenue and costs that vary across treatments, KBS-LTER, Hickory Corners, Michigan, 1993-2007*



* Except for alfalfa:1989-2004; poplar:1989-1998.

Figure 1.5 Mean yields for corn, soybean and wheat in the annual cropping systems, KBS-LTER, Hickory Corners, Michigan, 1993-1997

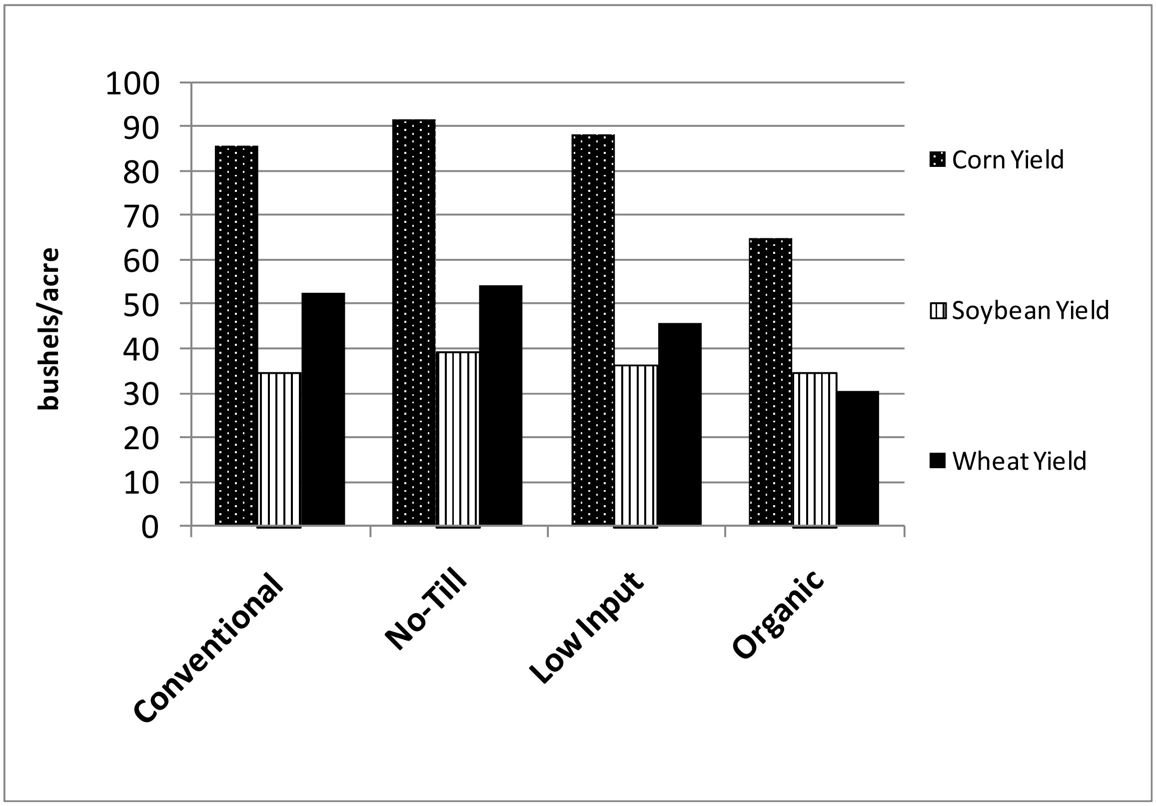
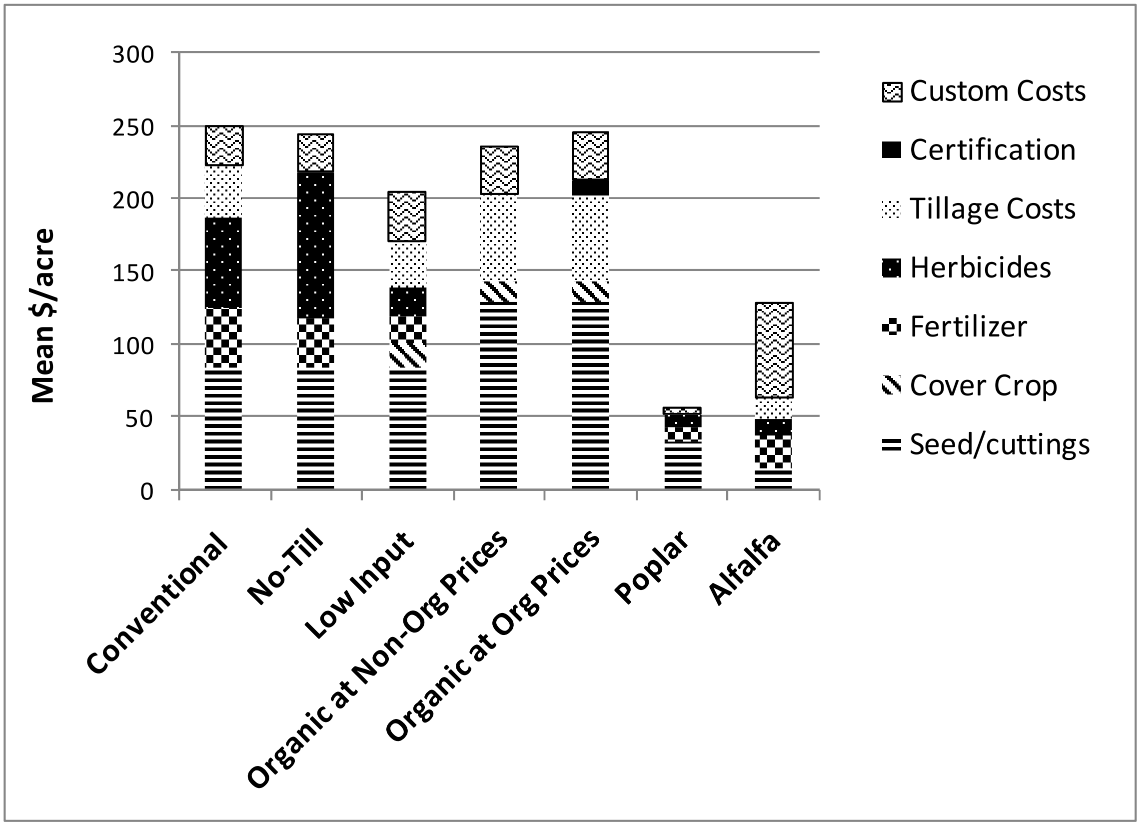


Figure 1.6 Proportion of inputs by cropping system, KBS-LTER, Hickory Corners, Michigan, 1993-1997*



* Except for alfalfa:1989-2004; poplar:1989-1998.

Figure 1.7 Sensitivity of profits based on crop prices for the annual cropping system treatments, KBS-LTER, Hickory Corners, Michigan, 1993-1997

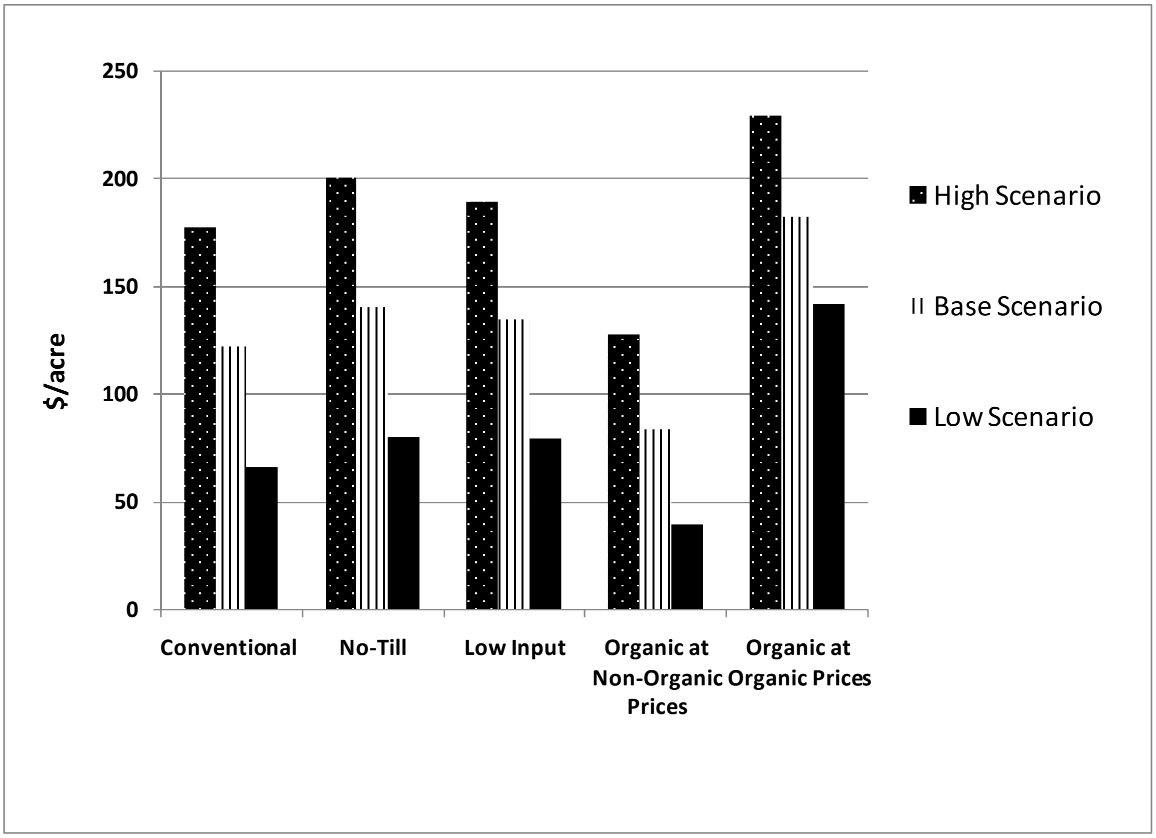
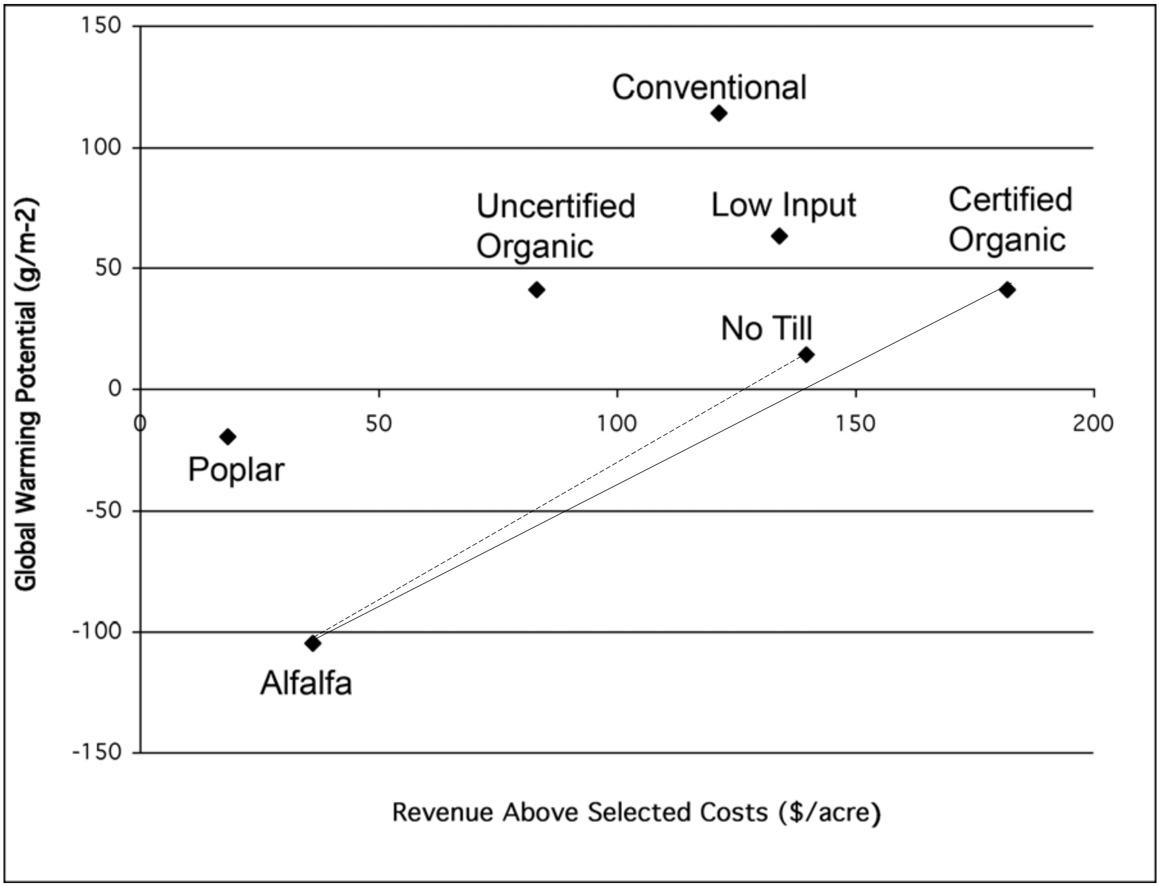
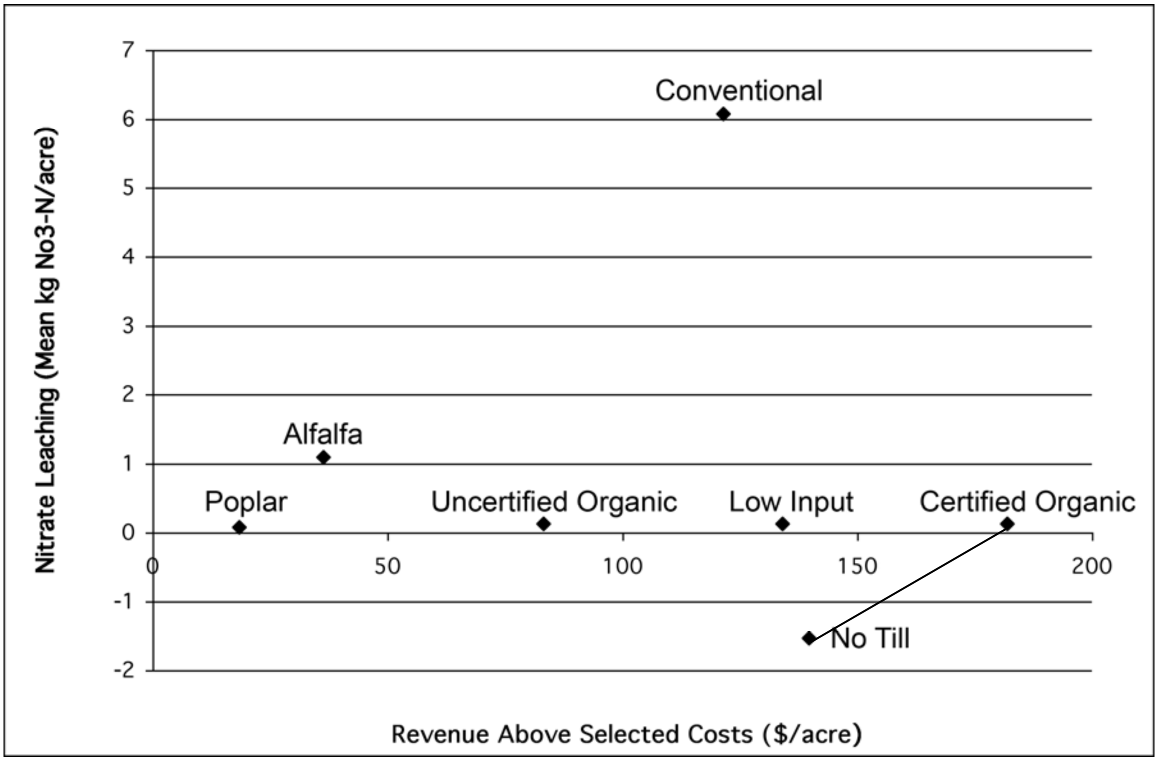


Figure 1.8 Tradeoffs between Global Warming Potential and revenue above selected costs, KBS-LTER, Hickory Corners, Michigan, 1993-2007*



* Except for alfalfa:1989-2004; poplar:1989-1998.

Figure 1.9 Tradeoffs between nitrate leaching and revenue above selected costs, kbs-lter, Hickory Corners, Michigan, 1993-2007*



* Except for alfalfa:1989-2004; poplar:1989-1998.

References

Antle, J.M., J.J. Stoorvogel, C.C. Crissman, and W. Bowen. 2004. The Tradeoff Analysis Model: Integrated Bio-physical and Economic Modeling of Agricultural Production Systems. *Journal of Agricultural Systems* 80(1):43-66.

Antle, J.M., C.C. Crissman, and S.M. Capalbo.1998. *Economic, Environmental and Health Tradeoffs in Agriculture: Pesticides and the Sustainability of Andean Potato Production.* Kluwer Academic Publishers, Boston. 281 pp.

Braden, J.B. and S.B. Lovejoy, eds. 1990. *Overview in Agriculture and Water Quality: Agriculture and Water Quality International Perspectives*. Lynne Rienner Publishers, Boulder, CO, 1-37.

Cary, J.W. and R.L. Wilkinson. 1997. Perceived Profitability and Producers' Conservation Behavior. *Journal of Agricultural Economics* 48(1):13-21.

Center for Dairy Profitability. 2008. Crop Enterprise Budgets. http://cdp.wisc.edu/

Choi, J.S. and P.G. Helmberger. 1993. How Sensitive are Crop Yields to Price Changes and Farm Programs. *Journal of Agricultural and Applied Economics* 25(2):237-244.

Chouinard, H., T. Peterson, P. Wandscheneider, and A. Ohler. 2006. *Will Farmers Trade Profits for Stewardship? Heterogeneous Motivations for Farm Practice Selection.* Washington State University.

Christensen, D.R., W.A. Dick, R.L. Blevins, W.W. Frye, S.E. Peters, F.J. Pierce, and M.L. Vitosh. 1998. Impacts of Agricultural Management Practices on Carbon Sequestration in Forest Derived soils of the Eastern Corn Belt. *Soil and Tillage Research* 47(3) 235-244.

Christenson, D.R., R.S. Gallagher, T.M. Harrigan, and J.R. Black. 1995. Net returns from twelve Cropping Systems Containing Sugar Beet and Navy Beans. *Journal of Production Agriculture* 8:276–281.

Cohen, S., D. Demeritt, J. Robinson, and Rothman, D. 1995. Climate Change and Sustainable Development: Towards Dialogue. *Global Environmental Change* 8(4): 341-371.

Coiner, C., J. Wu, and S. Polasky. 2001. Economic and Environmental Implications of Alternative Landscapes Design in the Walnut Creek Watershed of Iowa. *Journal of Ecological Economics* 38(1):119-139.

CIMMYT Economics program. 1988. From agronomic data to farmer recommendations: An economics-training manual. Mexico, DF: CIMMYT.

De Voil, P., W.A. Rossing, and G.L. Hammer. 2006. Exploring Profit –Sustainability Trade-offs in Cropping Systems Using Evolutionary Algorithms. *Environmental Modelling and Software*. 21:1368-1374.

Dhuyvetter, K.C., C.R. Thompson, C.A. Norwood, and A.D. Halvorson. 1996. Economics of dryland cropping systems in the Great Plains: A review. *Journal of Production Agriculture* 9:216-222.

Dobbs, T. and J. Pretty. 2004. Agri-environmental Stewardship Schemes and Multifunctionality. *Review of Agricultural Economics* 26(2):220-37.

Economic Research Service, USDA. Organic Farmgate and Wholesale Prices. April, 2008. http://www.ers.usda.gov/Data/OrganicPrices/

Fenn, M.E., M.A. Poth, J. D. Aber, J.S. Baron, B.T. Bormann, D.W. Johnson, A.D. Lemly, S.G. McNulty, D.F. Ryan, and R.Stottlemyer. 1998. Nitrogen Excess in North American Ecosystems: Predisposing Factors, Ecosystem Responses and Management. *Ecological Applications* 8(3) 706-733.

Ferguson, J.L. 2004. *Organic Certification Procedures and Costs.* University of Florida, Institute of Food and Agricultural Sciences Extension Report. http://edis.ifas.ufl.edu/pdffiles/HS/HS20800.pdf

Garrett, H.E., and L.E. Buck. 1997. Agroforestry practice and policy in the United States of America. *Forest Ecology and Management*. 91:5–15.

Gebremedhin, B. and G. Schwab. 1998. *The Economic Importance of Crop Rotation Systems: evidence from the literature.* Department of Agricultural Economics, Michigan State University, Staff paper No. 98-13.

Graafland, J. 2004. Modelling the Trade-off between Profits and Principles. *De Economist.* 150 (2): 129-154.

Graham, R.L. 1995. *Evaluating the Economic Costs, Benefits and Tradeoffs of Dedicated Biomass Energy Systems: The importance of scale.* National Renewable Energy Laboratory, Golden, Colorado.

Grandy, A. S., and G. P. Robertson. 2007. Land Use Intensity Effects on Soil Carbon Accumulation Rates and Mechanisms. *Ecosystems* 10(1): 59-74.

Gruber, N. and J. Galloway. 2008. An Earth-system Perspective of the Global Nitrogen Cycle. *Nature* 451, 293-296.

Heimlich, R, ed. 2003. *Agricultural Resource and Environmental Indicators*. US Department of Agriculture, Economic Research Service Agriculture, Washington D.C.

Honlonkou, A. N. 2004. Modeling Adoption of Natural Resources Management Technologies: the Case of Fallow Systems. *Environment and Development Economics* 9(1): 289-314.

Houck, J.P. and P.W. Gallagher. 1976. The Price Responsiveness if U.S. Corn yields. *American Journal of Agricultural Economics* 58:731-34.

Hoffman, G.J., T.A. Howell and K.H. Soloman, eds. 1996. *Crop growth models: Management of Farm Irrigation Systems*. ASAE St. Joseph, MI.

Iowa State University- 2008 *Iowa Farm Custom Rates* – FM1698. http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf .

Jansen, R. and J.E. Padilla. 1996. *Extended benefit-cost analysis of Management Alternatives: Pagbilao Mangrove forest.* Resources, Environment and Economics Center for Studies Inc., Quezon City, Philippines.

Kelly, T.C., Y. Lu, and J. Teasdale. 1997. Economic-Environmental Tradeoffs Among Alternative Crop Rotations. *Agriculture Ecosystems and Environment*. 60(1):17-28.

King, R.P and L.J. Robison. 1984. *Risk Efficiency Models*. in *Risk Management in Agriculture.* P. J. Barry, ed. Iowa State University Press.

Lakshminarayan, P.G., S.R. Johnson, and A. Bouzaher. 1995. A Multi-objective Approach to Integrating Agricultural Economic and Environmental Policies. *Journal of Environmental Management* 45: 365-378.

Lankonski, J., M. Ollikainen, and P. Uusitalo. 2004. No-till Technology: Benefits to Farmers and the Environment? Theoretical Analysis and Application to Finnish Agriculture. *European Review of Agricultural Economics* 33(2):193-221.

Lichtenberg, E. 2004. Cost-Responsiveness of Conservation Practice Adoption: A Revealed Preference Approach. *Journal of Agricultural and Resource Economics* 29(3):420-35.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well Being: Systhesis.* Reid. Island Press, Washington D.C.

NASS 2008 Agricultural Statistics Report. National Agricultural Statistics Service (NASS), Farm Production Expenditures and Agricultural Prices, April 2008; http://www.nass.usda.gov/QuickStats/index2.jsp

Roberts, W. and S.M. Swinton. 1996. Economic Methods for Comparing Alternative Crop Production Systems: A Review of the Literature. *American Journal of Alternative Agriculture* 11(1):10-17.

Robertson, P.G. 1997. Nitrogen Use Efficiency in Row-Crop Agriculture: Crop Nitrogen Use and Soil Nitrogen Loss. in *Ecology in Agriculture*, ed. Jackson, L.E. Academic Press, San Diego, CA, 347–365.

Robertson, G. P., E. A. Paul, and R. R. Harwood. 2000. Greenhouse Gases in Intensive Agriculture: Contributions of Individual Gases to the Radiative Forcing of the Atmosphere. *Science* 289:1922-1925

Rodríguez, J. P., T. D. Beard, Jr., E. M. Bennett, G. S. Cumming, S. Cork, J. Agard, A. P. Dobson, and G. D. Peterson. 2006. Trade-offs Across Space, Time, and Ecosystem Services. *Ecology and Society* 11(1): 28-40.

Ryan, R., D. Erickson, and R. De Young. 2003. Producers' Motivations for Adopting Conservation Practice along Riparian Zones in Midwestern Agricultural Watershed. *Journal of Environmental Planning and Management* 36(1): 19-37.

Ryan, R., R. Kaplan, and R.E. Grese. 2001. Predicting Volunteer Commitment in Stewardship Programs. *Journal of Environmental Planning and Management* 44(5): 629-48.

Sanchez, J.E., R.R. Harwoodb, T.C. Willsonc, K. Kizilkayad, J. Smeenk, E. Parkerb, E.A. Paule, B.D. Knezek, and G.P. Robertson. 2004. Managing Soil Carbon an Nitrogen for Productivity and Environmental Quality. *Agronomy Journal* 96: 769-775.

Schaltegger, S. 2002. The Sustainability Balanced Scorecard-linking Sustainability Management to Business Strategy. *Business Strategy and the Environment* 11(5): 269-284.

Schlegel, A.J., K.C. Dhuyvetter, and J.L. Havlin. 1996. Economic and Environmental Impact of Long-term Nitrogen in Phosphorus Fertilization. *Journal of Production Agriculture*. 9(1): 114–118.

Seed, E. 2008. *Hybrid Poplar Profits.* Center for Integrated Natural Resources and Agricultural Management, University of Minnesota, http://www.cinram.umn.edu/newsletter/Poplar-Profits.htm

Stein, Dennis. 2007. *Machine Work Rates for Saginaw Valley of Michigan.* Michigan State University Extension, www.ewashtenaw.org/government/departments/extension/Ag/crops/machineworkrate.pdf

Swift, T.A., D.L. Owen, and C. Humphrey. 2001. *The Management Information Systems Dimensions of Social Accounting and Accountability.* Research Report for the Chartered Institute of Management Accountants (CIMA). London: CIMA.

Swinton S.M., Y.Liu, and N. Miller. 2006. Is Site-Specific Yield Response Consistent over Time? Does It Pay? *American Journal of Agricultural Economics*. 88(2):471-483.

Syswerda, S.P. 2009. *Ecosystem Services from Agriculture Across a Management Intensity Gradient in Southwest, Michigan.* Department of Crop and Soil Sciences, Michigan State University. PhD Dissertation.

Varian, H.R. 1984. *Microeconomic Analysis*. Norton Publishing, New York.

Van der Veeren R.J.H.M.,and C.M. Lorenz. 2002. Integrated Economic–Ecological Analysis and Evaluation of Management Strategies on Nutrient Abatement in the Rhine Basin. *Journal of Environmental Management* 66 (4):361-376.

Weersink, A., J. Livernois, J.F. Shogren, and J.S. Shortle. 1998. Economic Instruments and Environmental Policy in Agriculture. *Canadian Public Policy* 24(3):309-327.

Weston, J.F. and T.E. Copeland. 1986. *Managerial Finance*. Dryden Press, Chicago.

Whitehouse Economic Report. 2008. *Producer Price Index for Farm Products, 1978-1998*. Government Printing Office. http://www.gpoaccess.gov/eop/tables08.html

Williams, A.G. 2003. *A Framework to Analyze the Interactions of Whole Farm Profits and Environmental Burdens.* EFITA 2003 Conference 5-9. July 2003, Debrecen, Hungary.

Wossink A. and S.M. Swinton. 2007. Jointness in Production and Farmers' Willingness to Supply Non-marketed Ecosystem Services. *Ecological Economics* 64(2):297-304.

Wunderlich, G. 1991. *Owning Farmland in the United States*. Agriculture Information Bulletin 637. U.S. Department of Agriculture, Economics Research Service, Washington D.C..

APPENDIX TABLES

Appendix Table 1. Enterprise Budget for Treatment 1, Conventional System, KBS-LTER, Hickory Corners, Michigan, 1993-2007

Revenue Sources	Unit	Corn	Soybean	Wheat	Average*
Yield	bu/acre	86.2	34.7	52.6	
Price	$/bu	2.66	6.09	3.29	
Revenue	$/acre	229	211	173	**204.68**
Cash Expenses					
Seed	$/acre	36.6	28.5	19.6	
Fertilizer	$/acre	20.5	12.4	7.89	
Herbicides	$/acre	18.8	21.6	20.8	
Tillage Costs	$/acre	11.5	11.9	12.7	
Custom Costs (Planting and Harvesting)	$/acre	12.1	6.73	7.39	
Cash Expenses	$/acre	99.6	81.2	68.5	**83.16**
Revenue Above Selected Cash Expenses		129.72	129.95	104.89	**121.52**

* Average was taken to assume a balanced rotation where a third of available land is planted to each crop in each year.

Appendix Table 2. Enterprise Budget for Treatment 2, No Till Cropping System, KBS-LTER, Hickory Corners, Michigan, 1993-2007

Revenue Sources	**Unit**	**Corn**	**Soybean**	**Wheat**	**Average***
Yield	bu/acre	92.0	39.4	54.4	
Price	$/bu	2.66	6.09	3.29	
Revenue	$/acre	244	239	179	**221.42**
Cash Expenses					
Seed	$/acre	37.2	29.4	18.2	
Fertilizer	$/acre	18.1	10.1	5.07	
Herbicides	$/acre	30.4	35.3	34.7	
Tillage Costs	$/acre	0	0	0	
Custom Costs (Planting and Harvesting)	$/acre	12.2	6.73	7.39	
Cash Expenses	$/acre	97.9	81.6	65.4	**81.63**
Revenue Above Selected Cash Expenses		147.09	158.35	113.19	**139.79**

* Average was taken to assume a balanced rotation where a third of available land is planted to each crop in each year.

Appendix Table 3. Enterprise Budget for Treatment 3, Low Input Cropping System, KBS-LTER, Hickory Corners, Michigan, 1993-2007

Revenue Sources	**Unit**	**Corn**	**Soybean**	**Wheat**	**Average***
Yield	bu/acre	88.4	36.2	46.0	
Price	$/bu	2.66	6.09	3.29	
Revenue	$/acre	235	220	151	**202.33**
Cash Expenses					
Seed	$/acre	37.2	26.7	19.7	
Cover Crop	$/acre	5.88	5.88	5.88	
Fertilizer	$/acre	11.7	2.98	3.93	
Herbicides	$/acre	6.86	7.02	5.35	
Tillage Costs	$/acre	10.9	10.4	11.2	
Custom Costs (Planting and Harvesting)	$/acre	12.2	6.73	13.9	
Cash Expenses	$/acre	84.7	59.7	60.0	**68.14**
Revenue Above Selected Cash Expenses		150.58	160.56	91.41	**134.19**

* Average was taken to assume a balanced rotation where a third of available land is planted to each crop in each year.

Appendix Table 4. Enterprise Budget for Treatment 4, Organic System (Non-Organic Prices), KBS-LTER, Hickory Corners, Michigan, 1993-2007

Revenue Sources	**Unit**	**Corn**	**Soybean**	**Wheat**	**Average***
Yield	bu/acre	65.0	34.9	30.6	
Price	$/bu	2.66	6.09	3.30	
Revenue	$/acre	173	212	100	**161.96**
Cash Expenses					
Seed	$/acre	52.2	32.0	45.0	
Cover Crop	$/acre	4.77	4.77	4.77	
Fertilizer	$/acre	0	0	0	
Herbicides	$/acre	0	0	0	
Tillage Costs	$/acre	18.6	20.7	20.5	
Custom Costs (Planting and Harvesting)	$/acre	12.2	6.73	13.9	
Cash Expenses	$/acre	87.8	64.2	84.2	**78.72**
Revenue Above Selected Cash Expenses		85.32	147.97	16.42	**83.24**

* Average was taken to assume a balanced rotation where a third of available land is planted to each crop in each year.

Appendix Table 5. Enterprise Budget for Treatment 4, Organic System (Organic prices), KBS-LTER, Hickory Corners, Michigan, 1993-2007

Revenue Sources	Unit	Corn	Soybean	Wheat	Average*
Yield	bu/acre	65.0	34.9	30.6	
Price	$/bu	3.01	12.3	5.49	
Revenue	$/acre	195	428	167	**263.98**
Cash Expenses					
Seed	$/acre	52.2	32.0	45.0	
Cover Crop	$/acre	4.77	4.77	4.77	
Fertilizer	$/acre	0	0	0	
Herbicides	$/acre	0	0	0	
Tillage Costs	$/acre	18.6	20.1	20.6	
Custom Costs (Planting and Harvesting)	$/acre	12.2	6.73	13.9	
Cost of certification procedures and costs	$/acre	3.14	3.14	3.14	
Cash Expenses	$/acre	91.0	67.3	87.3	**81.87**
Revenue Above Selected Cash Expenses		104.81	361.14	80.40	**182.12**

* Average was taken to assume a balanced rotation where a third of available land is planted to each crop in each year.

Appendix Table 6. Enterprise Budget for Perennial Crop Poplar based on a single ten-year cycel, adjusted to reflect Net Present Value

		Quantity	Unit	Price per Unit ($)	1989	1990	1991	1992	1993	1994	1995
					1	2	3	4	5	6	7
Revenue Sources											
	Wood yield	2.60	ton	45.00	0	0	0	0	0	0	0
Total Revenue					0	0	0	0	0	0	0
Cash Expenses											
Planting											
	Cutting	1100.00	cutting	0.20	220.00	0	0	0	0	0	0
	Oats	3.00	Bu	8.19	25.00	25.00	0	0	0	0	0
Fertilizers											
	Nitrogen	109.73	lbs/acre	0.71	77.91	0	0	0	0	0	0
Pest Control											
	Lorox	55.84	gal/acre	133.67	55.84	0	0	0	0	0	0
	Princep	6.93	gal/acre	16.60	6.93	0	0	0	0	0	0
	Roundup	12.71	gal/acre	33.80	0	0	0	0	0	0	0
Custom Costs											
	Disking	1 acre		7.55	7.55	0	0	0	0	0	0
	Plowing	1 acre		3.54	3.54	0	0	0	0	0	0
Harvest											
	Cutting/Hauling	2.60	ton	18.00	0	0	0	0	0	0	0
Total Cash Expenses											
Revenue Above Selected Cash Expenses											

Note: This analysis uses a single ten-year cycle, and average ton/year is based on annual average of total growth over ten years in previous studis on short rotation poplar (Miller, 2008; Miller, 2002; Dickmann, 2001). Profit from Poplar is a one-off event at year 10, and this is reflected in the annualized present value of the profitability of the system.

Source: Application rates from KBS-LTER project; prices are at current prices (see input prices and out prices table sources)

* annuity is computed at present value of an annuity of t years (PVA) at an interest rate r=5% and time-t, divided by the present value interest factor for an annuity (PVIFA) whose value was taken from table A.4 Appendix A of Weston and Copeland, Managerial Finance, 1986 at PVIFA for a 10 year 5% interest rate

Continued Appendix Table 6. Enterprise Budget for Perennial Crop Poplar based on a single ten-year cycel, adjusted to reflect Net Present Value

		Quantity	Unit	Price per Unit ($)	1996 8	1997 9	1998 10	Total	Present Value (at 5% interest rate)	Annualized*
Revenue Sources										
	Wood yield	2.60	ton	45.00	0	0	26.00			
Total Revenue					0	0	1170.00	1170.00	**718.30**	**93.02**
Cash Expenses										
Planting										
	Cutting	1100.00	cutting	0.20	0	0	0	220.00	209.52	27.13
	Oats	3.00	Bu	8.19	0	0	0	49.00	46.49	6.02
Fertilizers										
	Nitrogen	109.73	lbs/acre	0.71	0	0	0	78.62	74.20	9.61
Pest Control										
	Lorox	55.84	gal/acre	133.67	0	0	0	55.84	53.18	6.89
	Princep	6.93	gal/acre	16.60	0	0	0	6.93	6.60	0.86
	Roundup	12.71	gal/acre	33.80	0	12.71	0.00	12.71	8.19	1.06
Custom Costs										
	Disking	1 acre		7.55	0	0	0	7.55	7.19	0.93
	Plowing	1 acre		3.54	0	0	0	3.54	3.37	0.44
Harvest										
	Cutting/Hauling	2.60	ton	18.00	0	0	46.89	46.89	28.79	3.73
Total Cash Expenses									**437.54**	**56.66**
Revenue Above Selected Cash Expenses									**280.76**	**36.36**

Note: This analysis uses a single ten-year cycle, and average ton/year is based on annual average of total growth over ten years in previous studis on short rotation poplar (Miller, 2008; Miller, 2002; Dickmann, 2001). Profit from Poplar is a one-off event at year 10, and this is reflected in the annualized present value of the profitability of the system.

Source: Application rates from KBS-LTER project; prices are at current prices (see input prices and out prices table sources)

* annuity is computed at present value of an annuity of t years (PVA) at an interest rate r=5% and time-t, divided by the present value interest factor for an annuity (PVIFA) whose value was taken from table A.4 Appendix A of Weston and Copeland, Managerial Finance, 1986 at PVIFA for a 10 year 5% interest rate

Appendix Table 7. Enterprise Budget for Perennial Crop Alfalfa based on a 3 five-year cycle, adjusted to reflect Net Present Value (at current prices)

	1989	1990	1991	1992	1993	1994	1995	1996	1997
	1	2	3	4	5	1	2	3	4
Revenue Sources									
Alfalfa Haylage	0	6.60	5.84	4.56	3.25	1.65	5.39	3.05	4.30
Total Revenue	0	257.34	227.65	177.79	126.61	64.26	210.26	118.93	167.61
Cash Expenses									
Planting									
Seed	52.19	0	0	0	0	80.30	0	0	0
Fertilizers									
K20	0	0	34.70	9.92	19.33	13.39	6.77	24.79	29.75
0-46-0	0	0	21.60	0	0	0	0	21.60	0
boron	0	0	0	0	0	0	0	4.76	4.25
lime	0	0	0	0	0	0	3.08	3.08	3.08
Pest Control									
Ambush	0	0	21.95	0	0	0	0	0	0
Sevin	0	1.20	0	0	0	0	0	12.40	0
Concentrate	0	0	0	0	0	3.06	0	0	0
Dimate	0	0	0	0	0	1.90	0	3.70	0
Poast Plus	0	0	15.06	0	0	15.06	0	0	17.60
2, 4-D	0	0	0	0	3.32	0	0	0	0
Roundup	0	0	0	0	17.43	0	0	0	0
Field Operations									
Plowing	13.70	0	0	0	0	0	0	0	0
Cultivating	20.50	0	0	0	0	20.50	0	0	0
Disking	13.90	0	0	0	0	0	0	0	0
Raking	5.65	16.95	22.60	5.65	11.30	11.30	0	0	0
Harvest									
Cutting Hay	0	0	0	0	20.50	0	0	0	0
Baling	1.00	1.50	2.00	0.50	0.50	1.00	1.00	0.50	0
Chopping Silage	0	0	0	0	107.70	35.90	71.80	71.80	71.80
Flail Mowing	0	10.70	0	0	0	0	10.70	0	10.70
Haybine	18.40	36.80	36.80	36.80	27.60	18.40	9.20	27.60	0
Total Cash Expenses									
Revenue Above Selected Cash Expenses									

Source: Application rates from KBS-LTER project; prices are at current prices (see input prices and out prices table sources)

* annuity is computed at present value of an annuity of t years (PVA) at an interest rate r=5% and time-t, divided by the present value interest factor for an annuity (PVIFA) whose value was taken from table A.4 Appendix A of Weston and Copeland, Managerial Finance, 1986 at PVIFA for a 17 year 5% interest rate

Continued Appendix Table 7. Enterprise Budget for Perennial Crop Alfalfa based on a 3 five-year cycle, adjusted to reflect Net Present Value (at current prices)

	1998	1999	2000	2001	2002	2003	2004	Total	Present Value (at 5% interest rate)	Annualized*
	5	1	2	3	4	5	1			
Revenue Sources										
Alfalfa Haylage	3.84	0.85	0.13	0.08	5.36	4.79	4.59	58.36		
Total Revenue	149.81	33.16	4.90	2.99	208.93	186.98	178.94	2276.14	**1524.37**	**140.65**
Cash Expenses										
Planting										
Seed	0	40.59	0	0	0	0	52.20	225.28	161.00	15.50
Fertilizers										
K20	6.77	0	0	0	0	41.64	0	211.84	139.00	13.38
0-46-0	0	0	0	0	43.20	21.60	0	123.25	72.14	6.94
boron	0	0	0	0	0	7.87	0	24.83	13.00	1.25
lime	3.08	4.01	0	0	0	0	0	16.35	11.00	1.06
Pest Control										
Ambush	0	0	0	0	0	0	0	21.95	19.00	1.83
Sevin	0	0	0	0	0	0	0	13.60	9.48	0.91
Concentrate	0	0	0	3.68	0	0	0	6.74	4.24	0.41
Dimate	0	0	0	0	0	0	0	5.60	3.92	0.38
Poast Plus	0	0	0	13.21	0	0	13.21	74.14	48.65	4.68
2, 4-D	0	0	0	3.88	0	0	0	7.20	4.66	0.45
Roundup	0	12.55	0	8.16	0	0	0	38.14	25.32	2.44
Field Operations										
Plowing	0	0	0	0	0	0	0	13.70	13.05	1.26
Cultivating	0	0	10.25	0	0	0	0	51.25	40.53	3.90
Disking	0	13.90	0.0	0	0	0	0	27.80	21.37	2.06
Raking	0	0	0	0	5.65	16.95	0	101.70	75.68	7.29
Harvest										
Cutting Hay	10.25	10.25	0	20.50	10.25	0	0	82.00	48.87	4.70
Baling	0.50	0.50	0	0	0.50	1.00	0	11.00	8.00	0.77
Chopping Silage	0	71.80	0	0	71.80	35.90	0	574.40	368.00	35.43
Flail Mowing	0	0	0	10.70	32.10	32.10	0	117.70	66.20	6.37
Haybine	9.20	0	0	0	0	0	0	220.80	179.19	17.25
Total Cash Expenses									**1332**	**128.26**
Revenue Above Selected Cash Expenses									192.07	**18.49**

Source: Application rates from KBS-LTER project; prices are at current prices (see input prices and out prices table sources)

* annuity is computed at present value of an annuity of t years (PVA) at an interest rate r=5% and time-t, divided by the present value interest factor for an annuity (PVIFA) whose value was taken from table A.4

Appendix Table 8. Price Standard Deviations Computed from Detrended Prices (1978-2008)

Crop	Standard Deviation	Mean
Corn	0.74	2.66
Soybean	1.61	6.09
Wheat	0.9	3.29